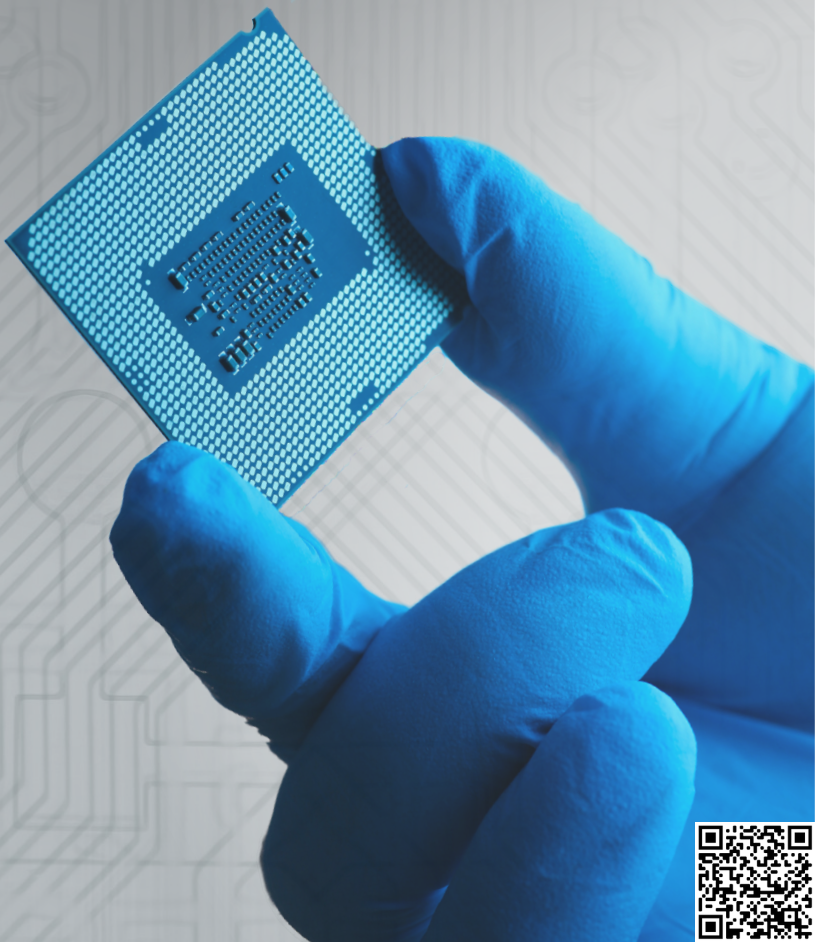
A Publication of Ascensus Specialties

MOCVD, CVD & ALD Precursors



BY ASCENSUS SPECIALTIES

STREM CATALOG

MOCVD, CVD & ALD Precursors

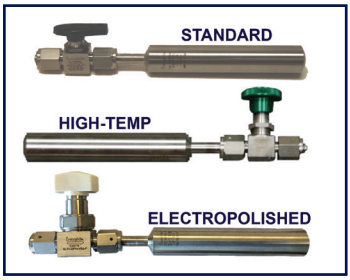
We manufacture and market specialty chemicals of high purity. Our products are used for research and development, as well as commercial scale applications, especially in the pharmaceutical, microelectronic and chemical/petrochemical industries. We also provide custom synthesis and cGMP manufacturing services. For more information, visit www.strem.com.

Our more than fifty years of experience in manufacturing inorganic and organometallic chemicals has allowed us to expand our product offering of MOCVD, CVD, and ALD precursors. We are continually adding new products for this dynamic and exciting field. Our range of products is presented in this brochure (sorted by key element) and include:

- Metal alkyls
- Metal alkylamides and alkylimides
- Metal amidinates
- Metal alkoxides
- Metal β-diketonates
- Metal cyclopentadienyls
- Metal halides
- Volatile organometallics
- Volatile metal carbonyls
- Fluorinated derivatives
- Electronic grade chemicals
- Single source precursors for mixed metal oxides

In addition to our 500+ precursors, we offer a variety of electropolished stainless steel bubblers at capacities ranging from 150ml to 3000ml. These bubblers are available in horizontal-in-line and vertical configurations. While standard bubblers are equipped with diaphragm valves rated to 121°C (PCTFE stem tips), we also supply bubblers with high temperature bellows valves rated to 315°C. DOT approved configurations are available.

An assortment of cylinders for ALD can be found on page 55 with standard, high-temperature and high-purity options.



We are happy to provide additional services to our customers for their MOCVD, CVD & ALD needs such as:

- **Cylinder/Bubbler Cleaning**
- **Precursor Filling & Refilling**
- **Prepackaged Precursors in ALD Cylinders**

For more information please contact our friendly Customer Service Representatives at 978.499.1600 or info@ascensusspecialties.com.

Glossary of Terms

$[\alpha]_D$	.....	Specific rotation
AAS	.....	Atomic Absorption Standard
ACS	.....	Conforms to American Chemical Society specifications
air sensitive	.....	Product may chemically react with atmospheric oxygen or carbon dioxide at ambient conditions. Handle and store under an inert atmosphere of nitrogen or argon.
amp	.....	Ampouled
b.p.	.....	Boiling point in °C at 760mm of Hg (Torr), unless otherwise noted
d.	.....	Density
dec.	.....	Decomposes
elec. gr.	.....	Electronic Grade, suitable for electronic applications
f.p.	.....	Flash point in °F
gran.	.....	Granular
heat sensitive	.....	Product may chemically degrade if stored for prolonged periods of time at ambient temperatures or higher. Store at 5°C or lower.
hydrate	.....	Unspecified water content which may vary slightly from lot to lot
hygroscopic	.....	Product may absorb water if exposed to the atmosphere for prolonged periods of time (dependent on humidity and temperature). Handle and store under an inert atmosphere of nitrogen or argon.
light sensitive	.....	Product may chemically degrade if exposed to light
liq.	.....	Liquid
m.p.	.....	Melting point in °C
moisture sensitive	.....	Product may chemically react with water. Handle and store under an inert atmosphere of nitrogen or argon.
NMR grade		Suitable as a Nuclear Magnetic Resonance reference standard
optical grade	.....	For optical applications
pwdr.	.....	Powder
primary standard	.....	Used to prepare reference standards and standardize volumetric solutions
PURATREM	.....	Product has a minimum purity of 99.99% (metals basis)
purified	.....	A grade higher than technical, often used where there are no official standards
P. Vol.	.....	Pore volume
pyrophoric	.....	Product may spontaneously ignite if exposed to air at ambient conditions
reagent	.....	High purity material, generally used in the laboratory for detecting, measuring, examining or analyzing other substances
REO	.....	Rare Earth Oxides. Purity of a specific rare-earth metal expressed as a percentage of total rare-earths oxides.
SA	.....	Surface area
store cold	.....	Product should be stored at -18°C or 4°C, unless otherwise noted (see product details)
subl.	.....	Sublimes
superconductor grade	.....	A high purity, analyzed grade, suitable for preparing superconductors
tech. gr.	.....	Technical grade for general industrial use
TLC	.....	Suitable for Thin Layer Chromotography
v.p.	.....	Vapor pressure mm of Hg (Torr)
xtl.	.....	Crystalline

About Purity

Chemical purity	.....	is reported after the chemical name, e.g. Ruthenium carbonyl, 99%
Metals purity	.....	is reported in parentheses with the respective element, e.g. Gallium (III) bromide, anhydrous, granular (99.999%-Ga) PURATREM where 100% minus the metal purity is equal to the maximum allowable percentage of trace metal impurity

MOCVD, CVD & ALD PRECURSORS
INDEX OF PRECURSOR TYPES

Halides for CVD & ALD

Metal Alkoxides

Visit strem.com for new product announcements.

Metal Alkylamides

Metal Alkyls

Metal Alkyls

Metal Amidinates

Metal β-diketonates

Metal β-diketonates

Metal β-diketonates

Metallocenes

Visit strem.com for new product announcements.

Metallocenes

Metallocenes

Silanes & Silanols for CVD & ALD

Single-source metal oxide precursors for CVD & ALD

Volatile Metal Carbonyls for CVD & ALD

Volatile Organometallics for CVD & ALD

This article is reproduced from The Strem Chemiker XXV No. 1

Hybrid Organic-Inorganic Films Grown Using Molecular Layer Deposition

Steven M. George
Depts. of Chemistry and Chemical Engineering
University of Colorado, Boulder, CO 80309

1. Introduction

There has been a dramatic growth in the field of atomic layer deposition (ALD) over the past 10 years [1]. Some of this ALD development has been driven by the needs of the semiconductor industry. Other developments have resulted from the application of ALD to non-semiconductor arenas. The atomic layer control and conformality of the ALD film thickness have proved useful for a diverse array of applications such as the fabrication of photonic bandgap materials [2] and gas diffusion barriers [3]. In addition to the new technological developments, there also has been an expansion of the types of films that can be grown using ALD-inspired processes. The introduction of organic precursors using molecular layer deposition (MLD) has greatly extended the compositional identity of the deposited film. MLD is distinguished from ALD because a molecular fragment can be added during one self-limiting sequential surface reaction [4]. An illustration of the sequential, self-limiting growth in MLD is displayed in Figure 1 [5].

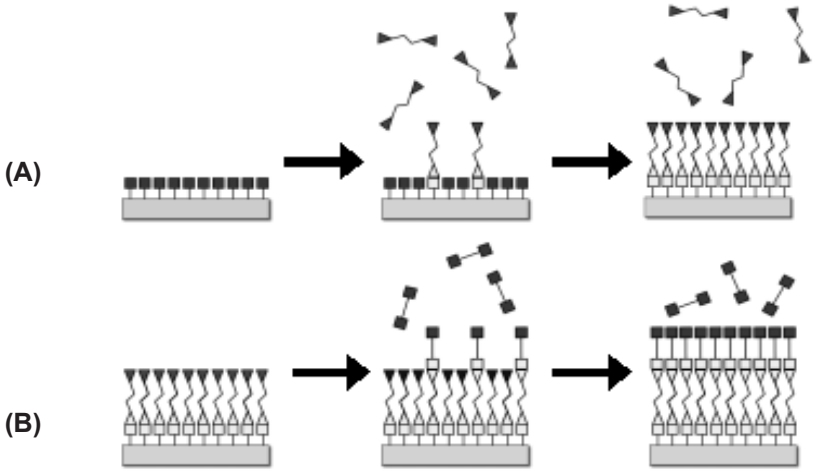


Figure 1 *Schematic illustrating ideal sequential, self-limiting reactions for MLD growth using two homobifunctional reactants.*

The original definition of MLD described the sequential, self-limiting chemistry used for the growth of an organic polymer. The first MLD system was based on condensation polymerization reactions and deposited a polyimide [6]. More recently, the MLD of a variety of organic polymers has been demonstrated including polyimide [7], polyamide [5, 8], polyurea [9], polyurethane [10], polythiourea [11] and polythiolene [12]. The organic precursors used for all-organic MLD can also be mixed with the inorganic ALD precursors to define new hybrid organic-inorganic materials [13, 14]. The expanded basis set introduced by these hybrid materials has greatly enlarged the possible materials that can be grown using ALD and MLD. The large quantity of organic precursors available from organic chemistry leads to a huge variety of possibilities for hybrid organic-inorganic films using MLD.

Several hybrid organic-inorganic materials have been developed recently using MLD techniques [4, 13-20]. These systems have begun to define the wide range of materials that can be deposited using MLD. The possibility to mix and match organic and inorganic precursors and their relative fraction in the film will lead to a wide spectrum of film properties. In particular, the mechanical properties can be tuned by controlling the organic and inorganic proportions. This short report will first review several MLD systems that have been demonstrated to illustrate the current state-of-the-art. Some new systems will then be introduced to show the diversity of chemistries that can be employed to grow various hybrid organic-inorganic films. Lastly, speculations will be offered on the future prospects for the MLD of hybrid organic-inorganic materials.

2. Previously Demonstrated Hybrid Organic-Inorganic MLD Films

One of the first hybrid organic-inorganic materials grown using MLD was an "alucone" [21] based on the reaction between trimethylaluminum (TMA) and ethylene glycol (EG) [13]. The EG molecule, HO-CH_2-CH_2-OH, contains two hydroxyls groups and is very analogous to H_2O as a reactant in the well-studied Al_2O_3 ALD process [22, 23]. The difference is that a –CH_2-CH_2- molecular fragment is introduced into the hybrid organic-inorganic film. A schematic showing the growth of the alucone based on TMA and EG is displayed in Figure 2 [13].

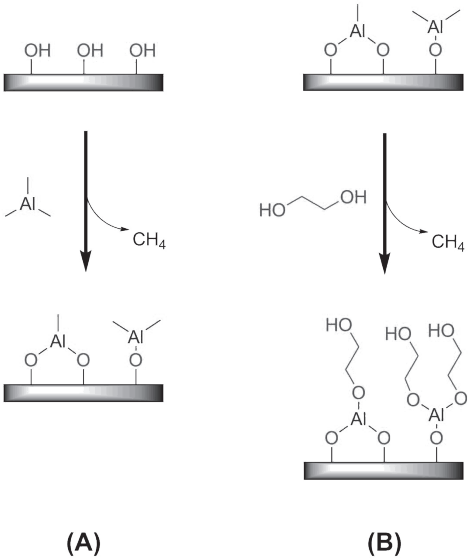


Figure 2 *Schematic depicting two-step AB alucone MLD growth using trimethylaluminum (TMA) and ethylene glycol (EG). TMA is exposed to a hydroxylated surface and produces a surface covered with -$AlCH_3$ species. The subsequent EG exposure produces a surface covered with –OCH_2CH_2OH species.*

In general, a two-step MLD reaction between a metal alkyl, such as TMA, and a diol, such as EG, can be written as follows [4, 13]:

(A) $SR'OH^* + MR_x \rightarrow SR'O\text{-}MR_{x-1}^* + RH$ (1)

(B) $SMR^* + HOR'OH \rightarrow SM\text{-}OR'OH^* + RH$ (2)

The asterisks indicate the surface species and S denotes the substrate with the reaction products from the previous reactions. In the A reaction, the reaction stops when all the SR'OH* species have completely reacted to produce SR'O-MR_{x-1}* species. In the B reaction, the reaction stops when all the SMR* species have completely reacted to produce SM-OR'OH* species. The sequential and self-limiting reactions of TMA and EG ideally yield a polymeric film described by (Al-(O-CH_2-CH_2-O-) linkages.

Previous studies have demonstrated that alucone MLD using TMA and EG is very efficient [13]. X-ray reflectivity (XRR) investigations showed that the MLD growth rate was linear versus the number of TMA/EG cycles. In addition, the MLD growth rate was temperature dependent and decreased from 4.0 Å per TMA/EG cycle at 85°C to 0.4 Å per TMA/EG cycle at 175°C [13]. Quartz crystal microbalance (QCM) measurements also revealed the linearity of alucone MLD growth versus TMA and EG exposures [13]. The QCM results also showed a large mass increase during the TMA exposures that subsequently decayed immediately after the TMA exposure. This mass transient was consistent with TMA diffusion into and out of the AB alucone MLD film [24]. The TMA diffusion also helped explain the temperature dependence of the MLD growth.

The surface reactions during MLD with TMA and EG displayed self-limiting behavior [13]. The AB alucone MLD films also displayed a contraction of ~22% over the first 3 days that the films were exposed to air. After this contraction, the films were extremely stable. The AB alucone films were extremely smooth and conformal when deposited on nanoparticles. Figure 3 shows the TEM image of a $BaTiO_3$ particle that was coated with 40 AB cycles of Al_2O_3 ALD and then 50 AB cycles of AB alucone MLD at 135°C [13]. The quality of the overlying MLD film is comparable with the underlying ALD film.

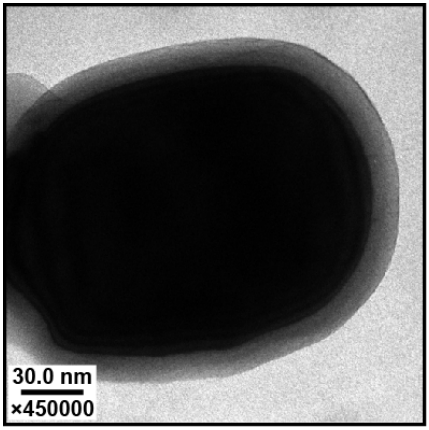


Figure 3 *TEM image of a $BaTiO_3$ particle coated at 135 °C with 40 AB cycles of Al_2O_3 ALD and then 50 AB cycles of AB alucone MLD using TMA and EG.*

EG is one of many organic diols that can be used together with TMA for alucone film growth. One difficulty with diols is that they are homobifunctional precursors and can react twice with the AlCH3* surface species [4, 8]. These “double reactions” lead to a loss of reactive surface sites and could produce a decreasing growth per cycle during MLD. The problem of double reactions may be minimized using polyols to assure that a hydroxyl group will be available for the subsequent TMA exposure. This strategy will be discussed below for the MLD of the alucone based on TMA and glycerol.

Alternatively, a heterobifunctional precursor, such as ethanolamine, HO- CH_2-CH_2-NH_2 (EA) can be employed that shows preferential reactivity between its hydroxyl group and the $AlCH_3$* surface species [20]. This preference leaves an amine (-NH_2) group available for the subsequent surface reaction. Likewise, ring-opening reactions can be employed that will react and then express a new functional group when the ring is opened [4, 20]. The ring-opening reaction also has the advantage of containing the functional group in a hidden form. The hidden functionality leads to higher vapor pressures and shorter purge times compared with precursors that have the same exposed functionality.

One three-step ABC MLD process that can be accomplished without using homobifunctional precursors is based on: (1) TMA, a homomultifunctional inorganic precursor; (2) ethanolamine (EA),

a heterobifunctional organic reactant and (3) maleic anhydride (MA) a ring-opening organic reactant [20]. The proposed surface reactions during the ABC growth are [20]:

(A) S-COOH* + $Al(CH_3)_3$ → S–COO-$Al(CH_3)_2$* + CH_4 (3)
(B) S–$AlCH_3$* + $HO(CH_2)_2$-NH_2 → S–Al–$O(CH_2)_2NH_2$* + CH_4 (4)
(C) S–NH_2* + $C_4H_2O_3$ (MA) → S–NH-C(O)CHCHCOOH* (5)

This surface reaction mechanism is illustrated in Figure 4 [20].

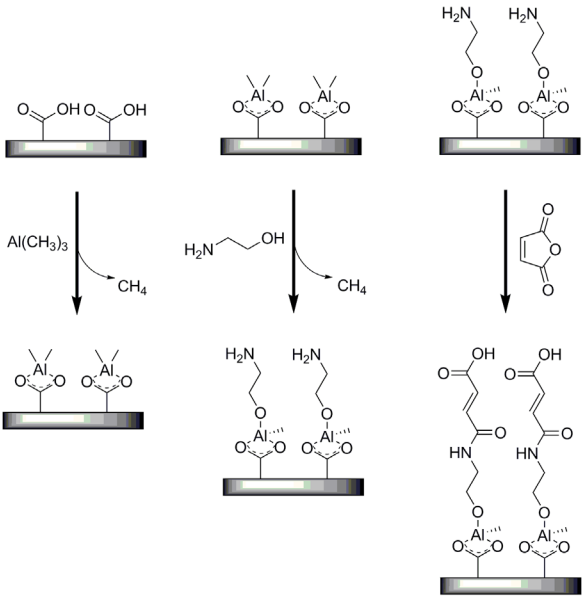


Figure 4 *Schematic showing the three-step reaction sequence for ABC MLD growth using (A) trimethylaluminum (TMA), (B) ethanolamine (EA), and (C) maleic anhydride (MA).*

In this ABC reaction sequence, TMA reacts with carboxylic groups in reaction A given by Eqn. 3 to form $AlCH_3$* species. Subsequently, the $AlCH_3$* species react preferentially with the hydroxyl end of the EA reactant to form Al-$OCH_2CH_2NH_2$* surface species in reaction B given by Eqn. 4. MA then reacts with amine-terminated surface functional groups to reform carboxylic groups through a ring-opening reaction in reaction C given by Eqn. 5. The three-step reaction sequence is repeated by exposure to TMA, EA and MA to grow the ABC MLD film.

A variety of studies have characterized the ABC MLD process [18, 20]. FTIR difference spectra were consistent with the reaction mechanism shown in Figure 4. The ABC MLD displayed linear growth as evidenced by the QCM measurements. However, large mass gains of ~2500 ng/cm^2 per ABC cycle were observed at 90°C [18]. This large mass gain may indicate the diffusion of a substantial quantity of TMA into the ABC MLD film. After the TMA exposure, there was also a subsequent mass loss that was consistent with the diffusion of TMA out of the ABC MLD film. The diffusion of TMA in and out of the ABC film was measured experimentally and then fit using a numerical model based on Fick's Law [18]. The importance of TMA diffusion into and out of the ABC film was verified by observing that the mass gain per cycle was dependent on the TMA purge time. In addition to TMA, other inorganic ALD precursors can be matched with various organic precursors to define other classes of hybrid organic-inorganic materials. For example, diethylzinc (DEZ) can react with diols to produce "zincone" MLD films [17, 19]. Zincone MLD has been demonstrated

using DEZ and EG [17, 19]. The growth and film characteristics of zincone MLD were similar to alucone MLD. Linear growth rates were observed for zincone MLD versus number of MLD cycles [19]. However, the growth rates were lower for higher growth temperatures and the EG precursor was observed to react twice almost exclusively at the highest growth temperatures [19].

3. New Hybrid Organic-Inorganic MLD Films

A. Use of Homotrifunctional Precursor to Promote Cross-linking

The AB alucone MLD system using TMA and EG displayed efficient reactions [13]. However, this MLD system suffered from double reactions because EG is a homobifunctional precursor. This MLD system also displayed some film contraction over the first several days after this film was exposed to air [13]. In addition, tensile strain measurements of MLD films grown using TMA and EG with a thickness of 100 nm had a low critical tensile strain of 0.69% [25]. This low critical tensile strain may result from the small amount of cross-linking in the MLD film. These problems with the TMA + EG MLD system led to the recent exploration of the TMA + glycerol system. Glycerol provides an additional hydroxyl group for reaction and should increase the cross-linking between the chains in the deposited film. The proposed reaction sequence TMA and glycerol (GL) is displayed in Figure 5 [26].

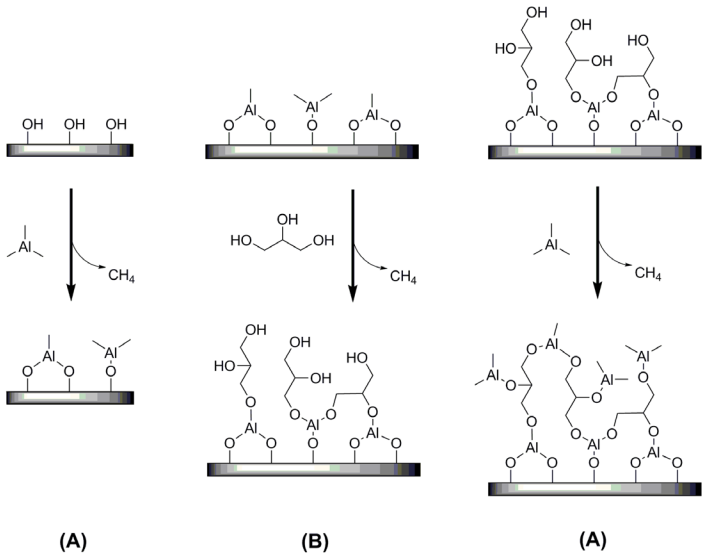


Figure 5 *Schematic depicting two-step AB alucone MLD growth using trimethylaluminum (TMA) and glycerol (GL).*

Studies of the surface species using Fourier transform infrared (FTIR) difference spectra after the TMA and GL exposures revealed that the surface reactions are efficient and proceed to near completion [26]. Figure 6 shows the FTIR difference spectra for Glycerol – TMA and TMA – Glycerol [26]. The spectra are displaced for clarity in presentation. The added surface species appear as positive absorbance features and the removed surface species appear as negative absorbance features. The FTIR spectra show the "flipping" of the O-H stretching vibrations at higher frequencies with each TMA and GL exposure. This flipping between positive absorbance for one reactant and then a mirror image negative absorbance for the second reactant is consistent with repetitive self-limiting reactions. There is also a flipping of the strong $AlCH_3$ deformation mode at lower frequencies that is consistent with the addition and subtraction of the $AlCH_3$* surface species.

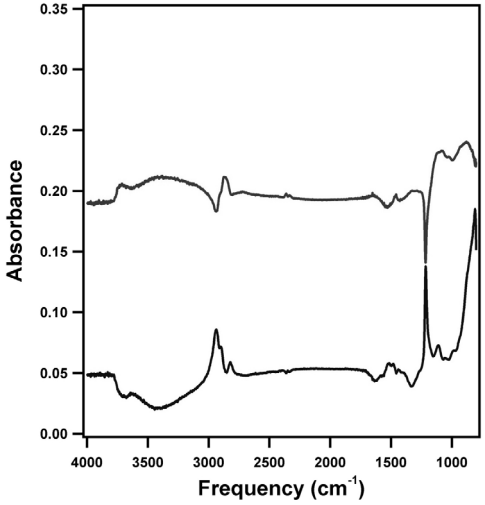


Figure 6 *FTIR difference spectra after TMA and GL exposures during AB alucone MLD at 150 ºC. The FTIR difference spectra are referenced with respect to the previous reactant exposure.*

The TMA + GL reaction can also be characterized using QCM studies. The QCM analysis revealed linear MLD growth with an average mass gain of 41.5 ng/cm^2/cycle at 150ºC. This mass gain of 41.5 ng/cm^2/cycle is equivalent to a growth rate of 2.5 Å/cycle. Figure 7 displays QCM results for two TMA + GL cycles at 150°C [26]. The QCM shows that a mass gain is observed during the TMA exposure. Likewise, a small mass loss is observed after the TMA exposure. This behavior suggests that some TMA may be diffusing out of the MLD film after the TMA exposure. A similar mass gain is observed during the GL exposure. The slight mass loss after the GL exposure may also indicate that some GL diffuses out of the MLD film.

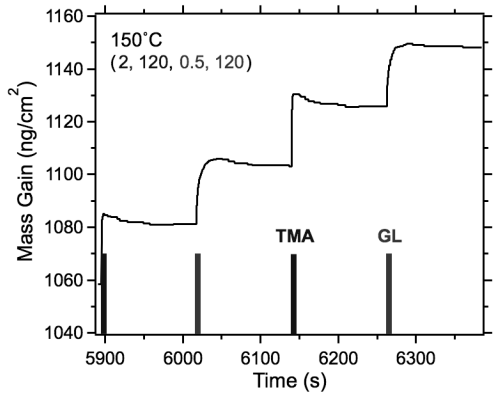


Figure 7 *Mass gain from QCM measurements for two cycles of AB alucone MLD film growth with TMA and GL in the linear growth region at 150 ºC. The pulse sequence was TMA 2 s, N_2 purge 120 s, GL 0.5 s and N_2 purge 120 s.*

The TMA + GL system also shows a growth rate that is much less dependent on temperature than the growth rate for TMA + EG [13]. XRR analysis was employed to study the film thickness after various numbers of MLD cycles at temperatures of 150, 170 and 190°C. These XRR results are

shown in Figure 8 [26]. The film thicknesses are similar for all three temperatures and are consistent with a growth rate of 2.0-2.3 Å per cycle. The growth rate of 2.3 Å per cycle at 150°C is in reasonable agreement with the QCM measurement of 2.5 Å/cycle at 150°C under similar reaction conditions. These more constant growth rates versus temperature compared with TMA + EG suggests that TMA diffusion may be less of a factor because of the more extensive cross-linking between the growing chains.

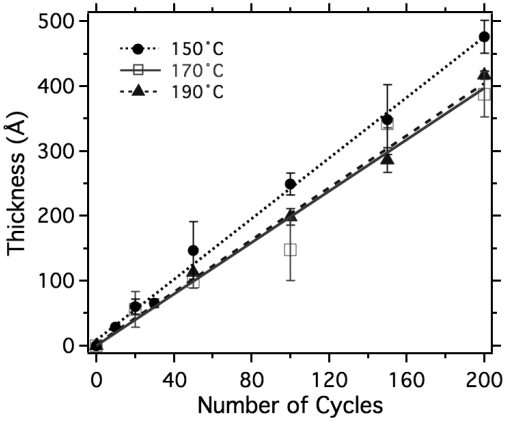


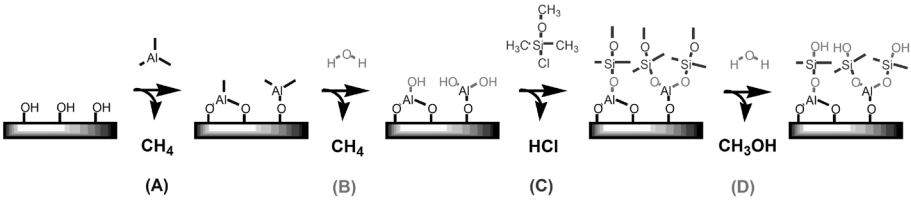
Figure 8 *Thickness of AB alucone MLD films grown using TMA and GL measured using XRR analysis versus number of AB reaction cycles. Results are shown for growth temperatures of 150, 170 and 190 °C.*

The XRR analysis of the TMA + GL MLD films indicated that the film thickness was nearly constant versus time after exposure to ambient [26]. The MLD films grown using TMA + GL were not observed to contract like the MLD films grown using TMA + EG [13]. This higher film stability may indicate that there is more cross-linking that increases the MLD film stability. Recent mechanical testing has also revealed that the MLD films grown using TMA + GL have a higher critical tensile strain for cracking than the MLD films grown using TMA + EG [26].

B. MLD of Hybrid Alumina-Siloxane Films Using an ABCD Process

Polydimethylsiloxane (PDMS) is one of the most important organic-inorganic polymers and contains $[\text{-Si}(\text{CH}_3)_2\text{-O}]_n$ chains. The strength and flexibility of the Si-O bonds and bond angles give PDMS desirable thermal and mechanical properties [27, 28]. PDMS MLD would be extremely useful for the growth of flexible and compliant thin films. However, initial attempts at PDMS MLD revealed that the growth rate became negligible after approximately 15 MLD cycles. These attempts were made using the sequential dosing of water with homobifunctional silane molecules such as bis(dimethylamino) dimethylsilane and 1,3-dichlorotetramethyldisiloxane or hetrobifunctional silane molecules such as dimethylmethoxychlorosilane (DMMCS). The lack of growth after approximately 15 MLD cycles was attributed to the competing desorption of cyclic siloxanes such as hexamethylcyclotrisiloxane (D3) or decamethylcyclopentasiloxane (D5) from the PDMS film [29, 30].

To prevent the desorption of cyclic siloxanes, a new approach was pursued where DMMCS and H_2O were used together with TMA in an ABCD process defined by TMA/H_2O/DMMCS/H_2O [31]. A schematic of this reaction sequence is given in Figure 9 [31]. This reaction sequence introduces the $\text{-Si}(\text{CH}_3)_2\text{-O-}$ linkage into the growing film. The addition of TMA adds –Al-O- subunits into the growing chain and prevents the competing desorption of cyclic siloxanes. The TMA can be introduced during every reaction cycle. The TMA can also be introduced less frequently to grow longer $[\text{-Si}(\text{CH}_3)_2\text{-O-}]_n$ chains before inserting the –Al-O- subunit.



Initial work has explored the ABCD process to demonstrate the growth of alumina-siloxane hybrid organic-inorganic films [31]. QCM experiments revealed that the MLD growth was linear with a mass gain of ~21 ng/cm^2/cycle at 200°C. The film growth at 200°C was also examined using XRR analysis. The XRR measurements confirmed linear growth at 200°C with a growth rate of 0.9 Å/cycle [31]. Using the density of 2.3 g/cm^3 for the alumina-siloxane MLD films, the mass gain of ~21 ng/cm^2/cycle yields a growth rate of 0.9 Å/cycle. FTIR analysis of the surface reactions was also consistent with the reaction mechanism shown in Figure 9. However, a low atomic concentration of silicon in the MLD film measured by x-ray photoelectron spectroscopy indicated that the chlorosilane reaction with the hydroxylated surface was not very efficient.

8. Future Prospects for MLD of Hybrid Organic-Inorganic Films

The use of various organic and inorganic precursors offers a nearly limitless set of combinations for the MLD of hybrid organic-inorganic films. Many of these combinations can be used to fabricate films with specific functional properties. One example of a functional hybrid organic-inorganic film is an MLD film grown using TMA and triethylenediamine (TED). TMA is a Lewis acid and TED is a Lewis base. An exposure sequence of TMA and TED can be used to grow an MLD film with unreacted $AlCH_3$ species remaining in the film [32]. A schematic of this reaction sequence is given in Figure 10 [32]. These AlCH3 species can react with H_2O and serve as a H_2O getter. The H_2O getters may be useful as interlayers in multilayer gas diffusion barrier films.

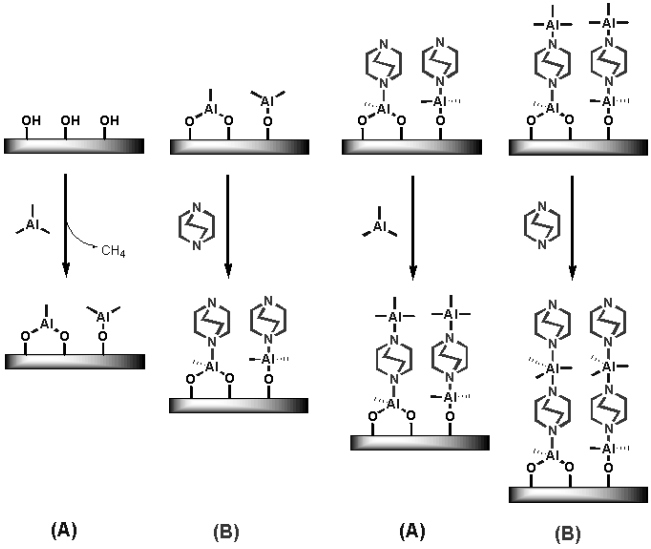


Figure 10 *Schematic depicting the two-step reaction sequence for AB MLD growth of a Lewis acid-Lewis base film using trimethylaluminum (TMA) and triethylenediamine (TED).*

Conductive hybrid organic-inorganic films may also be useful for flexible displays. ZnO ALD films are known to have a low resistivity of ~1 x 10^{-2} W cm [33]. ZnO ALD films are grown using diethylzinc (DEZ) and H_2O [34]. Hybrid organic-inorganic MLD films can be grown using DEZ and

EG as mentioned earlier and are called “zincones” [17, 19]. Although the zincone MLD film based on DEZ and EG does not display any conductivity, recent results have shown that zincone films based on DEZ and hydroquinone (HQ) have displayed some conductivity when alloyed with ZnO ALD films [35]. The schematic showing the surface chemistry for zincone MLD using DEZ and HQ is given in Figure 11 [35]. If these conducting MLD alloy films display sufficient toughness because of their organic constituents, then they may be useful for flexible displays and may be candidates to replace indium tin oxide (ITO).

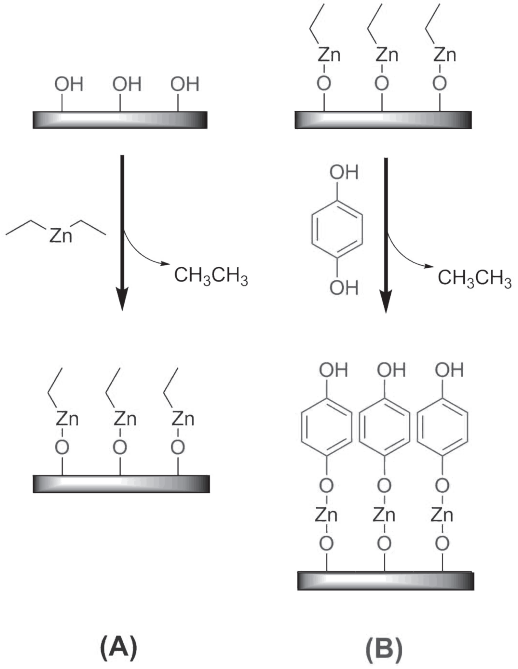


Figure 11 *Schematic showing the two-step reaction sequence for AB zincone MLD growth using diethylzinc (DEZ) and hydroquinone (HQ).*

The hybrid organic-inorganic MLD films have a low density that approaches the low densities of organic polymers. In contrast, inorganic ALD films have a much higher density. Mixtures of hybrid organic-inorganic MLD layers with ALD layers can be used to obtain films with a density that varies from the low density of the pure MLD film to the high density for the inorganic ALD film [36]. As an example, the density of hybrid Al_2O_3 ALD: AB Alucone MLD films are shown in Figure 12 [36]. Al_2O_3 ALD was grown using TMA and H_2O [22, 23]. AB Alucone MLD was grown using TMA and EG [13]. The density was varied by changing the relative number of ALD and MLD cycles during the alloy growth.

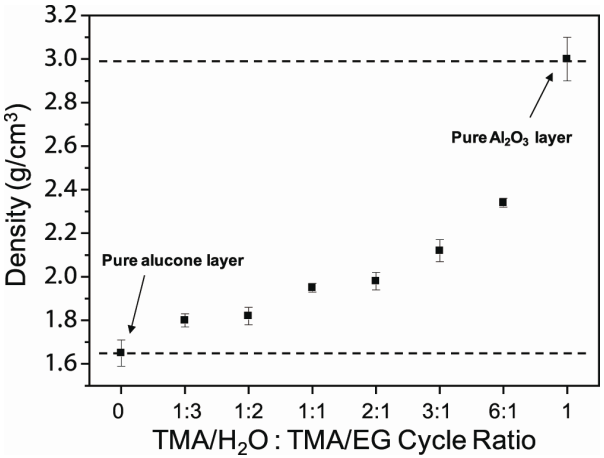


Figure 12 *Density of alloys of Al_2O_3 and AB alucone using TMA and EG from XRR analysis. The alloys were prepared using different numbers of TMA/H_2O and TMA/EG cycles. For example, the 3:1 ratio sample was prepared using repetitive sequences of 3 cycles of TMA/H_2O and then 1 cycle of TMA/EG.*

Figure 12 indicates that the density can be varied widely with changing organic-inorganic film composition. Other properties that are dependent on density will also change accordingly. For example, mechanical properties such as the elastic modulus and stiffness should be tunable [37]. Optical and electrical properties such as refractive index and dielectric constant should also vary with the composition of the alloy film [38]. In general, films with a variety of tunable properties should be possible by changing the ratio of ALD and MLD cycles used to grow the alloy film.

Most of the MLD systems reviewed in this chapter have been based on AB, ABC or ABCD processes using TMA. Other organometallic and organic precursors are also possible. As mentioned earlier, hybrid organic-inorganic films based on zinc are possible using DEZ [17, 19]. Other hybrid organic-inorganic systems based on zirconium and titanium are possible using $Zr(O\text{-}t\text{-}Bu)_4$ and $TiCl_4$, respectively [36, 39]. Many other organometallic precursors can also be used to define other hybrid organic-inorganic MLD polymers. For example, metal alkyls based on magnesium (Mg) and manganese (Mn) are available as $Mg(EtCp)_2$ and $Mn(EtCp)_2$. These metal alkyls are expected to react with diols or carboxylic acids to define new MLD systems [40, 41].

The possibilities for the MLD of hybrid organic-inorganic films are virtually unlimited given all the metals on the periodic table and organic compounds available from organic chemistry. The challenge over the next few years will be to determine the hybrid organic-inorganic films that may be grown easily and that may display useful properties. The tunable mechanical, optical, dielectric, conductive and chemical properties of the hybrid organic-inorganic films should be valuable for a wide range of applications.

Acknowledgements

This research was funded by the National Science Foundation (NSF), the Air Force Office of Scientific Research (AFOSR), the Defense Advanced Research Program Agency (DARPA) and DuPont Central Research and Development. The author also thanks B. Yoon, R.A. Hall, A.I. Abdulagatov, Y. Lee, and B.H. Lee. These members of his research group were responsible for the recent MLD and ALD results presented in this report.

References:

1. S.M. George, Chem. Rev. 2010, 110, 111.
2. J.S. King, E. Graugnard, C.J. Summers, Advanced Materials 2005, 17, 1010.
3. P.F. Carcia, R.S. McLean, M.D. Groner, A.A. Dameron, S.M. George, Journal of Applied Physics 2009, 106.
4. S.M. George, B. Yoon, A.A. Dameron, Acc. Chem. Res. 2009, 42, 498.
5. Y. Du, S.M. George, J. Phys. Chem. C. 2007, 111, 8509.
6. T. Yoshimura, S. Tatsuura, W. Sotoyama, Appl. Phys. Lett. 1991, 59, 482.
7. M. Putkonen, J. Harjuoja, T. Sajavaara, L. Niinisto, J. Mater. Chem. 2007, 17, 664.
8. N.M. Adamcyzk, A.A. Dameron, S.M. George, Langmuir 2008, 24, 2081.
9. A. Kim, M.A. Filler, S. Kim, S.F. Bent, J. Am. Chem. Soc. 2005, 127, 6123.
10. J.S. Lee, Y.J. Lee, E.L. Tae, Y.S. Park, K.B. Yoon, Science 2003, 301, 818.
11. P.W. Loscutoff, H.B.R. Lee, S.F. Bent, Chemistry of Materials 2010, 22, 5563.
12. Y.H. Li, D. Wang, J.M. Buriak, Langmuir 2010, 26, 1232.
13. A.A. Dameron, D. Seghete, B.B. Burton, S.D. Davidson, A.S. Cavanagh, J.A. Bertand, S.M. George, Chem. Mater. 2008, 20, 3315.
14. O. Nilsen, K.B. Klepper, H.O. Nielson, H. Fjellvag, ECS Trans. 2008, 16, 3.
15. B.H. Lee, K.K. Im, K.H. Lee, S. Im, M.M. Sung, Thin Solid Films 2009, 517, 4056.
16. B.H. Lee, M.K. Ryu, S.Y. Choi, K.H. Lee, S. Im, M.M. Sung, J. Am. Chem. Soc. 2007, 129, 16034.
17. Q. Peng, B. Gong, R.M. VanGundy, G.N. Parsons, Chem. Mater. 2009, 21, 820.
18. D. Seghete, R.A. Hall, B. Yoon, S.M. George, Langmuir 2010, 26, 19045.
19. B. Yoon, J.L. O'Patchen, D. Seghete, A.S. Cavanagh, S.M. George, Chem. Vap. Deposition 2009, 15, 112.
20. B. Yoon, D. Seghete, A.S. Cavanagh, S.M. George, Chem. Mater. 2009, 21, 5365.
21. C.N. McMahon, L. Alemany, R.L. Callender, S.G. Bott, A.R. Barron, Chem. Mater. 1999, 11, 3181.
22. A.C. Dillon, A.W. Ott, J.D. Way, S.M. George, Surf. Sci. 1995, 322, 230.
23. A.W. Ott, J.W. Klaus, J.M. Johnson, S.M. George, Thin Solid Films 1997, 292, 135.
24. C.A. Wilson, R.K. Grubbs, S.M. George, Chem. Mater. 2005, 17, 5625.
25. D.C. Miller, R.R. Foster, Y. Zhang, S.H. Jen, J.A. Bertrand, Z. Lu, D. Seghete, J.L. O'Patchen, R. Yang, Y.C. Lee, S.M. George, M.L. Dunn, J. Appl. Phys. 2009, 105, 093527.
26. R.A. Hall, B. Yoon, S.M. George, Unpublished Results (2010)
27. Z.L. Li, J.C.M. Brokken-Zijp, G. de With, Polymer 2004, 45, 5403.
28. J.C. Lotters, W. Olthuis, P.H. Veltink, P. Bergveld, J. Micromech. Microeng. 1997, 7, 145.
29. G. Camino, S.M. Lomakin, M. Lageard, Polymer 2002, 43, 2011.
30. N. Grassie, I.G. Macfarlane, Eur. Polym. J. 1978, 14, 875.
31. A.I. Abdulagatov, D.N. Goldstein, S.M. George, Unpublished Results (2010).
32. B. Yoon, S.M. George, Unpublished Results (2010).
33. J.W. Elam, D. Routkevitch, S.M. George, J. Electrochem. Soc. 2003, 150, G339.
34. J.W. Elam, S.M. George, Chem. Mater. 2003, 15, 1020.
35. B. Yoon, S.M. George, Unpublished Results (2010).
36. B.H. Lee, S.M. George, Unpublished Results (2010).
37. L.D. Salmi, E. Puukilainen, M. Vehkamaki, M. Heikkila, M. Ritala, Chem. Vap. Deposition 2009, 15, 221.
38. S. Zaitsu, T. Jitsuno, M. Nakatsuka, T. Yamanaka, S. Motokoshi, Appl. Phys. Lett. 2002, 80, 2442.
39. A.I. Abdulagatov, S.M. George, Unpublished Results (2010).
40. B.B. Burton, F.H. Fabreguette, S.M. George, Thin Solid Films 2009, 517, 5658.
41. B.B. Burton, D.N. Goldstein, S.M. George, J. Phys. Chem. C 2009, 113, 1939.

ALUMINUM (Compounds)

93-1302 — **Aluminum acetylacetonate, 99%** *(13963-57-0)* — 100g, 500g
$Al(CH_3COCHCOCH_3)_3$; FW: 324.31; white pwdr.; m.p. 192-193°; b.p. dec. 320° (subl. 150°/1mm)

93-1308 — **Aluminum s-butoxide, 98%** *(2269-22-9)* — 100g, 450g
HAZ
$Al(OC_4H_9)_3$; FW: 246.33; colorless liq.; b.p. 200-206°/30 mm; f.p. 82°F; d. 0.9671
moisture sensitive

93-1370 — **Aluminum ethoxide, 99%** *(555-75-9)* — 25g, 100g
HAZ
$Al(OC_2H_5)_3$; FW: 162.17; white chunks; m.p. 130°; b.p. 210°/10 mm
moisture sensitive

13-0200 — **Aluminum hexafluoroacetylacetonate, min. 98%** *(15306-18-0)* — 5g, 25g
$Al(CF_3COCHCOCF_3)_3$; FW: 648.169; white to off-white xtl.; m.p. 70-73°; b.p. dec. 170° (subl. 50°/0.1mm)
moisture sensitive

93-1345 — **Aluminum i-propoxide, 98+%** *(555-31-7)* — 250g, 1kg
HAZ
$Al[OCH(CH_3)_2]_3$; FW: 204.25; white pwdr.; m.p. 118.5°; b.p. 140.5°/8 mm; d. 1.0346
moisture sensitive

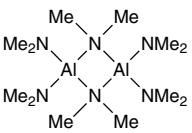
97-0139 — **Aluminum i-propoxide (99.99+%-Al) PURATREM** *(555-31-7)* — 25g, 100g
HAZ
$Al[(OCH(CH_3)_2]_3$; FW: 204.25; white pwdr.; m.p. 118.5°; b.p. 140.5°/8 mm; d. 1.0346
moisture sensitive

13-1600 — **Dimethylaluminum i-propoxide, 98% (99.99+%-Al) PURATREM** — 1g, 5g
HAZ
(6063-89-4)
$(CH_3)_2Al(OC_3H_7)$; FW: 116.14; colorless liq.; d. 0.824
air sensitive, moisture sensitive

Technical Note:
1. Useful starting material for the atomic layer deposition of Al_2O_3 films.

References:
1. *J. Vac. Sci. Tech. A.,* **2003**, *21*, 1366

13-4500 — **Hexakis(dimethylamino)dialuminum 98% (99.9%-Al) TDMAA** *(32093-39-3)* — 1g, 5g, 25g
$C_{12}H_{36}Al_2N_6$; FW: 318.42; white to yellow pwdr.; m.p. 82-84°; d. 0.865
air sensitive, moisture sensitive



Technical Notes:
1. An overlooked atomic layer deposition precursor.

References:
1. *Journal of Vacuum Science & Technology, A: Vacuum, Surfaces and Films,* **2017**, *35*, 01B128/1.

93-1358 — **Tri-i-butylaluminum, min. 95%** *(100-99-2)* — 100g, 225g
HAZ
$(C_4H_9)_3Al$; FW: 198.33; colorless liq.; m.p. 4°; b.p. 73°/5 mm; d. 0.781
moisture sensitive, pyrophoric

13-1850 — **Triethylaluminum, min. 93%** *(97-93-8)* — 25g, 100g, 500g
HAZ
$(C_2H_5)_3Al$; FW: 114.17; colorless liq.; m.p. -52.5°; b.p. 186°; f.p. -1°F; d. 0.835
moisture sensitive, pyrophoric

98-1855 — **Triethylaluminum, elec. gr. (99.999+%-Al) PURATREM** *(97-93-8)* — 100g
HAZ
$(C_2H_5)_3Al$; FW: 114.17; colorless liq.; m.p. -52.5°; b.p. 186°; f.p. -1°F; d. 0.835
moisture sensitive, pyrophoric

13-1900 — **Triethyl(tri-sec-butoxy)dialuminum (contains diethyl(tetra-sec-butoxy) dialuminum and tetraethyl(di-sec-butoxy)dialuminum)** — 25g, 100g
HAZ
$(C_2H_5)_3Al_2(OC_4H_9)_3$; colorless liq.; b.p. 183-186°/40mm
air sensitive, moisture sensitive

Technical Note:
1. Non-pyrophoric precursor for the chemical vapor deposition of aluminum oxide.

ALUMINUM (Compounds)

93-1360 HAZ	**Trimethylaluminum, min. 98%** *(75-24-1)* $(CH_3)_3Al$; FW: 72.09; colorless liq.; m.p. 15.4°; b.p. 20°/8 mm; f.p. 1.4°F; d. 0.752 (20°) *moisture sensitive, pyrophoric* Note: Available prepacked in ALD cylinder- see 98-4003, 98-4004.	100g 225g
98-4003 HAZ	**Trimethylaluminum, min. 98%, 93-1360, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(75-24-1)* $(CH_3)_3Al$; FW: 72.09; colorless liq.; m.p. 15.4°; b.p. 20°/8 mm; f.p. 1.4°F; d. 0.752 (20°) *moisture sensitive, pyrophoric* Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost. See 98-4004.	10g 25g
98-4004 HAZ	**Trimethylaluminum, min. 98%, 93-1360, contained in high-temp 50 ml Swagelok® cylinder (96-1071) for CVD/ALD** *(75-24-1)* $(CH_3)_3Al$; FW: 72.09; colorless liq.; m.p. 15.4°; b.p. 20°/8 mm; f.p. -1°F; d. 0.752 (20°) *moisture sensitive, pyrophoric*	25g
98-1955 HAZ	**Trimethylaluminum, elec. gr. (99.999+%-Al) PURATREM** *(75-24-1)* $(CH_3)_3Al$; FW: 72.09; colorless liq.; m.p. 15.4°; b.p. 20°/8 mm; f.p. 1.4°F; d. 0.752 (20°) *moisture sensitive, pyrophoric* Note: Available prepacked in ALD cylinder- see 98-4007, 98-4008.	25g 100g 200g
98-4008 HAZ	**Trimethylaluminum, elec. gr. (99.999+%-Al) PURATREM, 98-1955, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(75-24-1)* $(CH_3)_3Al$; FW: 72.09; colorless liq.; m.p. 15.4°; b.p. 20°/8 mm; f.p. 1.4°F; d. 0.752 (20°) *moisture sensitive, pyrophoric*	25g
98-4007 HAZ	**Trimethylaluminum, elec. gr. (99.999+%-Al) PURATREM, 98-1955, contained in 50 ml electropolished Swagelok® cylinder (96-1077) for CVD/ALD** *(75-24-1)* $(CH_3)_3Al$; FW: 72.09; colorless liq.; m.p. 15.4°; b.p. 20°/8mm; f.p. 1.4°F; d. 0.752 (20°) *moisture sensitive, pyrophoric*	25g
13-5000	**Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)aluminum, 99% (99.9%-Al) [Al(TMHD)$_3$]** *(14319-08-5)* $Al(C_{11}H_{19}O_2)_3$; FW: 576.80; white xtl.; m.p. 255-258°; b.p. dec. >400° (subl. 150°/0.01mm)	1g 5g 25g

ANTIMONY (Compounds)

93-5113	**Antimony(III) n-butoxide, 99%** *(2155-74-0)* $Sb(OC_4H_9)_3$; FW: 341.10; colorless liq.; b.p. 133-135°/4 mm; d. 1.23 *moisture sensitive*	5g 25g
93-5131 HAZ	**Antimony(III) chloride (99%-Sb)** *(10025-91-9)* $SbCl_3$; FW: 228.11; off-white xtl.; m.p. 73.4°; b.p. 283°; d. 3.140 *moisture sensitive*	250g 1kg
97-0373 amp HAZ	**Antimony(III) chloride, elec. gr. (99.999%-Sb) PURATREM** *(10025-91-9)* $SbCl_3$; FW: 228.11; off-white xtl.; m.p. 73.4°; b.p. 283°; d. 3.140 *moisture sensitive*	5g 25g
93-5115 HAZ	**Antimony(III) ethoxide, 99%** *(10433-06-4)* $Sb(OC_2H_5)_3$; FW: 256.90; colorless liq.; b.p. 95°/11 mm; f.p. 140°F; d. 1.524 *moisture sensitive*	5g 25g
51-3000 HAZ	**Triphenylantimony, 97%** *(603-36-1)* $(C_6H_5)_3Sb$; FW: 353.07; off-white xtl.; m.p. 54°; b.p. > 360°; d. 1.4343	10g 50g
51-5000 HAZ	**Tris(dimethylamino)antimony (99.99%-Sb) PURATREM** *(7289-92-1)* $((CH_3)_2N)_3Sb$; FW: 253.99; colorless liq.; b.p. 32-34°/0.45mm; d. 1.325 *air sensitive, moisture sensitive*	1g 5g 25g

ARSENIC (Compounds)

33-3400 amp HAZ	**Triethylarsine, 99%** *(617-75-4)* $(C_2H_5)_3As$; FW: 162.09; colorless to pale yellow liq.; m.p. -91°; b.p. 140°; d. 1.152 *air sensitive*	5g 25g
33-3750 amp HAZ	**Trimethylarsine, 99%** *(593-88-4)* $(CH_3)_3As$; FW: 120.03; colorless liq.; m.p. -87.3°; b.p. 51°; f.p. 100°F; d. 1.124 *air sensitive*	5g 25g

ARSENIC (Compounds)

98-1975	**Trimethylarsine, elec. gr. (99.995%-As) PURATREM** *(593-88-4)*	25g
amp	$(CH_3)_3As$; FW: 120.03; colorless liq.; m.p. -87.3°; b.p. 51°; f.p. 100°F; d. 1.124	
HAZ	*air sensitive*	
33-4000	**Triphenylarsine, min. 97%** *(603-32-7)*	5g
HAZ	$(C_6H_5)_3As$; FW: 306.24; white pwdr.; m.p. 59-60°; b.p. 233°/14 mm; d. 1.2225	25g
33-5000	**Tris(dimethylamino)arsine, 99%** *(6596-96-9)*	5g
HAZ	$((CH_3)_2N)_3As$; FW: 207.15; colorless liq.; b.p. 55°/10mm	25g
	air sensitive, moisture sensitive	

Technical Notes:

1. Precursor for arsenic doping in MOCVD of HgCdTe films. Absence of As–H bonds prevents the formation of As–H complexes and its incorporation in the As-doped films [1]
2. ALD/CVD dopant for CdTe/CdS thin films for photovoltaics grown by MOCVD [2-3]
3. ALD/CVD dopant for $GaAs_{(1-x)}N_x$ films deposited by N-ALD technique [4]
4. ALD/CVD precursor for *p*-type epitaxial growth of CdTe on *p*-type GaAs films [5]
5. CVD precursor for GaAs thin films deposition from $As(NMe_2)_3$ and $GaMe_3$ for solar cells [6]

References:

1. *J. Electron. Mater*., **1996**, *25*, 1328.
2. *J. Cryst. Growth*., **1998**, *195*, 718.
3. *Semicond. Sci. Technol*., **2008**, *23*, 015017.
4. *J. Cryst. Growth*, **2009**, *311*, 2821
5. *J. Electron. Mater*., **2014**, *43*, 2895.
6. *RSC Adv.,* **2015**, *5*, 11812.

BARIUM (Compounds)

56-5656	**Barium bis(N,N,N',N',N''-pentamethyldiethylenetriamine)bis[BREW] (99.99+%-Ba) PURATREM**	1g 5g
	$Ba(C_9H_{23}N_3)_2[C_xH_yC(O)CHC(O)C_xH_y]_2$ (x=3-4, y=2x +1); pale yellow liq.	25g
	moisture sensitive	
	Note: 13-16 wt% Ba; ***Limited quantities available.***	

Technical Note:

1. H-BREW is a mixture of propyl and butyl substituted beta-diketonates capable of forming a wide variety of metal complexes suitable for MOCVD. In most cases, the metal complexes are liquids and completely miscible with polar and non-polar organic solvents as well as other metal complexes in essentially all proportions.

56-8400	**Bis(6,6,7,7,8,8,8-heptafluoro-2,2-dimethyl-3, 5-octanedionate)barium [$Ba(FOD)_2$]**	1g
HAZ	*(36885-31-1)*	5g
	$Ba(C_{10}H_{10}F_7O_2)_2$; FW: 727.71; white to off-white pwdr.; m.p. 194-198°; b.p. dec. 280-300° (subl. 210°/0.2mm)	25g
56-8450	**Bis(pentamethylcyclopentadienyl)barium, 98%** *(112379-49-4)*	500mg
amp	$C_{20}H_{30}Ba$; FW: 407.78; white solid	2g
HAZ	*air sensitive, moisture sensitive*	

Technical Note:

1. Barium precursor for Atomic Layer Deposition and Chemical Vapor Deposition (ALD/CVD)

References:

1. *J. Phys. Chem. A,* **2007**, *111*, 8147

56-8460	**Bis(n-propyltetramethylcyclopentadienyl)barium, min. 98%** *(210758-43-3)*	250mg
HAZ	$Ba[(C_3H_7)(CH_3)_4C_5]_2$; FW: 463.90; viscous yellow liq.	1g
	air sensitive, moisture sensitive	5g
56-8500	**Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)barium hydrate [$Ba(TMHD)_2$]** *(17594-47-7)*	1g
HAZ	$Ba(C_{11}H_{19}O_2)_2{\cdot}XH_2O$; FW: 503.85; white pwdr.; m.p. 195-200°;	5g
	b.p. dec. 285° (subl. 225°/0.05mm)	25g
	moisture sensitive	
56-8600	**Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)barium tetraglyme adduct**	1g
HAZ	**(99.99%-Ba, Sr-0.5%) PURATREM** *(136629-60-2)*	5g
	$Ba(C_{11}H_{19}O_2)_2{\cdot}CH_3(OCH_2CH_2)_4OCH_3$; FW: 503.85 (726.13); white xtl.; m.p. 103°	
56-8610	**Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)barium triglyme adduct**	1g
HAZ	**(99.99%-Ba, Sr-0.5%) PURATREM** *(149160-45-2)*	5g
	$Ba(C_{11}H_{19}O_2)_2{\cdot}CH_3(OCH_2CH_2)_3OCH_3$; FW: 503.85 (682.09); off-white pwdr.; m.p. 88°	

BISMUTH (Compounds)

93-8314	**Bismuth(III) chloride, anhydrous, 99+% (99.9+%-Bi)** *(7787-60-2)* $BiCl_3$; FW: 315.34; white xtl.; m.p. 230-232°; b.p. 447°; d. 4.75 *moisture sensitive*	25g 100g
93-8315	**Bismuth(III) chloride, anhydrous (99.999%-Bi) PURATREM** *(7787-60-2)* $BiCl_3$; FW: 315.34; white xtl.; m.p. 230-232°; b.p. 447°; d. 4.75 *moisture sensitive*	5g 25g
93-8350	**Triphenylbismuth, 99%** *(603-33-8)* $(C_6H_5)_3Bi$; FW: 440.30; white xtl.; m.p. 77-78°; b.p. dec. 310° (subl. 100°/0.2mm); d. 1.585 Note: For sale in USA. For other countries contact Strem.	10g 50g
83-1000	**Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)bismuth(III), min. 98% (99.9%-Bi) [Bi(TMHD)$_3$]** *(142617-53-6)* $Bi(C_{11}H_{19}O_2)_3$; FW: 758.74; off-white xtl.; m.p. 114-116°; b.p. dec. 295° (subl. 150°/0.05mm)	1g 5g 25g

BORON (Compounds)

93-0514 HAZ	**Boron bromide, 99+%** *(10294-33-4)* BBr_3; FW: 250.54; pale yellow to orange liq.; m.p. -46°; b.p. 91.3°; d. 2.6431 *moisture sensitive, (store cold)*	25g 100g 500g
97-1725 amp HAZ	**Boron bromide, elec. gr. (99.999%-B) PURATREM** *(10294-33-4)* BBr_3; FW: 250.54; pale yellow to orange liq.; m.p. -46°; b.p. 91.3°; d. 2.6431 *moisture sensitive*	5g 25g 100g
05-1035	**Tetrakis(dimethylamino)diboron, min. 97%** *(1630-79-1)* $B_2(N(CH_3)_2)_4$; FW: 197.93; colorless liq.; b.p. 55-57° (2.5mm); f.p. 99°C; d. 0.926 *moisture sensitive*	1g 5g
93-0540 HAZ	**Triethylborane, 98%** *(97-94-9)* $B(C_2H_5)_3$; FW: 98.00; colorless liq.; m.p. -92.9°; b.p. 95°; f.p. 32.8°F; d. 0.6961 (23°) *pyrophoric*	100g
93-0531 HAZ	**Trimethylborate, 98%** *(121-43-7)* $B(OCH_3)_3$; FW: 103.92; colorless liq.; m.p. -29°; b.p. 68.7°; f.p. 30°F; d. 0.915 *moisture sensitive*	500g 2kg
05-1320 HAZ	**Trimethylborate, 99.95+%** *(121-43-7)* $B(OCH_3)_3$; FW: 103.92; colorless liq.; m.p. -29°; b.p. 68.7°; f.p. 30°F; d. 0.915 *moisture sensitive*	25g 100g

BROMINE (Compounds)

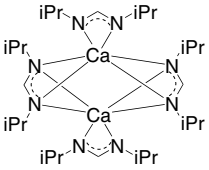
06-0201	**Carbon tetrabromide, vacuum sublimed (99.998%-C) PURATREM** *(558-13-4)* *See* page 16	

CADMIUM (Compounds)

48-5040 HAZ	**Dimethylcadmium, min. 97%** *(506-82-1)* $(CH_3)_2Cd$; FW: 142.88; colorless liq.; m.p. -4.5°; b.p. 105.5°; f.p. -1°F; d. 1.985 (18°) *moisture sensitive, pyrophoric* Note: Material may contain a small amount of precipitate.	5g 25g 100g
97-5040 HAZ	**Dimethylcadmium, elec. gr. (99.995+%-Cd) PURATREM** *(506-82-1)* $(CH_3)_2Cd$; FW: 142.88; colorless liq.; m.p. -4.5°; b.p. 105.5°; f.p. -1°F; d. 1.985 (18°) *moisture sensitive, pyrophoric* Note: Material may contain a small amount of precipitate.	25g 100g

CALCIUM (Compounds)

20-8200 NEW — **Bis(N,N'-diisopropylformamidinato)calcium(II) dimer, (99.99 %-Ca) PURATREM** *(1959584-78-1)* — 1g, 5g



$C_{28}H_{60}Ca_2N_8$; FW: 588.99; tan to light-brown pwdr.
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.

Technical Note:
1. Calcium amidinate precursor for the atomic layer deposition (ALD) of calcium containing thin films.

References:
1. *Angew. Chem. Int. Ed.*, **2016**, *55*, 10228 –10233.

20-8400 — **Bis(6,6,7,7,8,8,8-heptafluoro-2,2-dimethyl-3, 5-octanedionate)calcium [Ca(FOD)$_2$]** *(36885-29-7)* — 1g, 5g, 25g
$Ca[C_3F_7COCHCOC(CH_3)_3]_2$; FW: 630.30; white pwdr.; m.p. 208-210°; b.p. dec. 250° (subl. 170°/0.1mm)

20-8450 HAZ — **Bis(pentamethylcyclopentadienyl)calcium tetrahydrofuran, 98%** *(101200-05-9)* — 500mg, 2g
$[(CH_3)_5C_5]_2Ca(C_4H_8O)_2$; FW: 454.74; pale yellow pwdr.
air sensitive

20-1000 — **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)calcium, min. 97% [Ca(TMHD)$_2$]** *(118448-18-3)* — 1g, 5g, 25g
$Ca(C_{11}H_{19}O_2)_2$; FW: 406.62; white pwdr.; m.p. 220-223°; b.p. dec. 280° (subl. 205°/0.1mm)

Technical Notes:
1. Volatile source of calcium for use in the growth of: calcium carbonate.[1]
2. Volatile source of calcium for use in the growth of: calcium oxide.[2]
3. Volatile source of calcium for use in the growth of: calcium fluoride.[3]

References:
1. *Thin Solid Films,* **2004**, *450*, 161
2. *Physica B: Condensed Matter (Amsterdam, Netherlands)* **2009**, *404*, 8, 11, 1398
3. *Chem. Mater.* **2007**, *19*, 3387

20-2500 — **Calcium hexafluoroacetylacetonate dihydrate, 97%** *(203863-17-6)* — 1g, 5g, 25g
$Ca(CF_3COCHCOCF_3)_2.2H_2O$; FW: 454.18 (486.18); off-white pwdr.; m.p. 135-140°; b.p. dec. 230-240° (subl. 180°/0.07mm)

CARBON (Compounds)

06-0201 amp HAZ — **Carbon tetrabromide, vacuum sublimed (99.998%-C) PURATREM** *(558-13-4)* — 25g, 100g
CBr_4; FW: 331.65; white xtl.; m.p. 88-90°; b.p. 190°

CERIUM (Compounds)

93-5836 — **Cerium(III) trifluoroacetylacetonate hydrate** *(63356-25-2)* — 5g, 25g
$Ce(CF_3COCHCOCH_3)_3 \cdot XH_2O$; FW: 599.36; yellow xtl.

58-5000 — **Tetrakis(2,2,6,6-tetramethyl-3,5-heptanedionato)cerium(IV), min. 97% (99.9%-Ce) (REO) [Ce(TMHD)$_4$]** *(18960-54-8)* — 1g, 5g, 25g
$Ce(C_{11}H_{19}O_2)_4$; FW: 873.20; red pwdr.; m.p. 275-280°; b.p. dec. 295° (subl. 140°/0.05mm)

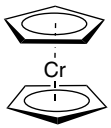
58-7500 amp — **Tris(cyclopentadienyl)cerium(III) (99.9%-Ce) (REO)** *(1298-53-9)* — 1g, 5g
$(C_5H_5)_3Ce$; FW: 335.41; yellow pwdr.; m.p. 452° dec.; b.p. subl. 230°/0.01 mm
air sensitive, moisture sensitive

58-8000 amp — **Tris(i-propylcyclopentadienyl)cerium(III) (99.9%-Ce) (REO)** *(122528-16-9)* — 1g, 5g
$[(C_3H_7)C_5H_4]_3Ce$; FW: 461.64; violet-blue xtl.
air sensitive

58-9000 — **Tris(1,2,3,4-tetramethyl-2,4-cyclopentadienyl)cerium(III) (99.9%-Ce) (REO)** *(251984-08-4)* — 1g, 5g
$[(CH_3)_4C_5H]_3Ce$; FW: 503.73; green pwdr.
air sensitive

CHROMIUM (Compounds)

24-0135 amp HAZ
Bis(cyclopentadienyl)chromium, min. 95%, sublimed (Chromocene) *(1271-24-5)*
$(C_5H_5)_2Cr$; FW: 182.18; scarlet xtl.; m.p. 172-173°
air sensitive

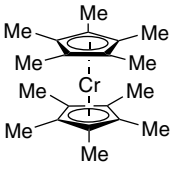


1g
5g

24-0145 amp HAZ
Bis(ethylbenzene)chromium (mixture of $(C_2H_5)_xC_6H_{6-x}$ where x= 0-4) *(12212-68-9)*
$[(C_2H_5)_xC_6H_{6-x}]_2Cr$; dark brown liq.; b.p. 140-160°/1mm; d. 1.14-1.18
air sensitive

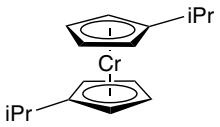
1g
5g
25g

24-0150 amp HAZ
Bis(pentamethylcyclopentadienyl)chromium, min. 95% (Decamethylchromocene) *(74507-61-2)*
$[(CH_3)_5C_5]_2Cr$; FW: 322.45; brown pwdr.
air sensitive



1g
5g

24-0153 amp HAZ
Bis(i-propylcyclopentadienyl)chromium, min. 98%
(329735-69-5)
$[(C_3H_7)C_5H_4]_2Cr$; FW: 266.35; red liq.
air sensitive



1g
5g

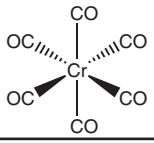
24-0160
Chromium(III) acetylacetonate, 97.5% *(21679-31-2)*
$Cr(CH_3COCHCOCH_3)_3$; FW: 349.33; maroon xtl.; m.p. 214°;
b.p. subl. 100°/0.2mm

50g
250g
1kg

24-0183 HAZ
Chromium carbonyl, 98+% *(13007-92-6)*
$Cr(CO)_6$; FW: 220.06; white to off-white solid

5g
25g
100g

24-0180 HAZ
Chromium carbonyl, sublimed, 99% *(13007-92-6)*
$Cr(CO)_6$; FW: 220.06; white xtl.; m.p. 154-155°; d. 1.77



5g
25g
100g
500g

24-0400
Chromium(III) hexafluoroacetylacetonate, min. 98% *(14592-80-4)*
$Cr(CF_3COCHCOCF_3)_3$; FW: 673.14; green xtl.; m.p. 83-85°

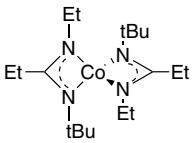
1g
5g

24-1500
Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)chromium(III), 99% [Cr(TMHD)$_3$] *(14434-47-0)*
$Cr(C_{11}H_{19}O_2)_3$; FW: 601.82; purple xtl.; m.p. 230-232°; b.p. dec. 270°

1g
5g

COBALT (Compounds)

27-0468
Bis(N-t-butyl-N'-ethylpropanimidamidato)cobalt(II), min. 98%
(1011477-51-2)
$C_{18}H_{38}CoN_4$; FW: 369.45; blue-green liq.
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2



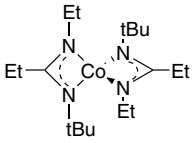
1g
5g

Technical Note:
1. Volatile cobalt complex for the atomic layer deposition of cobalt metal.

References:
1. *Chemistry of Materials,* **2014**, *26*, 2642
2. *J. Phys. Chem. Lett.,* **2014**, *5*, 1091
3. *Dalton T.,* **2008**, *19*, 2592

COBALT (Compounds)

27-0469 **Bis(N-t-butyl-N'-ethylpropanimidamidato)cobalt(II), min. 98% (99.99%-Co) PURATREM** *(1011477-51-2)* 1g 5g
$C_{18}H_{38}CoN_4$; FW: 369.45; blue-green liq.
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2

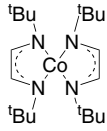


Technical Note:
1. Volatile cobalt precursor for ALD/CVD

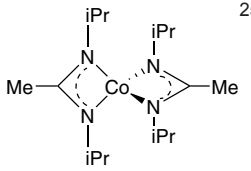
References:
1. *J. Phys. Chem. Lett.,* **2014**, *5*, 1091
2. *Chem. Mater.,* **2014**, *26*, 2642
3. *J. Mater. Chem. C.,* **2015**, *3*, 2500

27-0475 **Bis(cyclopentadienyl)cobalt(II), min. 98% (Cobaltocene)** *(1277-43-6)* 1g
amp $(C_5H_5)_2Co$; FW: 189.12; purplish-black xtl.; m.p. 173° 5g
HAZ *air sensitive, light sensitive, (store cold)* 25g

27-1025 **Bis(1,4-di-t-butyl-1,3-diazabutadienyl)cobalt(II) Co(DAD)$_2$, min. 98% (99.999%-Co) PURATREM** *(177099-51-3)* 250mg 1g 5g
NEW
$C_{20}H_{40}CoN_4$; FW: 395.49; dark green-blue xtl.
air sensitive
Note: U.S. Patent Application No. 13/818,154. Product sold under, use subject to, terms and conditions of label license at www.strem.com/waynestate1



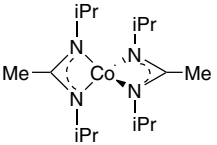
27-0485 **Bis(N,N'-di-i-propylacetamidinato)cobalt(II), min. 98% Co(iPr-MeAMD)$_2$** *(635680-58-9)* 250mg 1g 5g
amp
$C_{16}H_{34}CoN_4$; FW: 341.40; green xtl.; m.p. 84°;
b.p. sublimes 50°C (50 mTorr)
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.



Technical Notes:
1. Precursor with metal nitrogen bonds used for the atomic layer deposition of metals, nitrides, and oxides. See WO 2004/046417A2.
2. Copper complex used in the vapor phase, atomic layer deposition of Co_9S_8 and its application for super conductors.
3. Complex used in the atomic layer deposition of cobalt sulfide.

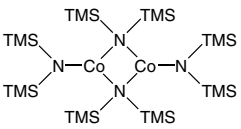
References:
1. *Nano Letters,* **2015**, *15*, 6689
2. *ACS Nano,* **2015**, *9*, 8484

27-0486 **Bis(N,N'-di-i-propylacetamidinato)cobalt(II), min. 98% (99.99%-Co) PURATREM (Co(iPr-MeAMD)$_2$** *(635680-58-9)* 250mg 1g 5g
amp
HAZ
$C_{16}H_{34}CoN_4$; FW: 341.40; green xtl.; m.p. 84°;
b.p. sublimes 50°C (50 mTorr)
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.



Technical Note:
1. See 27-0485 (page 18)

27-0515 **Bis{[μ-[di(trimethylsilyl)amide]}bis{[di(trimethylsilyl)amide]}dicobalt(II), 98%** *(93280-44-5)* 250mg 1g 5g
$C_{24}H_{72}Co_2N_4Si_8$; FW: 759.41; brown solid
air sensitive, moisture sensitive



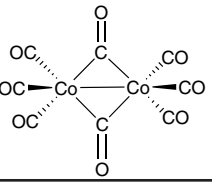
Technical Note:
1. Starting material for the synthesis of a variety of cobalt amines and alkoxides.

COBALT (Compounds)

27-0400 HAZ — **Cobalt carbonyl (Dicobalt octacarbonyl) (Stabilized with 1-5% hexanes)** *(10210-68-1)* — 5g, 25g, 100g

$Co_2(CO)_8$; FW: 341.95; dark orange xtl.; m.p. 51-52° dec.; f.p. -9°F (hexane); d. 1.73

air sensitive, (store cold)

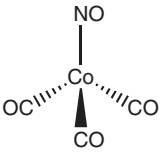


27-0500 amp HAZ — **Cobalt tricarbonyl nitrosyl** *(14096-82-3)* — 1g, 5g, 25g

$Co(CO)_3NO$; FW: 172.97; dark red liq.; b.p. 50°; d. 1.47

air sensitive, (store cold)

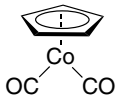
Note: Volatile cobalt precursor for the molecular layer deposition of cobalt metal.



27-0550 amp HAZ — **Cyclopentadienylcobalt dicarbonyl, min. 95%** *(12078-25-0)* — 2g, 10g

$C_5H_5Co(CO)_2$; FW: 180.05; dark red liq.; b.p. 37-38.5°/2 mm; f.p. 80°F; d. 1.35

air sensitive, (store cold)



Technical Notes:

1. Volatile cobalt complex used for the deposition of cobalt and cobalt oxide films.

References:

1. *Thin Solid Films,* **2014**, *567*, 8.
2. *J. Vac. Sci. Technol. A: Vacuum, Surfaces, and Films,* **2013**, *31*, 01A145/1.

27-0770 HAZ — **(3,3-Dimethyl-1-butyne)dicobalt hexacarbonyl, 98% CCTBA** *(56792-69-9)* — 250mg, 1g

$Co_2(CO)_6[HC{\equiv}C(C(CH_3)_3)$; FW: 368.07; dark red liq.

air sensitive

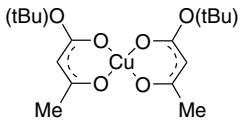
27-3000 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)cobalt(III), 99% (99.9+%-Co) [$Co(TMHD)_3$]** *(14877-41-9)* — 1g, 5g, 25g

$Co(C_{11}H_{19}O_2)_3$; FW: 608.74; green pwdr.; m.p. 254-256°; b.p. 250° dec. (subl. 120°/0.5mm)

COPPER (Compounds)

29-7110 — **Bis(t-butylacetoacetato)copper(II), 99%** *(23670-45-3)* — 1g, 5g, 25g

$C_{16}H_{26}CuO_6$; FW: 377.92; green xtls.



Technical Notes:

1. A new, non-fluorinated, copper CVD precursor exhibiting a higher sublimation rate and lower decomposition rate than $Cu(dpm)_2$
2. Copper CVD precursor used in the deposition of copper films with low carbon content[2]

References:

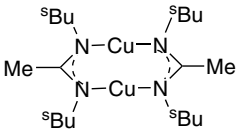
1. *J. Mater. Res.,* **1998**, *13*, 687
2. *Surface and Coating Technology,* **2002**, *150*, 205

29-7100 amp — **Bis(N,N'-di-sec-butylacetamidinato)dicopper(I), 99%** *(695188-31-9)* — 250mg, 1g, 5g

$(C_{10}H_{21}N_2)_2Cu_2$; FW: 465.67; white to off-white xtl.

air sensitive, moisture sensitive, (store cold)

Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.



Technical Note:

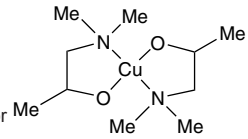
1. Precursor with metal nitrogen bonds used for the atomic layer deposition of metals, metal nitrides, and oxides. See WO 2004/046417A2.

References:

1. *Chem. Mater.,* **2011**, *23*, 4411
2. *J. Am. Chem. Soc.,* **2009**, *131*, 18159
3. *Appl. Phys. Lett.,* **2009**, *94*, 123107
4. *Inorg. Chem.*, **2005**, *44*, 1728

COPPER (Compounds)

29-7120 amp — **Bis(dimethylamino-2-propoxy)copper(II), min. 97% Cu(dmap)$_2$** *(185827-91-2)* — 250mg, 1g



$Cu(C_5H_{12}NO)_2$; FW: 267.86; purple xtl.
air sensitive, moisture sensitive

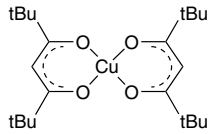
Technical Note:

1. ALD/CVD precursor for the preparation of Cu, Cu_2O, or Cu_2S films for electronic applications at temperatures ranging from 135 to 170°C. The T_{Subl} = 90°C/0.05 Torr and has a decomposition temperature of 185-188°C.

References:

1. *Chem. Mater.,* **2011**, *23*, 4411
2. *Chem. Mater.,* **2014**, *26*, 3731.
3. *J. Phys. Chem. C* **2015**, *119*, 9375

29-3000 — **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)copper(II), 99% [Cu(TMHD)$_2$]** *(14040-05-2)* — 1g, 5g, 25g



$Cu(C_{11}H_{19}O_2)_2$; FW: 430.05; blue xtl.; m.p. 198°; b.p. dec. 315° (subl. 88°/0.05mm)

29-2928 — **Copper(II) hexafluoroacetylacetonate, anhydrous, elec. gr. (99.99+%-Cu) PURATREM** *(14781-45-4)* — 1g, 5g

$Cu(CF_3COCHCOCF_3)_2$; FW: 477.64; blue xtl.
moisture sensitive

93-2929 — **Copper(II) hexafluoroacetylacetonate hydrate** *(14781-45-4)* — 1g, 5g, 25g

$Cu(CF_3COCHCOCF_3)_2 \cdot XH_2O$; FW: 477.64; green to blue xtl.; m.p. 97-99°; b.p. dec. 220° (subl. 100°/0.5mm)

29-2929 — **Copper(II) hexafluoroacetylacetonate hydrate, elec. gr. (99.99+%-Cu) PURATREM** *(14781-45-4)* — 1g, 5g, 25g

$Cu(CF_3COCHCOCF_3)_2 \cdot XH_2O$; FW: 477.64; green to blue xtl.; m.p. 85-89°; b.p. dec. 220° (subl. 70°/0.05mm)
hygroscopic

93-2966 — **Copper(II) trifluoroacetylacetonate, 97+%** *(14324-82-4)* — 5g, 25g

$Cu(CF_3COCHCOCH_3)_2$; FW: 369.70; purple pwdr.; m.p. 194-196°; b.p. dec. 260° (subl. 140°/0.1mm)

29-5500 — **Cyclopentadienyl(triethylphosphine)copper(I), min. 98%** *(12261-30-2)* — 1g, 5g

$(C_5H_5)CuP(C_2H_5)_3$; FW: 246.80; white to off-white xtl.; b.p. subl. 60°/0.01mm
air sensitive, moisture sensitive

DYSPROSIUM (Compounds)

66-3000 amp — **Tris(i-propylcyclopentadienyl)dysprosium(III) (99.9%-Dy) (REO)** *(952518-08-0)* — 1g, 5g

$(C_3H_7C_5H_4)_3Dy$; FW: 484.02; yellow solid
air sensitive, moisture sensitive

66-8500 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)dysprosium(III), 98+% (99.9%-Dy) (REO) [Dy(TMHD)$_3$]** *(15522-69-7)* — 1g, 5g

$Dy(C_{11}H_{19}O_2)_3$; FW: 712.31; off-white xtl.; m.p. 182-185°; b.p. dec. 265°
hygroscopic

ERBIUM (Compounds)

68-6900 — **Erbium(III) hexafluoroacetylacetonate hydrate (99.9%-Er) (REO)** *(18923-92-7)* — 1g, 5g

$Er(CF_3COCHCOCF_3)_3 \cdot XH_2O$; FW: 788.45; pink xtl.

68-7000 amp — **Tris(n-butylcyclopentadienyl)erbium(III) (99.9%-Er) (REO)** *(153608-51-6)* — 1g, 5g

$(C_4H_9C_5H_4)_3Er$; FW: 530.87; yellow to orange liq.; b.p. 240°/0.1mm; d. 1.309
air sensitive, moisture sensitive

68-8000 amp HAZ — **Tris(cyclopentadienyl)erbium(III) (99.9%-Er) (REO)** *(39330-74-0)* — 1g, 5g

$(C_5H_5)_3Er$; FW: 362.55; pink pwdr.; m.p. 285°; b.p. subl. 200°/0.01mm
air sensitive, moisture sensitive

68-8740 amp — **Tris(methylcyclopentadienyl)erbium(III) (99.9%-Er) (REO)** *(39470-10-5)* — 1g, 5g

$(CH_3C_5H_4)_3Er$; FW: 404.62; yellow pwdr.
air sensitive

ERBIUM (Compounds)

68-7200 — **Tris(i-propylcyclopentadienyl)erbium(III) (99.9%-Er) (REO)** *(130521-76-5)* — 1g, 5g
amp
$(C_3H_7C_5H_4)_3Er$; FW: 488.79; yellow to orange xtl.; m.p. 222° (subl.); b.p. subl. 222°/10mm
air sensitive, moisture sensitive

68-8750 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)erbium(III), 99% (99.9%-Er) (REO) [Er(TMHD)$_3$]** *(35733-23-4)* — 1g, 5g, 25g
$Er(C_{11}H_{19}O_2)_3$; FW: 717.08; pink xtl.; m.p. 179-180°; b.p. dec. 345° (subl. 160°/0.1mm)

EUROPIUM (Compounds)

93-6328 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)europium(III), 99% (99.9%-Eu) (REO) [Eu(TMHD)$_3$]** *(15522-71-1)* — 1g, 5g
$Eu(C_{11}H_{19}O_2)_3$; FW: 701.78; yellow pwdr.; m.p. 188-189°; b.p. dec. 275°

GADOLINIUM (Compounds)

64-4000 — **Tris(cyclopentadienyl)gadolinium(III) (99.9%-Gd) (REO)** *(1272-21-5)* — 1g, 5g
amp
HAZ
$(C_5H_5)_3Gd$; FW: 352.54; off-white pwdr.
air sensitive, moisture sensitive

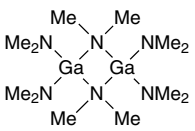
64-6000 — **Tris(i-propylcyclopentadienyl)gadolinium(III), 98% (99.9%-Gd) (REO)** *(126970-21-6)* — 250mg, 1g, 5g
NEW
amp
HAZ
$C_{24}H_{33}Gd$; FW: 478.77; yellow solid
air sensitive

64-4500 — **Tris(tetramethylcyclopentadienyl)gadolinium(III), min. 98%** *(308847-85-0)* — 1g, 5g
amp
HAZ
$[(CH_3)_4C_5H]_3Gd$; FW: 520.86; orange pwdr.
air sensitive, moisture sensitive

64-5000 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato) gadolinium(III), 99% (99.9%-Gd) (REO) [Gd(TMHD)$_3$]** *(14768-15-1)* — 1g, 5g
$Gd(C_{11}H_{19}O_2)_3$; FW: 707.07; off-white xtl.; m.p. 178-183°; b.p. dec. 295°

GALLIUM (Compounds)

31-2030 — **Bis(μ-dimethylamino)tetrakis (dimethylamino)digallium, 98%** — 1g, 5g, 25g
amp
HAZ
(57731-40-5)
$C_{12}H_{36}Ga_2N_6$; FW: 403.90; white xtl.
moisture sensitive



93-3130 — **Gallium(III) acetylacetonate (99.99+%-Ga) PURATREM** *(14405-43-7)* — 5g, 25g
$Ga(CH_3COCHCOCH_3)_3$; FW: 367.05; white to pale yellow pwdr.;
m.p. 192-194° dec. >280°; b.p. 140°/10 mm subl.; d. 1.42

98-1862 — **Triethylgallium, elec. gr. (99.9999%-Ga) PURATREM** *(1115-99-7)* — 50g, 100g
HAZ
$(C_2H_5)_3Ga$; FW: 156.91; colorless liq.; m.p. -82.3°; b.p. 143°; f.p. 69.8°F; d. 1.0586
moisture sensitive, pyrophoric

31-2000 — **Trimethylgallium, 99+%** *(1445-79-0)* — 25g, 100g
HAZ
$(CH_3)_3Ga$; FW: 114.83; colorless liq.; m.p. -15.8°; b.p. 55.7°; f.p. -1°F; d. 1.151
moisture sensitive, pyrophoric
Note: Available prepacked in ALD cylinder- see 98-4068.

98-4068 — **Trimethylgallium, 99+%, 31-2000, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(1445-79-0)* — 10g, 25g
HAZ
$(CH_3)_3Ga$; FW: 114.83; colorless liq.; m.p. -15.8°; b.p. 55.7°; f.p. -1°F; d. 1.151
moisture sensitive, pyrophoric

98-2000 — **Trimethylgallium, elec. gr. (99.9999%-Ga) PURATREM** *(1445-79-0)* — 50g, 100g
HAZ
$(CH_3)_3Ga$; FW: 114.83; colorless liq.; m.p. -15.8°; b.p. 55.7°; f.p. -1°F; d. 1.151
moisture sensitive, pyrophoric
Note: Available prepacked in ALD cylinder- see 98-4047.

GALLIUM (Compounds)

98-4047 — **Trimethylgallium, elec. gr. (99.9999%-Ga) PURATREM, 98-2000, contained in 50 ml electropolished Swagelok® cylinder (96-1077) for CVD/ALD** *(1445-79-0)* — 10g, 25g
HAZ
$(CH_3)_3Ga$; FW: 114.83; colorless liq.; m.p. -15.8°; b.p. 55.7°; f.p. -1°F; d. 1.151
moisture sensitive, pyrophoric

31-5000 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)gallium(III), 99% (99.999%-Ga) [Ga(TMHD)$_3$] PURATREM** *(34228-15-4)* — 1g, 5g, 25g
$Ga(C_{11}H_{19}O_2)_3$; FW: 619.54; white xtl.; m.p. 219-220°; b.p. dec. 360° (subl. 170°/0.2mm)

GERMANIUM (Compounds)

93-3206 — **Germanium(IV) ethoxide (99.99+%-Ge) PURATREM** *(14165-55-0)* — 1g, 5g, 25g
HAZ
$Ge(OC_2H_5)_4$; FW: 252.85; colorless liq.; m.p. -81°; b.p. 185.5°; d. 1.14
moisture sensitive

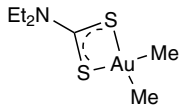
32-2050 — **Tetra-n-butylgermane, min. 98%** *(1067-42-1)* — 5g, 25g
$(n\text{-}C_4H_9)_4Ge$; FW: 301.05; colorless liq.; b.p. 130-133°/5 mm; d. 0.934

93-3227 — **Tetraethylgermane, 99%** *(597-63-7)* — 2g, 10g
HAZ
$(C_2H_5)_4Ge$; FW: 188.84; colorless liq.; m.p. -90°; b.p. 165.5°; f.p. 85°F; d. 1.1989

32-2125 — **Tetramethylgermane, 99%** *(865-52-1)* — 1g, 5g, 25g
HAZ
$(CH_3)_4Ge$; FW: 132.73; colorless liq.; m.p. -88°; b.p. 43.4°; f.p. -35°F; d. 0.978

GOLD (Compounds)

79-1700 — **(N,N-Diethyldithiocarbamato)dimethylgold(III), 97% (99.999%-Au) PURATREM** *(93166-53-1)* — 250mg, 1g
NEW
$(CH_3)_2Au(S_2CN(C_2H_5)_2)$; FW: 375.30; yellow xtl.; m.p. 40-44



Technical Note:
1. Volatile, air, light and thermally stable precursor used in the atomic layer deposition and chemical vapor deposition of Gold thin films.

References:

1. *Chem. Mater.*, **2017**, *29* (14), 6130
2. *Journal of Crystal Growth* **2015**, *414*, 143
3. *Physics Procedia* **2013**, *46*, 167
4. *Gold Bulletin (Berlin, Germany)* **2011**, *44(3)*, 177

79-1500 — **Dimethyl(acetylacetonate)gold(III), 98% (99.9%-Au)** *(14951-50-9)* — 500mg, 2g
$(CH_3)_2(C_5H_7O_2)Au$; FW: 326.60; white to off-white xtl.; m.p. 81-82°; b.p. subl. ~25°/0.01mm
(store cold)

Technical Notes:
1. Highly volatile gold source for MOCVD applications. Must ship overnight in dry ice.
2. Precursor for synthesis of gold nanoparticles. Au/ZrO_2 and Au/Al_2O_3 prepared in this way were extremely efficient catalysts for the aerobic oxidation of glucose.[1]

References:

1. *Angew. Chem. Int. Ed.,* **2008**, *47*, 9265

79-1600 — **Dimethyl(trifluoroacetylacetonate)gold(III), 98% (99.9%-Au)** *(63470-53-1)* — 500mg, 2g
HAZ
$(CH_3)_2Au(CF_3COCHCOCH_3)$; FW: 380.12; white to off-white xtl.
air sensitive, heat sensitive, light sensitive, (store cold)

Technical Note:
1. Highly volatile gold source for MOCVD applications. Must ship overnight in dry ice.

HAFNIUM (Compounds)

72-0700 — **Bis(cyclopentadienyl)dimethylhafnium, min. 97%** *(37260-88-1)* — 500mg, 2g
$(C_5H_5)_2Hf(CH_3)_2$; FW: 338.75; white xtl.; b.p. subl. 90°/0.1mm
air sensitive, (store cold)

72-1900 — **Dimethylbis(t-butylcyclopentadienyl)hafnium(IV), min. 98%** *(68193-45-3)* — 1g, 5g, 25g
$[(C_4H_9)C_5H_4]_2Hf(CH_3)_2$; FW: 450.96; white xtl.
air sensitive, moisture sensitive

HAFNIUM (Compounds)

72-5800 amp
Hafnium(IV) t-butoxide (99.9%-Hf, <1.5%-Zr) *(2172-02-3)*
$Hf[OC(CH_3)_3]_4$; FW: 470.65; liq. (may contain small amount of white sediment); m.p. 8°; b.p. 90°/5 mm; d. 1.166
light sensitive, moisture sensitive
2g 10g 50g

72-5900
Hafnium(IV) ethoxide, 99% *(13428-80-3)*
$Hf(OC_2H_5)_4$; FW: 358.73; white to off-white xtl.
moisture sensitive
5g 25g

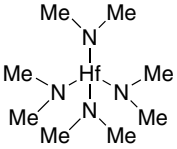
72-5950
Hafnium(IV) i-propoxide monoisopropylate, 99% *(2171-99-5)*
$Hf(OC_3H_7)_4 \cdot C_3H_7OH$; FW: 414.84 (474.94); white xtl.
moisture sensitive
5g 25g

Technical Note:
1. Precursor for the atomic layer deposition of hafnium oxide films.

References:
1. *Thin Solid Films,* **2009**, *517*, 5695

72-7750 amp HAZ
Tetrakis(diethylamino)hafnium, 99% (99.99+%-Hf, <0.2% Zr) PURATREM *(19824-55-6)*
$Hf[N(CH_2CH_3)_2]_4$; FW: 467.01; light yellow liq.
moisture sensitive
1g 5g 25g

72-8000 HAZ
Tetrakis(dimethylamino)hafnium, 98+% (99.99+%-Hf, <0.2% Zr) TDMAH, PURATREM *(19782-68-4)*
$Hf(N(CH_3)_2)_4$; FW: 354.79; colorless to pale yellow xtl.; m.p. 38-41°; b.p. 85°/0.1mm; d. 1.098
moisture sensitive, (store cold)
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1. Available prepacked in ALD cylinder- see 98-4021, 98-4022.

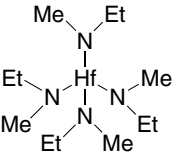


1g 5g 25g

98-4021 HAZ
Tetrakis(dimethylamino)hafnium, 98+% (99.99+%-Hf, <0.2%-Zr) TDMAH, PURATREM, 72-8000, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD *(19782-68-4)*
$Hf(N(CH_3)_2)_4$; FW: 354.79; colorless to pale yellow xtl.; m.p. 38-41°; b.p. 85°/0.1mm; d. 1.098
moisture sensitive, (store cold)
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost. See 98-4022. Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1.
25g

98-4022 HAZ
Tetrakis(dimethylamino)hafnium, 98+% (99.99+%-Hf, <0.2%-Zr) TDMAH, PURATREM, 72-8000, contained in 50ml Swagelok® cylinder (96-1071) for CVD/ALD *(19782-68-4)*
$Hf(N(CH_3)_2)_4$; FW: 354.79; colorless to pale yellow xtl.; m.p. 38-41°; b.p. 85°/0.1mm; d. 1.098
moisture sensitive, (store cold)
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1.
25g

72-7720 amp HAZ
Tetrakis(ethylmethylamino)hafnium, 99% (99.99+%-Hf, <0.15% Zr) TEMAH PURATREM *(352535-01-4)*
$Hf[N(CH_3)(CH_2CH_3)]_4$; FW: 410.90; colorless to yellow liq.; b.p. 79°/0.1mm; d. 1.324
moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4048. Volatile precursor for the ALD, CVD and MOCVD deposition of hafnium oxide.



2g 10g

98-4048 HAZ
Tetrakis(ethylmethylamino)hafnium, 99% (99.99+%-Hf, <0.15% Zr) TEMAH, PURATREM, 72-7720, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD *(352535-01-4)*
$Hf[N(CH_3)(CH_2CH_3)]_4$; FW: 410.90; colorless to yellow liq.; f.p. 52°F
moisture sensitive
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost.
10g

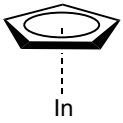
72-7580
Tetrakis(2,2,6,6-tetramethyl-3,5-heptanedionato)hafnium(IV), 99% *(63370-90-1)*
$C_{44}H_{76}HfO_8$; FW: 911.56; white xtl.
1g 5g 25g

HOLMIUM (Compounds)

67-5000
Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)holmium(III), 99% (99.9%-Ho) (REO) [Ho(TMHD)$_3$] *(15522-73-3)*
$Ho(C_{11}H_{19}O_2)_3$; FW: 714.75; off-white xtl.; m.p. 179-181°; b.p. dec. 290°
1g 5g

INDIUM (Compounds)

97-3425 HAZ — **Cyclopentadienylindium(I), elec. gr. (99.99+%-In) PURATREM** *(34822-89-4)* — 250mg, 1g, 5g



C_5H_5In; FW: 179.92; off-white to light yellow xtl.; b.p. subl. 50°/0.01 mm
air sensitive, heat sensitive, light sensitive
Note: Available prepacked in ALD cylinder- see 98-4057, 98-4054.

Technical Note:
1. Precursor for area selective ALD of In_2O_3:H. [1-4]
2. ALD precursor for indium oxide using cyclopentadienyl indium, and as co-reactants, a mixture of water and oxygen.[1]

References:

1. *Chem. Mater.,* **2017**, *29 (3),* 921.
2. *Sol. Energy. Mater. Sol. Cells,* **2017**, *163,* 43
3. *Rapid Res. Lett.,* **2014**, *8,* 987.
4. *ACS Appl. Mater. Interfaces.,* **2015**, *7*, 16723.
5. *ECS Transactions,* **2011**, *41*, 2, 147

98-4057 HAZ — **Cyclopentadienylindium (I), elec. gr. (99.99+%-In) PURATREM, 97-3425, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(34822-89-4)* — 5g

C_5H_5In; FW: 179.92; off-white to light yellow xtl.; b.p. subl. 50°/0.01mm
air sensitive, heat sensitive, light sensitive

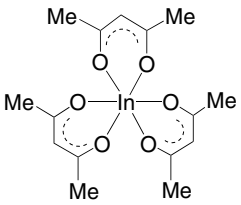
98-4054 HAZ — **Cyclopentadienylindium(I), elec. gr. (99.99+%-In) PURATREM, 97-3425, contained in 50 ml electropolished Swagelok® cylinder (96-1077) for CVD/ALD** *(34822-89-4)* — 5g

C5H5In; FW: 179.92; off-white to light yellow xtl.; b.p. subl. 50°/0.01 mm
air sensitive, heat sensitive, light sensitive

93-4905 — **Indium(III) trifluoroacetylacetonate, 99%** *(15453-87-9)* — 1g

$In(CF_3COCHCOCH_3)_3$; FW: 574.06; white pwdr.

49-4901 NEW — **Indium(III) acetylacetonate (99.99+%-In) PURATREM** *(14405-45-9)* — 5g, 25g



$In(CH_3COCHCOCH_3)_3$; FW: 412.15; off-white pwdr.; m.p. 180-185; b.p. 260-280 subl.; d. 1.41

49-2010 amp HAZ — **Trimethylindium, 98+% (99.9+%-In)** *(3385-78-2)* — 2g, 10g

$(CH_3)_3In$; FW: 159.92; white xtl.; m.p. 88°; f.p. -1°F; d. 1.568
heat sensitive, moisture sensitive, pyrophoric, (store cold)

WARNING - Trimethylindium may undergo rapid thermal decomposition if exposed to temperatures above 100ºC. Never attempt to distill the material at atmospheric pressure

---

98-2010 HAZ — **Trimethylindium, elec. gr. (99.999%-In) PURATREM** *(3385-78-2)* — 25g, 100g

$(CH_3)_3In$; FW: 159.93; white xtl.; m.p. 88°; f.p. -1°F; d. 1.568
heat sensitive, moisture sensitive, pyrophoric, (store cold)
Note: Available prepacked in ALD cylinder- see 98-4056.

WARNING - Trimethylindium may undergo rapid thermal decomposition if exposed to temperatures above 100ºC. Never attempt to distill the material at atmospheric pressure

---

98-4056 HAZ — **Trimethylindium, elec. gr. (99.999%-In) PURATREM, 98-2010, contained in 50 ml electropolished Swagelok® cylinder (96-1077) for CVD/ALD** *(3385-78-2)* — 25g

$(CH_3)_3In$; FW: 159.93; white xtl.; m.p. 88°; f.p. -1°F; d. 1.568
heat sensitive, moisture sensitive, pyrophoric, (store cold)

WARNING - Trimethylindium may undergo rapid thermal decomposition if exposed to temperatures above 100ºC. Never attempt to distill the material at atmospheric pressure

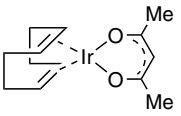
---

49-2200 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)indium(III), 99% (99.9%-In) [In(TMHD)$_3$]** *(34269-03-9)* — 1g, 5g

$In(C_{11}H_{19}O_2)_3$; FW: 664.63; white to off-white pwdr.; m.p. 167°

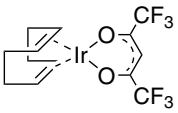
IRIDIUM (Compounds)

77-0900 **1,5-Cyclooctadiene(acetylacetonato)iridium(I), 99% (99.9%-Ir)** *(12154-84-6)* — 100mg, 500mg
$Ir(C_8H_{12})(C_5H_7O_2)$; FW: 399.49; yellow xtl.; m.p. 145-150° dec.



Technical Note:
1. Convenient precursor to a variety of Iridium complexes and catalysts.

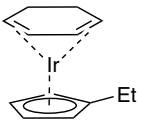
77-0930 **1,5-Cyclooctadiene(hexafluoroacetylacetonato)iridium(I), 98%** *(34801-95-1)* — 100mg, 500mg
$Ir(C_8H_{12})(C_5HF_6O_2)$; FW: 507.45; red-purple xtl.



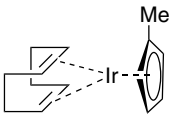
Technical Notes:
1. Useful precursor for chemical vapor deposition of iridium[5-6]

References:
1. *Materials Research Society Symposium Proceedings.*, **1999**, *541*, 129.
2. *Chemistry of Materials.*, **1998**, *10*, 2329.

77-1105 **1-Ethylcyclopentadienyl-1,3-cyclohexadieneiridium(I), 99% (99.9%-Ir)** *(721427-58-3)* — 250mg, 1g
$C_{13}H_{17}Ir$; FW: 365.49; pale yellow liq.



77-5000 **(Methylcyclopentadienyl) (1,5-cyclooctadiene)iridium(I), 99% (99.9%-Ir)** *(132644-88-3)* — 250mg, 1g
$(C_6H_7)(C_8H_{12})Ir$; FW: 379.53; white to off-white pwdr.; m.p. 38-40°; b.p. subl. 100°/0.05mm



Technical Note:
1. Air-stable product used in the low-temperature vapor deposition of iridium.

References:
1. *J. Material Chem.,* **1991**, *1*, 4, 551
2. *J. Vac. Sci. Tech. A,* **2000**, *18*, 10
3. *Surface and Coating Technology,* **2003**, *163*, 164, 208
4. *J. of Material Research,* **2001**, *16*, 8, 2192

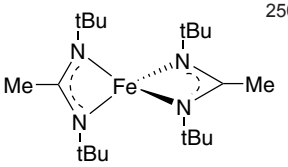
77-9700 **Tris(norbornadiene)(acetylacetonato)iridium(III), 98% (99.9%-Ir)** *(41612-46-8)* — 100mg, 500mg
$Ir(C_7H_8\text{-}C_7H_8)(C_7H_8)(C_5H_7O_2)$; FW: 567.75; light yellow pwdr.; m.p. 189°

IRON (Compounds)

26-1699 **Bis(cyclopentadienyl)iron, 98% (Ferrocene)** *(102-54-5)* — 500g, 2kg
$(C_5H_5)_2Fe$; FW: 186.04; orange xtl.; m.p. 172-173°

26-1700 **Bis(cyclopentadienyl)iron, 99% (Ferrocene)** *(102-54-5)* — 100g, 500g, 2kg
$(C_5H_5)_2Fe$; FW: 186.04; orange xtl.; m.p. 172-173°

26-0145 amp **Bis(N,N'-di-t-butylacetamidinato)iron (II), min. 98%** — 250mg, 1g, 5g
(635680-56-7)
$C_{20}H_{42}N_4Fe$; FW: 394.42; dark gray solid; m.p. 107°
air sensitive, moisture sensitive
Note: Extremely air-sensitive.
Contact Strem to discuss. Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.



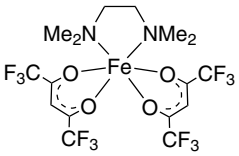
Technical Notes:
1. Iron amidinate used in the chemical vapor deposition of iron, iron carbides and iron nitride films.
2. Precursor for the MOCVD of iron-containing thin films.
3. Fabrication of thin films of iron oxide via atomic layer deposition.

References:
1. *Journal of the Electrochemical Society,* **2010**, *157*, D454
2. *ECS Transactions,* **2009**, *25*, 181
3. *ACS Appl. Mater. Interfaces* **2015**, *7*, 16138

26-0310 **Bis(ethylcyclopentadienyl)iron, min. 98%** *(1273-97-8)* — 1g, 5g
$[(C_2H_5)C_5H_4]_2Fe$; FW: 242.14; orange liq.; d. 1.18

IRON (Compounds)

26-1640 **Bis(1,1,1,5,5,5-hexafluoroacetylacetonato)(N,N,N',N'-tetramethylethylenediamine)iron(II), min. 98%** *(73450-43-8)*
$C_{16}H_{18}F_{12}FeN_2O_4$; FW: 586.15; black xtl.
air sensitive
Note: Sold under license from Universita degli Studi di Padova for research purposes only
Int. Patent App. PCT/IT2012/000276.
Italian Patent App. PD2011A000285.



100mg
500mg

Technical Notes:

1. Volatile iron complex used in the CVD of iron oxide thin films.
2. Volatile iron complex used in the vapor deposition of β-Fe_2O_3 nanosystems.
3. Volatile iron complex used in the controlled synthesis β-Fe_2O_3 nanosystems functionalized with silver and platinum nanoparticles, enabling an intimate metal-oxide contact and offering promising applications in gas-sensing devices.
4. Volatile iron complex used in the fabrication of β-Fe_2O_3 nanomaterials on titanium substrates, which exhibit promising performance as an anode for lithium batteries.
5. Volatile iron complex used in the preparation of supported ε and β iron oxide by CVD.
6. Volatile iron complex used in the preparation of supported fluorine-doped α-Fe_2O_3 via plasma-enhanced CVD.
7. Volatile iron complex used in the preparation of Fe_2O_3, and subsequent iron oxide ALD functionalization with a Fe-Ti-O overlayer for self-cleaning and antifogging applications.
8. Volatile iron complex used as a versatile CVD precursor for the phase-selective synthesis of β- and ε-Fe_2O_3.
9. Volatile iron complex used as a single source precursor for the one-pot synthesis of fluorine-doped α-Fe_2O_3 by a plasma-assisted strategy.
10. Volatile iron complex used for the plasma-enhanced CVD of fluorine-doped Fe_2O_3 films for photoelectrochemical applications.
11. Combined theoretical/experimental study on the molecular properties and CVD surface behavior of Fe(hfa)$_2$TMEDA and its homologous Co, Cu, and Zn compounds.
12. Phase-selective synthesis of α, β, and ε-Fe_2O_3 from Fe(hfa)$_2$TMEDA for sunlight-driven hydrogen production via photoreforming of aqueous solutions.
13. Theoretical study investigating the molecule-to-material conversion of Fe(hfa)$_2$TMEDA, and its homologous Co, Cu and Zn compounds in CVD applications.

References:

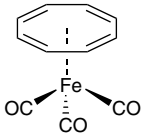
1. *Inorg. Chim. Acta.,* **2012**, *380*, 161
2. *Dalton Trans.,* **2012**, *41*, 149
3. *CrystEngComm,* **2012**, *14*, 6469
4. *ChemPhysChem,* **2012**, *13*, 3798
5. *CrystEngComm,* **2013**, *15*, 1039
6. *J. Nanosci. Nanotechnol.,* **2013**, *13*, 4962
7. *ACS Appl. Mater. Interfaces*, **2013**, *5*, 7130
8. *Eur. J. Inorg. Chem.,* **2013**, *5454*
9. *RSC Adv.,* **2013**, *3*, 23762
10. *Int. J. Hydrogen Energy,* **2013**, *38*, 14189
11. *Phys. Status Solidi (A),* **2014**, *211*, 251
12. *Adv. Funct. Mater.,* **2014**, *24*, 372
13. *Int. J. Quantum Chem.,* **2014**, *114*, 1

26-0400	**Bis(pentamethylcyclopentadienyl)iron, 99%** *(12126-50-0)* $[(CH_3)_5C_5]_2Fe$; FW: 326.31; orange xtl.; m.p. 298-300° subl. *air sensitive*	1g 5g
26-0450	**Bis(i-propylcyclopentadienyl)iron, min. 98%** *(12126-34-0)* $[(C_3H_7)C_5H_4]_2Fe$; FW: 270.20; orange liq.	1g 5g
26-0700	**t-Butylferrocene, min. 98%** *(1316-98-9)* $(CH_3)_3CC_5H_4FeC_5H_4$; FW: 242.15; dark-orange liq.; b.p. 80°/0.15mm; d. 1.201	1g 5g 25g
93-2602	**n-Butylferrocene, 99%** *(31904-29-7)* $(C_4H_9C_5H_4)Fe(C_5H_5)$; FW: 242.14; orange to brown liq.; b.p. 232°C/630 mm; d. 1.172 Note: For sale in USA. For other countries contact Strem.	10g 50g

IRON (Compounds)

26-0850 HAZ
Cyclohexadiene iron tricarbonyl, 98% *(12152-72-6)* — 5g
$C_6H_8Fe(CO)_3$; FW: 220.01; yellow to orange liq.; m.p. 8°
air sensitive, (store cold)

26-0875 HAZ
Cyclooctatetraene iron tricarbonyl, 98% *(12093-05-9)* — 1g, 5g
$C_8H_8Fe(CO)_3$; FW: 244.03; red to brown xtl.; m.p. 93-95°
air sensitive



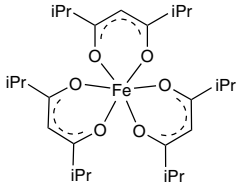
26-1600
Ethylferrocene, 98% *(1273-89-8)* — 5g, 25g
$C_2H_5C_5H_4FeC_5H_5$; FW: 214.09; red-orange liq.; d. 1.256

26-2800 HAZ
Iron pentacarbonyl, 99.5% (99.9+%-Fe) *(13463-40-6)* — 250g, 1kg
$Fe(CO)_5$; FW: 195.90; orange liq.; m.p. -20°; b.p. 103°; f.p. 5°F; d. 1.490
air sensitive, (store cold)

26-2801 HAZ
Iron pentacarbonyl, 99.5% (99.9+%-Fe) (Sure/Seal™ bottle) *(13463-40-6)* — 250g, 1kg
$Fe(CO)_5$; FW: 195.90; orange liq.; m.p. -20°; b.p. 103°; f.p. 5°F; d. 1.490
air sensitive, (store cold)

93-2644
Iron(III) trifluoroacetylacetonate, 99% (99.9%-Fe) *(14526-22-8)* — 5g, 25g
$Fe(CF_3C(O)CHC(O)CF_3)_3$; FW: 515.09; red xtl.; m.p. 110-112°

26-3915
Tris(2,6-dimethyl-3,5-heptanedionato)iron(III), 98% Fe(dibm)3 *(24444-72-2)* — 500mg, 2g, 10g
$C_{27}H_{45}FeO_6$; FW: 521.49; red-orange xtl.



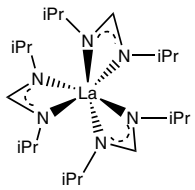
26-3910
Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)iron(III), 99% (99.9%-Fe) [Fe(TMHD)$_3$] *(14876-47-2)* — 1g, 5g, 25g
$Fe(C_{11}H_{19}O_2)_3$; FW: 605.66; red xtl.; m.p. 164°; b.p. dec. 300°

LANTHANUM (Compounds)

57-2550
Lanthanum(III) i-propoxide, 99% (99.9%-La) (REO) *(19446-52-7)* — 1g, 5g
$La(OC_3H_7)_3$; FW: 316.17; white to off-white pwdr.
moisture sensitive

57-3000 amp
Tris(cyclopentadienyl)lanthanum (99.9%-La) (REO) *(1272-23-7)* — 1g, 5g
$(C_5H_5)_3La$; FW: 334.19; white to off-white xtl.; m.p. 295° dec.
air sensitive, moisture sensitive

57-1200 amp HAZ
Tris(N,N'-di-i-propylformamidinato)lanthanum(III), (99.999+%-La) PURATREM La-FMD *(1034537-36-4)* — 1g, 5g
$C_{21}H_{45}LaN_6$; FW: 520.53; white to off-white pwdr.
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.



Technical Note:
1. Lanthanum precursor for the ALD/CVD of La_2O_3, $LaLuO_3$, $LaScO_3$, and $LaYO_3$ thin films.

References:

1. *Appl. Phys. Lett.,* **2009**, *94*, 262904
2. *Electrochem. Solid-State Lett.,* **2009**, *12*, G13
3. *Appl.Phys. Lett.,* **2010**, *97*, 162910
4. *J. Electrochem. Soc.,* **2011**, *158*, H447
5. *ECS Trans.,* **2012**, *45*, 95
6. *Nano Lett.,* **2013**, *13*, 594
7. *J. Crystal Growth,* **2013**, *363*, 150
8. *ECS Trans.,* **2013**, *54*, 255
9. *App. Surface Sci.,* **2014**, *292*, 880
10. *Proc. SPIE,* **2014**, *8987*, 898712

LANTHANUM (Compounds)

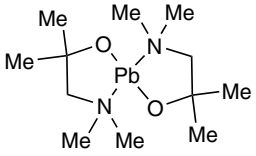
57-4000 amp
Tris(i-propylcyclopentadienyl)lanthanum (99.9%-La) (REO) *(68959-87-5)*
$(C_3H_7C_5H_4)_3La$; FW: 460.43; colorless to pale yellow liq.; b.p. 180-195°/0.02mm
air sensitive, moisture sensitive
1g 5g 25g

57-1000
Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)lanthanum(III), 99% (99.9%-La) (REO) [La(TMHD)$_3$] *(14319-13-2)*
$La(C_{11}H_{19}O_2)_3$; FW: 688.72; white pwdr.; m.p. 227-231°; b.p. dec. 370° (subl. 210°/0.2mm)
1g 5g 25g

57-1100
Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)lanthanum(III) tetraglyme adduct (99.9%-La) (REO) *(151139-14-9)*
$La(C_{11}H_{19}O_2)_3 \cdot CH_3(OCH_2CH_2)_4OCH_3$; FW: 688.72 (911.00); white to pale-yellow xtl.; m.p. 59°; b.p. 125°/0.1mm
1g 5g 25g

LEAD (Compounds)

82-2155
Bis(1-dimethylamino-2-methyl-2-propanolate)lead(II), 98% Pb(DMAMP)$_2$ *(934302-16-6)*
$C_{12}H_{28}N_2O_2Pb$; FW: 439.56; white solid
moisture sensitive
250mg 1g 5g



Technical Note:

1. Volatile compound used in the Chemical Vapor Deposition of lead oxide and lead oxide containing films.

References:

1. *Electrochem. Solid-State Lett.* **2007** *10(12)* G89.
2. *J. Electrochem. Soc*. **2007**, *154(3),* G69.
3. *Integrated Ferroelectrics*, **2006**, *81,* 261.

82-2100
Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)lead(II), 99% [Pb(TMHD)$_2$] *(21319-43-7)*
$Pb(C_{11}H_{19}O_2)_2$; FW: 573.75; white pwdr.; m.p. 126-128°; b.p. 325° dec. (subl. 134°/0.1mm)
1g 5g 25g

93-8265
Lead(II) hexafluoroacetylacetonate, min. 98% *(19648-88-5)*
$Pb(CF_3C(O)CHC(O)CF_3)_2$; FW: 621.29; white pwdr.; m.p. 153-158°; b.p. dec. 210° (subl. 180°/0.05 mm)
1g 5g

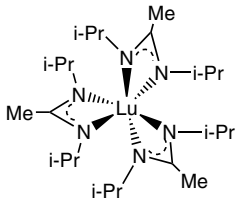
LITHIUM (Compounds)

03-0780 HAZ
Lithium t-butoxide, 98+% *(1907-33-1)*
$LiOC_4H_9$; FW: 80.06; off-white pwdr.; d. 0.89
moisture sensitive
25g 100g

03-5001
2,2,6,6-Tetramethyl-3,5-heptanedionato lithium, 98+% [Li(TMHD)] *(22441-13-0)*
$LiC_{11}H_{19}O_2$; FW: 190.24; white pwdr.; m.p. 265-268°; b.p. dec. 295°
1g 5g 25g

LUTETIUM (Compounds)

71-1050 amp
Tris(N,N'-di-i-propylacetamidinato)lutetium(III), 99%
$Lu(C_8H_{17}N_2)_3$; FW: 598.67; white to off-white pwdr.
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.
250mg 1g 5g



71-1080
Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)lutetium(III), 99% (99.9+%-Lu) (REO) [Lu(TMHD)$_3$] *(15492-45-2)*
$Lu(C_{11}H_{19}O_2)_3$; FW: 724.76; off-white xtl.
1g 5g 25g

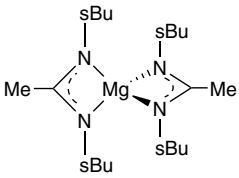
MAGNESIUM (Compounds)

12-0500 amp HAZ
Bis(cyclopentadienyl)magnesium (99.9+%-Mg) *(1284-72-6)*
$(C_5H_5)_2Mg$; FW: 154.49; white to light-pink xtl.; m.p. 176°; b.p. 290° (subl. 160°/0.1mm)
air sensitive, moisture sensitive
1g 5g 25g

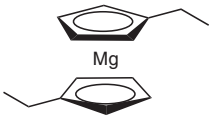
MAGNESIUM (Compounds)

97-1040 — **Bis(cyclopentadienyl)magnesium (99.99+%-Mg) PURATREM** — 1g, 5g, 25g
amp
HAZ
(1284-72-6)
$(C_5H_5)_2Mg$; FW: 154.49; white to light pink xtl.; m.p. 176°; b.p. 290° (subl. 160°/0.1mm)
air sensitive, moisture sensitive

12-0845 — **Bis(N,N'-di-sec-butylacetamidinato)magnesium, 99%** — 1g, 5g
$C_{20}H_{42}MgN_4$; FW: 362.88; colorless to pale yellow liq.
moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2



12-0510 — **Bis(ethylcyclopentadienyl)magnesium, min. 98%** — 1g, 5g, 25g
amp
HAZ
(114460-02-5)
$(C_2H_5C_5H_4)_2Mg$; FW: 210.60; colorless to pale yellow liq.; d. 1.912
air sensitive, moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4006, 98-4010.



References:

1. *Journal Nanosci. Nanotechno.,* **2011**, *11*, 7948
2. *J. Phys. Chem. C,* **2009**, *113*, 1939
3. *Jpn. J. Appl. Phys.,* **1**, *2007*, 46, 5040
4. *J. Cryst. Growth,* **2007**, *298*, 468

98-4006 — **Bis(ethylcyclopentadienyl)magnesium, min. 98%, 12-0510, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(114460-02-5)* — 10g
HAZ
$(C_2H_5C_5H_4)_2Mg$; FW: 210.60; colorless to pale yellow liq.; d. 1.912
air sensitive, moisture sensitive
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost. See 98-4010, 12-0510.

Technical Note:
1. See 12-0510 (page 29)

98-4010 — **Bis(ethylcyclopentadienyl)magnesium, min. 98%, 12-0510, contained in high-temp 50 ml Swagelok® cylinder (96-1071) for CVD/ALD** *(114460-02-5)* — 10g, 25g
HAZ
$(C_2H_5C_5H_4)_2Mg$; FW: 210.60; colorless to pale yellow liq.; d. 1.912
air sensitive, moisture sensitive

Technical Note:
1. See 12-0510 (page 29)

12-1045 — **Bis(pentamethylcyclopentadienyl)magnesium, min. 98%** *(74507-64-5)* — 500mg, 2g
amp
HAZ
$[(CH_3)_5C_5]_2Mg$; white to yellow xtl.
air sensitive, moisture sensitive

97-1045 — **Bis(pentamethylcyclopentadienyl)magnesium, elec. gr. (99.999%-Mg) PURATREM** — 1g, 5g, 25g
amp
HAZ
(74507-64-5)
$[(CH_3)_5C_5]_2Mg$; FW: 294.77; white to yellow xtl.
air sensitive, moisture sensitive

12-0550 — **Bis(n-propylcyclopentadienyl)magnesium, min. 98%** *(114504-74-4)* — 1g, 5g
amp
HAZ
$(C_3H_7C_5H_4)_2Mg$; FW: 238.66; colorless to pale yellow liq.; d. 0.94
air sensitive, moisture sensitive

12-0900 — **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)magnesium, anhydrous, min. 98% [Mg(TMHD)$_2$]** *(21361-35-3)* — 1g, 5g
$Mg(C_{11}H_{19}O_2)_2$; FW: 390.85; white pwdr.
hygroscopic
Note: Available prepacked in ALD cylinder- see 98-4069.

98-4069 — **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)magnesium, anhydrous, min. 98% [Mg(TMHD)2] , 12-0900, contained in high-temp 50 ml Swagelok® cylinder (96-1071) for CVD/ALD** *(21361-35-3)* — 15g
$Mg(C_{11}H_{19}O_2)_2$; FW: 390.85; white pwdr.
hygroscopic

MAGNESIUM (Compounds)

12-1000 **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)magnesium dihydrate, min. 98% [Mg(TMHD)$_2$]** *(625832-70-4)* — 1g, 5g, 25g
$Mg(C_{11}H_{19}O_2)_2{\cdot}2H_2O$; FW: 390.85 (426.88); white pwdr.; m.p. 135-150°(-H_2O); b.p. dec. 290° (subl. 150°/0.05mm)

12-1212 **Magnesium (N,N,N',N'-tetramethylethylenediamine)bis[BREW] (99.99+%-Mg) PURATREM** — 1g, 5g
$Mg(C_6H_{16}N_2)[C_xH_yC(O)CHC(O)C_xH_y]_2$ (x=3-4, y=2x+1); pale yellow liq.
moisture sensitive
Note: ***Limited quantities available. Will discontinue when stock gone***

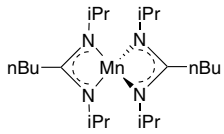
Technical Note:
1. See 56-5656 (page 14)

MANGANESE (Compounds)

98-4060 HAZ **Bis(cyclopentadienyl)manganese, 98+%, 25-0200, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(73138-26-8)* — 10g, 25g
$(C_5H_5)_2Mn$; FW: 185.13; brown xtl.; m.p. 172-173°
air sensitive, moisture sensitive

25-0200 amp HAZ **Bis(cyclopentadienyl)manganese, 98+% (Manganocene)** *(73138-26-8)* — 1g, 5g, 25g
$(C_5H_5)_2Mn$; FW: 185.13; brown xtl.; m.p. 172-173°
air sensitive, moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4060.

25-0230 amp **Bis(N,N'-di-i-propylpentylamidinato)manganese(II), min. 98%** *(1188406-04-3)* — 250mg, 1g, 5g
$C_{22}H_{46}MnN_4$; FW: 421.57; brown solid
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2



References:
1. *J. Phys. Chem. C,* **2012**, *116*, 23585

25-0210 amp HAZ **Bis(ethylcyclopentadienyl)manganese, min. 98%** *(101923-26-6)* — 1g, 5g, 25g
$[(C_2H_5)C_5H_4]_2Mn$; FW: 241.23; dark red liq.
air sensitive, moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4065.

98-4065 HAZ **Bis(ethylcyclopentadienyl)manganese, min. 98%, 25-0210, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(101923-26-6)* — 10g, 25g
$[(C_2H_5)C_5H_4]_2Mn$; FW: 241.23; dark red liq.
air sensitive, moisture sensitive

25-0235 amp **Bis(pentamethylcyclopentadienyl)manganese, min. 98% (Decamethylmanganocene)** *(67506-86-9)* — 1g, 5g
$[(CH_3)_5C_5]_2Mn$; FW: 325.38; orange xtl.; m.p. 292°
air sensitive, moisture sensitive

25-0245 amp HAZ **Bis(i-propylcyclopentadienyl)manganese, min. 98%** *(85594-02-1)* — 1g, 5g
$[(C_3H_7)C_5H_4]_2Mn$; FW: 269.28; dark red liq.
air sensitive, moisture sensitive

25-0390 HAZ **Cyclopentadienylmanganese tricarbonyl, 98% Cymantrene** *(12079-65-1)* — 1g, 5g, 25g
$C_5H_5Mn(CO)_3$; FW: 204.06; yellow xtl.; m.p. 77°
air sensitive

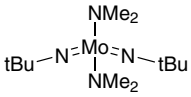
25-1330 **Manganese carbonyl, 98%** *(10170-69-1)* — 2g, 10g, 50g
$Mn_2(CO)_{10}$; FW: 389.99; yellow xtl.; m.p. 152-155°
air sensitive, (store cold)

25-1550 HAZ **Methylcyclopentadienylmanganese tricarbonyl, min. 97%** *(12108-13-3)* — 5g, 25g
$(CH_3C_5H_4)Mn(CO)_3$; FW: 218.09; yellow liq.; m.p. -2.2°; b.p. 233°; f.p. 205°F; d. 1.38

25-5000 **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)manganese(III), 99% [Mn(TMHD)$_3$]** *(14324-99-3)* — 1g, 5g, 25g
$Mn(C_{11}H_{19}O_2)_3$; FW: 604.74; black xtl.; m.p. 165°; b.p. dec. 255°

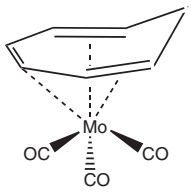
MOLYBDENUM (Compounds)

42-0215 — **Bis(t-butylimido)bis(dimethylamino)molybdenum(VI), 98%** *(923956-62-1)* — 500mg, 2g
$C_{12}H_{30}MoN_4$; FW: 326.33; orange liq.
air sensitive, moisture sensitive, (store cold)



42-0200 — **Bis(ethylbenzene)molybdenum [mixture of $(C_2H_5)_xC_6H_{6-x}$ where x = 0-4)]** *(32877-00-2)* — 1g
amp — $[(C_2H_5)_xC_6H_{6-x}]_2Mo$; dark green liq.; b.p. 150-170°/1mm — 5g
HAZ — *air sensitive* — 25g

42-0350 — **Cycloheptatriene molybdenum tricarbonyl, 99%** — 1g, 5g
amp
(12125-77-8)
$C_7H_8Mo(CO)_3$; FW: 272.11; orange to red xtl.; m.p. 100-101°
air sensitive, (store cold)



42-1350 — **Molybdenum carbonyl, 98%** *(13939-06-5)* — 5g
HAZ — $Mo(CO)_6$; FW: 264.01; white xtl.; m.p. 150-151° dec. — 25g, 100g, 500g

NEODYMIUM (Compounds)

93-6005 — **Neodymium(III) hexafluoroacetylacetonate dihydrate (99.9%-Nd) (REO)** *(47814-18-6)* — 5g
$Nd(CF_3COCHCOCF_3)_3{\cdot}2H_2O$; FW: 765.39 (801.42); purple xtl.

93-6017 — **Neodymium(III) trifluoroacetylacetonate (99.9%-Nd)** *(37473-67-9)* — 1g, 5g
$Nd(CF_3COCHCOCH_3)_3$; FW: 603.48; bluish-pink xtl.; m.p. 140-142°

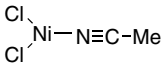
60-5000 — **Tris(cyclopentadienyl)neodymium, 99% (99.9%-Nd) (REO)** *(1273-98-9)* — 1g
amp — $(C_5H_5)_3Nd$; FW: 339.53; blue to purple pwdr.; b.p. subl. 220°/0.01mm — 5g
HAZ — *air sensitive, moisture sensitive* — 25g

60-6000 — **Tris(i-propylcyclopentadienyl)neodymium (99.9%-Nd) (REO)** *(69021-85-8)* — 1g
amp — $(C_3H_7C_5H_4)_3Nd$; FW: 465.77; purple solid — 5g
air sensitive, moisture sensitive

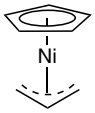
60-8750 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)neodymium(III), 99% (99.9%-Nd) (REO) [Nd(TMHD)$_3$]** *(15492-47-4)* — 1g, 5g
$Nd(C_{11}H_{19}O_2)_3$; FW: 694.06; light purple xtl.; m.p. 209-212°;
b.p. dec. 270° (subl. 150°/0.1mm)

NICKEL (Compounds)

28-1210 — **(Acetonitrile)dichloronickel(II), 99%** *(18897-44-4)* — 1g, 5g
NEW
$C_2H_3Cl_2NNi$; FW: 170.65; yellow pwdr.
air sensitive, hygroscopic



28-0009 — **Allyl(cyclopentadienyl)nickel(II), min. 97%** *(12107-46-9)* — 1g, 5g
NEW
HAZ
$C_8H_{10}Ni$; FW: 164.86; dark purple liq.; d. 1.31
air sensitive, moisture sensitive, pyrophoric



28-1301 — **Bis(cyclopentadienyl)nickel, 99% (Nickelocene)** *(1271-28-9)* — 5g
HAZ — $(C_5H_5)_2Ni$; FW: 188.90; dark green xtl.; m.p. 173-174° — 25g
air sensitive, (store cold) — 100g

Note: thermal stress induced decomposition of 28-1301;

Prolonged heating of this precursor may lead to accelerated decomposition of the precursor in the cylinder than would normally be expected. It is recommended, that to extend the useful life of the precursor, heating is suspended during “non-run time” periods to reduce prolonged thermal stress on this item.

NICKEL (Compounds)

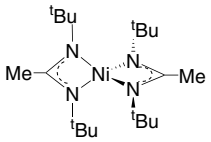
28-1301 **Bis(cyclopentadienyl)nickel, 99% (Nickelocene)** *(1271-28-9)*
(continued)

Technical Notes:
1. Precursor for the Plasma-assisted atomic layer deposition and post-annealing enhancement of low resistivity and oxygen-free nickel nano-films with ammonia as co-reactant[1]
2. Precursor for the ALD of nickel oxide thin films[2,3]
3. Precursor for the metalorganic chemical vapor deposition of Ni Films[4-6]

References:

1. *Journal of Materials Chemistry C,* **2016**, *4(47)*, 11059.
2. *Chemical vapor deposition*, **2011**, *17*, 177-180.
3. *Thin solid films*, **2001**, *391*, 57-61.
4. *Electrochem. Solid-State Lett*. **2002**, *5(6),* C64-C66.
5. *Journal of Materials Research*, **2000**,*15(8)*, 1828-1833.
6. *Chem. Vap. Deposition*, **1999**, *5*, 135-142.
7. *Chem. Vap. Deposition,* **1999**, *5*, 143-149.

28-0045 amp — **Bis(N,N'-di-t-butylacetamidinato)nickel(II), (99.999%-Ni) PURATREM** *(940895-79-4)* — 250mg, 1g, 5g
$C_{20}H_{42}N_4Ni$; FW: 397.27; dark, purple-black xtl.; m.p. 95-96°
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.

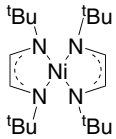


Technical Notes:
1. CVD/ALD precursor for the preparation of nickel nitride (NiNx) films.
2. CVD/ALD precursor for the preparation of nickel sulfide (NiSx) films co-deposited by H_2S.

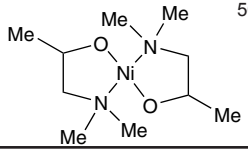
References:

1. *Chem. Mater.,* **2010**, *22*, 3060
2. *Chem. Mater.,* **2016**, *28*, 1155.

28-0225 NEW — **Bis(1,4-di-t-butyl-1,3-diazabutadienyl)nickel(II) Ni(DAD)$_2$, min. 98% (99.999%-Ni) PURATREM** — 250mg, 1g, 5g
$C_{20}H_{40}N_4Ni$; FW: 395.25; dichroic red/green xtl.
air sensitive
Note: U.S. Patent Application No. 13/818,154. Product sold under, use subject to, terms and conditions of label license at www.strem.com/waynestate1



28-0025 — **Bis[1-(N,N-dimethylamino)-2-propanolato]nickel(II), 99% NiDMAP** *(200284-92-0)* — 500mg, 2g
$C_{10}H_{24}N_2NiO_2$; FW: 263.00; green xtl.
air sensitive



28-0083 amp HAZ — **Bis(ethylcyclopentadienyl)nickel, min. 98%** *(31886-51-8)* — 1g, 5g
$[(C_2H_5)C_5H_4]_2Ni$; FW: 244.99; green liq.
air sensitive, (store cold)

28-0085 amp HAZ — **Bis(pentamethylcyclopentadienyl)nickel, 98% (Decamethylnickelocene)** *(74507-63-4)* — 1g, 5g
$[(CH_3)_5C_5]_2Ni$; FW: 329.17; greenish-black xtl.
air sensitive, (store cold)

28-0086 amp HAZ — **Bis(i-propylcyclopentadienyl)nickel, min. 98%** *(57197-55-4)* — 1g, 5g
$[(C_3H_7)C_5H_4]_2Ni$; FW: 273.04; green liq.
air sensitive, (store cold)

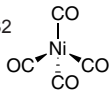
28-0088 — **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)nickel(II), min. 98% (99.9%-Ni) [Ni(TMHD)$_2$]** *(14481-08-4)* — 1g, 5g, 25g
$Ni(C_{11}H_{19}O_2)_2$; FW: 425.23; purple xtl.; m.p. 223-225°; b.p. subl. 90-110°/0.1mm
hygroscopic

28-1130 — **Nickel(II) acetylacetonate, anhydrous, min. 95%** *(3264-82-2)* — 25g, 100g
$Ni(CH_3COCHCOCH_3)_2$; FW: 256.93; light green pwdr.; m.p. 238° dec.
hygroscopic

28-1110 — **Nickel(II) acetylacetonate hydrate** *(120156-44-7)* — 100g, 500g
$Ni(CH_3COCHCOCH_3)_2 \cdot XH_2O$; FW: 256.93; light green pwdr.

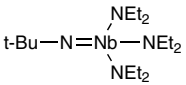
NICKEL (Compounds)

28-1150 HAZ
Nickel carbonyl *(13463-39-3)*
$Ni(CO)_4$; FW: 170.73; colorless liq.; m.p. -19.3°; b.p. 43°; f.p. -4°F; d. 1.32
heat sensitive
100g 450g



NIOBIUM (Compounds)

41-0450 HAZ
(t-Butylimido)tris(diethylamino)niobium(V), min. 98% TBTDEN *(210363-27-2)*
$C_{16}H_{39}N_4Nb$; FW: 380.41; brown liq.
air sensitive, moisture sensitive
1g 5g

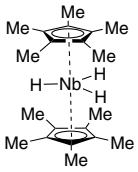


93-4104 amp HAZ
Niobium(V) ethoxide (99.9+%-Nb) *(3236-82-6)*
$Nb(OC_2H_5)_5$; FW: 318.22; colorless to orange liq.; m.p. 6°; b.p. 142°/0.1mm; d. 1.32
moisture sensitive
5g 25g

41-5300 HAZ
Pentakis(dimethylamino)niobium(V), 99% *(19824-58-9)*
$Nb[N(CH_3)_2]_5$; FW: 313.29; purple-black xtl.
moisture sensitive
1g 5g

41-7000
Tetrakis(2,2,6,6-tetramethyl-3,5-heptanedionato)niobium(IV), 99% [Nb(TMHD)$_4$] *(41706-15-4)*
$Nb(C_{11}H_{19}O_2)_4$; FW: 826.00; black xtl.; m.p. 219-220°; b.p. dec. 325°
1g 5g 25g

41-0510 HAZ
Trihydridobis(pentamethylcyclopentadienyl)niobium(V) *(93558-77-1)*
$[(CH_3)_5C_5]_2NbH_3$; FW: 366.38; light-brown pwdr.
air sensitive
100mg 500mg



OSMIUM (Compounds)

76-0150
Bis(cyclopentadienyl)osmium, 99% (99.9%-Os) (Osmocene) *(1273-81-0)*
$(C_5H_5)_2Os$; FW: 320.39; white xtl.; m.p. 226-228°
250mg 1g

76-0200 amp
Bis(pentamethylcyclopentadienyl)osmium, 99% (99.9%-Os) (Decamethylosmocene) *(100603-32-5)*
$[(CH_3)_5C_5]_2Os$; FW: 460.66; off-white pwdr.
500mg

OXYGEN (Compounds)

98-8000 NEW
Water, 99.999% (PURATREM), 98-0295, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD *(7732-18-5)*
H_2O; FW: 18.015; colorless liq.; m.p. 0; b.p. 100; d. 1.0
25g

PALLADIUM (Compounds)

46-0065
Allyl(cyclopentadienyl)palladium(II), 98% *(1271-03-0)*
$C_8H_{10}Pd$; FW: 212.58; red solid
air sensitive, (store cold)
100mg 500mg 2g

Technical Notes:
1. Volatile palladium catalyst with numerous uses in CVD and MOCVD applications.

References:
1. *Chem.Eur.J.,* **2012**, *19*, 13652
2. *Catalysis Letters,* **2012**, *142*, 313
3. *Chemistry of Materials,* **2009**, *21*, 2360

46-0248
Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)palladium(II), min. 98% [Pd(TMHD)$_2$] *(15214-66-1)*
$Pd(C_{11}H_{19}O_2)_2$; FW: 472.95; orange pwdr.
1g 5g

46-1870
Palladium(II) hexafluoroacetylacetonate, min. 95% *(64916-48-9)*
$Pd(CF_3COCHCOCF_3)_2$; FW: 520.52; yellow pwdr.
250mg 1g 5g

PHOSPHORUS (Compounds)

93-1587 — **Phosphorus(III) chloride, 98+%** *(7719-12-2)* — 250g
HAZ
PCl_3; FW: 137.33; colorless liq.; m.p. -111.8°; b.p. 76°; d. 1.574
moisture sensitive

93-1588 — **Phosphorus(III) chloride (99.998%-P) PURATREM** *(7719-12-2)* — 10g, 50g
amp
HAZ
PCl_3; FW: 137.33; m.p. -111.8°; b.p. 76°; d. 1.574
moisture sensitive

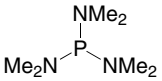
93-1543 — **Phosphorus oxychloride, 98+%** *(10025-87-3)* — 250g, 1kg
HAZ
$POCl_3$; FW: 153.35; colorless liq.; m.p. 2°; b.p. 105.3°; d. 1.675
moisture sensitive

97-8875 — **Phosphorus oxychloride, elec. gr. (99.999%-P) PURATREM** *(10025-87-3)* — 25g, 100g
amp
HAZ
$POCl_3$; FW: 153.35; colorless liq.; m.p. 2°; b.p. 105.3°; d. 1.675
moisture sensitive

93-1559 — **Triethylphosphate, 99%** *(78-40-0)* — 500g, 4 x 500g
$(C_2H_5O)_3PO$; FW: 182.16; colorless liq.; m.p. -56.4°; b.p. 215°; f.p. 240°F; d. 1.072

93-1561 — **Trimethylphosphate, min. 97%** *(512-56-1)* — 50g, 250g
$(CH_3O)_3P(O)$; FW: 140.08; colorless liq.; m.p. -46°; b.p. 197°; d. 1.197

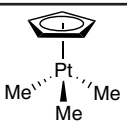
15-7800 — **Tris(dimethylamino)phosphine, min. 98% HMPT** — 1g, 5g
amp
HAZ
(1608-26-0)
$[(CH_3)_2N]_3P$; FW: 163.21; yellow liq.; b.p. 49-51°/12 mm; f.p. 98°F; d. 0.898
air sensitive, moisture sensitive



PLATINUM (Compounds)

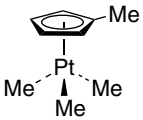
78-1550 — **Platinum(II) hexafluoroacetylacetonate, 98% (99.9%-Pt)** *(65353-51-7)* — 500mg, 2g
$Pt(CF_3COCHCOCF_3)_2$; FW: 609.22; orange xtl.; m.p. 143-145°; b.p. subl. 65°/0.1mm

78-1300 — **(Trimethyl)cyclopentadienylplatinum(IV), 99%** *(1271-07-4)* — 500mg, 2g
$(CH_3)_3(C_5H_5)Pt$; FW: 305.28; white to off-white pwdr.; m.p. 104-106°
air sensitive



Technical Note:
1. Platinum complex widely used in CVD and ALD applications due, in part, to its simplicity (only C,H and Pt), volatility, and moderate decomposition temperatures.

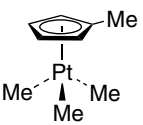
78-1350 — **(Trimethyl)methylcyclopentadienylplatinum(IV), 99%** — 500mg, 2g, 10g
HAZ
(94442-22-5)
$(CH_3)_3(CH_3C_5H_4)Pt$; FW: 319.32; off-white pwdr.; m.p. 30-31°; b.p. (subl. 23°/0.053mm); d. 1.88
air sensitive, (store cold)
Note: Available prepacked in ALD cylinder- see 98-4024, 98-4026.



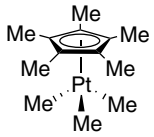
Technical Note:
1. Platinum complex widely used in CVD and ALD applications due, in part, to its simplicity (only C,H and Pt), volatility and moderate decomposition temperatures.

References:
1. *J. Am. Chem. Soc.*, **1989**, *111*, 8779.

98-1350 — **(Trimethyl)methylcyclopentadienylplatinum(IV), 99% (99.999%-Pt) PURATREM** *(94442-22-5)* — 500mg, 2g, 10g
$(CH_3)_3(CH_3C_5H_4)Pt$; FW: 319.32; off-white pwdr.; m.p. 30-31°; b.p. (subl. 23°C/0.053mm); d. 1.88
air sensitive, (store cold)



PLATINUM (Compounds)

98-4024 HAZ	**(Trimethyl)methylcyclopentadienylplatinum(IV), 99%, 78-1350, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(94442-22-5)* $(CH_3)_3(CH_3C_5H_4)Pt$; FW: 319.32; off-white pwdr.; m.p. 30-31°; b.p. subl. 23°/0.053mm; d. 1.88 *air sensitive, (store cold)* Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost. See 98-4026.	10g 25g
98-4026 HAZ	**(Trimethyl)methylcyclopentadienylplatinum(IV), 99%, 78-1350, contained in 50 ml Swagelok® cylinder high temperature valve (96-1071) for CVD/ALD** *(94442-22-5)* $(CH_3)_3(CH_3C_5H_4)Pt$; FW: 319.32; off-white pwdr.; m.p. 30-31°; b.p. subl. 23°/0.053mm; d. 1.88 *air sensitive, (store cold)*	20g
78-1358	**(Trimethyl)pentamethylcyclopentadienylplatinum(IV), 99%** *(97262-98-1)* $C_{13}H_{24}Pt$; FW: 375.41; off-white pwdr. *air sensitive* 	250mg 1g 5g

PRASEODYMIUM (Compounds)

93-5907	**Praseodymium(III) hexafluoroacetylacetonate (99.9%-Pr) (REO)** *(47814-20-0)* $Pr(CF_3COCHCOCF_3)_3$; FW: 762.06; light green pwdr.	1g 5g
59-7500 amp	**Tris(cyclopentadienyl)praseodymium (99.9%-Pr) (REO)** *(11077-59-1)* $(C_5H_5)_3Pr$; FW: 336.20; yellow pwdr.; m.p. 427° dec.; b.p. subl. 220°/0.01mm *air sensitive, moisture sensitive*	1g 5g
59-8000 amp	**Tris(i-propylcyclopentadienyl)praseodymium (99.9%-Pr) (REO)** *(69021-86-9)* $(C_3H_7C_5H_4)_3Pr$; FW: 462.44; light green xtl. *air sensitive, moisture sensitive*	1g 5g
93-5937	**Tris(2,2,6,6-tetramethyl-3,5-heptanedionato) praseodymium(III), 99% (99.9%-Pr) (REO) [Pr(TMHD)$_3$]** *(15492-48-5)* $Pr(C_{11}H_{19}O_2)_3$; FW: 690.72; light green pwdr.; m.p. 212-214°; b.p. dec. 300° (subl. 150°/0.1mm)	1g 5g

RHENIUM (Compounds)

75-2300	**Cyclopentadienylrhenium tricarbonyl, 99%** *(12079-73-1)* $(C_5H_5)Re(CO)_3$; FW: 335.33; white xtl.	250mg 1g 5g
75-2400	**Pentamethylcyclopentadienylrhenium tricarbonyl, min. 98%** *(12130-88-0)* $[(CH_3)_5C_5]Re(CO)_3$; FW: 405.46; off-white pwdr.; m.p. 149-151°	100mg 500mg 2g
75-2410 amp	**i-Propylcyclopentadienylrhenium tricarbonyl, min. 97%** *(126250-68-8)* $(C_3H_7)C_5H_4Re(CO)_3$; FW: 377.41; light-yellow liq. *(store cold)*	250mg 1g
75-1800	**Rhenium carbonyl, 98%** *(14285-68-8)* $Re_2(CO)_{10}$; FW: 652.51; white to yellow xtl.; m.p. 170° dec.; d. 2.87	1g 5g 25g

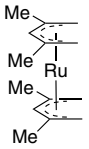
RHODIUM (Compounds)

45-0739	**Dicarbonyl(pentamethylcyclopentadienyl)rhodium(I), 99% (99.9%-Rh)** *(32627-01-3)* $(CH_3)_5C_5Rh(CO)_2$; FW: 294.16; red xtl. *air sensitive, (store cold)*	100mg 500mg
45-1800	**Rhodium(III) acetylacetonate, 97+% (99.9%-Rh)** *(14284-92-5)* $Rh(C_5H_7O_2)_3$; FW: 400.24; yellow xtl.; m.p. 260°; b.p. dec. >280° (subl. 240°/0.1mm)	250mg 1g 5g

RUTHENIUM (Compounds)

44-6200 **Bis(cyclopentadienyl)ruthenium, 99% (99.9%-Ru) (Ruthenocene)** *(1287-13-4)* — 1g, 5g
$(C_5H_5)_2Ru$; FW: 231.26; light yellow xtl.; m.p. 194-198°

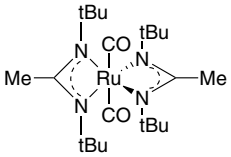
44-0030 **Bis(2,4-dimethylpentadienyl)ruthenium(II), 99%** — 250mg, 1g
(85908-78-7)
$(C_7H_{11})_2Ru$; FW: 291.39; yellow solid; m.p. 85°



Technical Note:
1. Volatile ruthenium complex, useful for the MOCVD of ruthenium and ruthenium oxide.

References:
1. *Electrochemical and Solid-State Letters,* **2007**, 10(6)
2. *ECS Transactions* **2006**, 1(5, Physics and Technology of High-k Gate Dielectrics III) 139-144.
3. *Journal of Crystal Growth,* **1998**, *195(1-4)*, 69-73
4. *Materials Research Society Symposium Proceedings,* **1998**, 495(Chemical Aspects of Electronic Ceramics Processing), 51-55 and 75-80.

44-0056 — 1g, 5g
NEW
amp
Bis(N,N'-di-tert-butylacetamidinato)ruthenium(II) dicarbonyl, 98% (99.99%-Ru) PURATREM *(949113-49-9)*
$C_{22}H_{42}N_4O_2Ru$; FW: 495.67; Beige to yellow solid; m.p. 204
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2



44-0040 **Bis(ethylcyclopentadienyl)ruthenium(II), 98% (99.9%-Ru)** *(32992-96-4)* — 500mg, 2g, 10g
$[(CH_3CH_2)C_5H_4]_2Ru$; FW: 287.37; pale yellow liq.; d. 1.3412
Note: Available prepacked in ALD cylinder- see 98-4009, 98-4067.

98-4009 **Bis(ethylcyclopentadienyl)ruthenium(II), 98% (99.9%-Ru), 44-0040, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(32992-96-4)* — 10g
$[(CH_3CH_2)C_5H_4]_2Ru$; FW: 287.37; pale yellow liq.; d. 1.3412
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost.
See 98-4067.

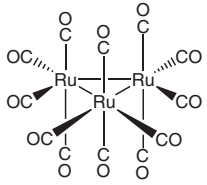
98-4067 **Bis(ethylcyclopentadienyl)ruthenium(II), 98% (99.9%-Ru), 44-0040, contained in high-temp 50 ml Swagelok® cylinder (96-1071) for CVD/ALD** *(32992-96-4)* — 10g, 20g
$[(CH_3CH_2)C_5H_4]_2Ru$; FW: 287.37; pale yellow liq.; d. 1.3412
Note: Liquid ruthenium CVD precursor.

44-0050 **Bis(pentamethylcyclopentadienyl)ruthenium, 99% (99.9%-Ru) (Decamethylruthenocene)** *(84821-53-4)* — 500mg, 2g
$[(CH_3)_5C_5]_2Ru$; FW: 371.53; off-white xtl.

44-0060 **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)(1,5-cyclooctadiene)ruthenium(II), 99% (99.9%-Ru)** *(329735-79-7)* — 1g, 5g
$(C_{11}H_{19}O_2)_2(C_8H_{12})Ru$; FW: 575.80; yellow-orange microxtl.; m.p. 187-190°;
b.p. dec. 220° (subl. 100°/0.05mm)

Technical Note:
1. Ruthenium precursor for MOCVD. Air stable, readily sublimable organometallic complex.

44-1850 **Ruthenium carbonyl, 99%** *(15243-33-1)* — 1g, 5g, 25g
$Ru_3(CO)_{12}$; FW: 639.34; orange xtl.; m.p. 150° dec.



44-8000 **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)ruthenium(III), 99% (99.9%-Ru) [Ru(TMHD)$_3$]** *(38625-54-6)* — 1g, 5g
$Ru(C_{11}H_{19}O_2)_3$; FW: 650.88; orange pwdr.; m.p. 210-213°;
b.p. dec. 250° (subl. 120°/0.5mm)

SAMARIUM (Compounds)

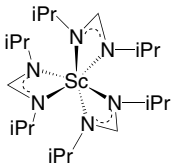
93-6219 **Samarium(III) trifluoroacetylacetonate (99.9%-Sm) (REO)** *(23301-82-8)* — 1g, 5g
$Sm(CF_3COCHCOCH_3)_3$; FW: 609.59; white pwdr.

62-3500 **Tris(cyclopentadienyl)samarium (99.9%-Sm) (REO)** *(1298-55-1)* — 1g, 5g
amp $(C_5H_5)_3Sm$; FW: 345.69; orange pwdr.; m.p. 356°
HAZ *air sensitive, moisture sensitive*

62-4000 **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)samarium(III) (99.9%-Sm) (REO) [Sm(TMHD)$_3$]** *(15492-50-9)* — 1g, 5g
$Sm(C_{11}H_{19}O_2)_3$; FW: 700.11; pale yellow xtl.; m.p. 191-193°;
b.p. dec. 250° (subl. 183°/1.3mm)

SCANDIUM (Compounds)

21-1200 **Tris(N,N'-di-i-propylformamidinato)scandium(III), (99.9%-Sc)** — 1g, 5g
NEW
$C_{21}H_{45}ScN_6$; FW: 426.58; white to off-white pwdr.
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2



21-1000 **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)scandium(III), 99% (99.9%-Sc) (REO) [Sc(TMHD)$_3$]** *(15492-49-6)* — 500mg, 2g
$Sc(C_{11}H_{19}O_2)_3$; FW: 594.77; white pwdr.; m.p. 150-152°; b.p. dec. 275°

SELENIUM (Compounds)

34-0380 **Diethyldiselenide, min. 97%** *(628-39-7)* — 2g, 10g, 50g
HAZ $C_2H_5SeSeC_2H_5$; FW: 216.04; red-brown liq.; b.p. 85°/21mm
air sensitive, (store cold), STENCH

34-0550 **Dimethylselenide, 99%** *(593-79-3)* — 10g, 50g
amp $(CH_3)_2Se$; FW: 109.03; colorless to yellow liq.; b.p. 57-58°; d. 1.4077
HAZ *air sensitive, heat sensitive, (store cold), STENCH*

SILICON (Compounds)

93-1402 **3-Aminopropyltriethoxysilane, 98%** *(919-30-2)* — 100g, 500g
HAZ $H_2N(CH_2)_3Si(OC_2H_5)_3$; FW: 221.38; colorless liq.; b.p. 217°; f.p. 220°F; d. 0.943
moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4036, 98-4037.

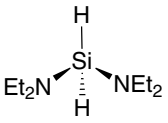
98-4036 **3-Aminopropyltriethoxysilane, 98%, 93-1402, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(919-30-2)* — 25g
HAZ $H_2N(CH_2)_3Si(OC_2H_5)_3$; FW: 221.38; colorless liq.; m.p. 300°; b.p. 217°; f.p. 220°F; d. 0.943
moisture sensitive
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost. See 98-4037.

98-4037 **3-Aminopropyltriethoxysilane, 98%, 93-1402, contained in high-temp 50 ml Swagelok® cylinder (96-1071) for CVD/ALD** *(919-30-2)* — 25g
HAZ $H_2N(CH_2)_3Si(OC_2H_5)_3$; colorless liq.; b.p. 217°; f.p. 220°F; d. 0.943
moisture sensitive

14-1060 **Bis(t-butylamino)silane, 97+% BTBAS** *(186598-40-3)* — 1g, 5g, 25g
amp $[NH(C_4H_9)]_2SiH_2$; FW: 174.36; colorless liq.; b.p. 167°C; f.p. 30°F; d. 0.816
HAZ *moisture sensitive, (store cold)*

14-1072 **Bis(t-butylamino)silane, BTBAS (99.999%-Si) PURATREM** *(186598-40-3)* — 1g, 5g, 25g
$C_8H_{22}N_2Si$; FW: 174.36; colorless liq.; b.p. 167°C; f.p. 30°C; d. 0.816
moisture sensitive

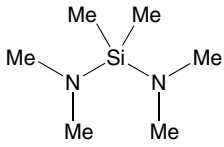
14-7030 **Bis(diethylamino)silane, 97% BDEAS** *(27804-64-4)* — 5g, 25g
HAZ $SiH_2[N(CH_2CH_3)_2]_2$; FW: 174.36; colorless liq.;
b.p. 70°(30mm); d. 0.804
air sensitive, moisture sensitive



References:
1. *ACS Applied Materials & Interfaces,* **2014**, *6*, 10534
2. *ECS Solid State Letters,* **2013**, *2*, P114

SILICON (Compounds)

98-8810 HAZ	**Bis(diethylamino)silane, 99% (99.999%-Si) BDEAS PURATREM** *(27804-64-4)* $SiH_2[N(CH_2CH_3)_2]_2$; FW: 174.36; colorless liq. *air sensitive, moisture sensitive*	5g 25g
14-1530 NEW	**Bis(dimethylamino)dimethylsilane, 99+% BDMADMS** *(3768-58-9)* $[N(CH_3)_2]_2(CH_3)_2Si$; FW: 146.31; colorless liq.; b.p. 128-129°; f.p. -3°C; d. 0.81 *moisture sensitive*	5g 25g



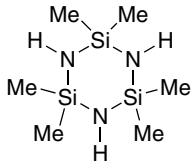
Technical Notes:

1. Used in the chemical vapor deposition of silicon nitride films, and also the atomic layer deposition of SiN_xC_y dielectric sealing layers using plasma-enhanced atomic layer deposition (PE-ALD).[1,2,3,4]
2. Used as a reagent for silylation.[5,6]

References:

1. *AIP Conference Proceedings*, **2015**, *1649(1, Irago Conference 2014)*, 41.
2. *Materials Science in Semiconductor Processing,* **2015**, *29*, 139.
3. *Applied Surface Science*, **2010**, *257(4),* 1196.
4. *Surface and Coatings Technology*, **2008**, *202(9),* 1606.
5. *Microelectronic Engineering,* **1991**, *13(1-4)*, 47.
6. *Journal of Vacuum Science & Technology, B: Microelectronics and Nanometer Structures*, **1990**, *8(6)*, 1481.

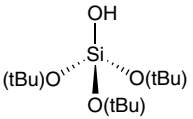
14-1955 HAZ	**Hexakis(ethylamino)disilane (99.995%-Si) PURATREM** *(532980-53-3)* $(C_2H_5NH)_6Si_2$; FW: 320.63; colorless liq.; m.p. -7°; b.p. 257°; d. 1.0 *moisture sensitive*	1g 5g
14-1510 HAZ	**2,2,4,4,6,6-Hexamethylcyclotrisilazane, 97%** *(1009-93-4)* $C_6H_{21}N_3Si_3$; FW: 219.51; colorless liq.	5g 25g



98-0147 HAZ	**Silicon(IV) chloride, fiber optic grade (99.9999%-Si, 50ppm-Fe) PURATREM** *(10026-04-7)* $SiCl_4$; FW: 169.90; colorless liq.; m.p. -70°; b.p. 57.6°; d. 1.483 *moisture sensitive* Note: Available prepacked in ALD cylinder- see 98-4027.	100g 500g
98-4027 HAZ	**Silicon(IV) chloride, fiber optic grade (99.9999%-Si, 50ppm-Fe) PURATREM, 98-0147, contained in a 50 ml electropolished Swagelok® cylinder (96-1077) for CVD/ALD** *(10026-04-7)* $SiCl_4$; FW: 169.90; colorless liq.; m.p. -70°; b.p. 57.6°; d. 1.483 *moisture sensitive*	50g
93-1451	**Tetrabutoxysilane, min. 97%** *(4766-57-8)* $Si(OC_4H_9)_4$; FW: 320.53; colorless liq.; b.p. 115°/3 mm; f.p. 174°F; d. 0.90 *moisture sensitive*	10g 50g
93-1454 HAZ	**Tetraethoxysilane, min. 98% TEOS** *(78-10-4)* $Si(OC_2H_5)_4$; FW: 208.33; colorless liq.; m.p. -77°; b.p. 165.8°; f.p. 116°F; d. 0.934 *moisture sensitive*	500g 2kg
14-6990 HAZ	**Tetrakis(ethylmethylamino)silane, 98%, TEMAS** *(477284-75-6)* $[CH_3(CH_2CH_2)N]_4Si$; FW: 260.57; colorless liq.; b.p. 40°C; d. 0.89 *moisture sensitive*	1g 5g 25g
93-1459 HAZ	**Tetramethoxysilane, 98%** *(681-84-5)* $Si(OCH_3)_4$; FW: 152.20; colorless liq.; m.p. 4-5°; b.p. 121-122°; f.p. 84°F; d. 1.032 *moisture sensitive*	25g 100g
93-1458 HAZ	**Tetramethylsilane, 99.9+% (NMR grade)** *(75-76-3)* $Si(CH_3)_4$; FW: 88.23; colorless liq.; b.p. 26.5°; f.p. -17°F; d. 0.651 (15°)	25g 100g

SILICON (Compounds)

14-7028 **Tri-t-butoxysilanol (99.9+%-Si)** *(18166-43-3)* 5g 25g
$[(CH_3)_3CO]_3SiOH$; FW: 264.43; colorless liq.; m.p. 63-65°
moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1.



Technical Note:
1. Silicon oxide source for rapid atomic layer deposition to prepare various nanolaminates.

References:
1. *Nanoscale,* **2013**, *5*, 11856
2. *Mater. Research Bulletin,* **2012**, *47*, 3004

14-7015 **Tri-t-butoxysilanol (99.999%-Si) PURATREM** *(18166-43-3)* 1g 5g
$[(CH_3)_3CO]_3SiOH$; FW: 264.43; white liquid to semi-solid; m.p. 63-65°
moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1. Available prepacked in ALD cylinder- see 98-6025.

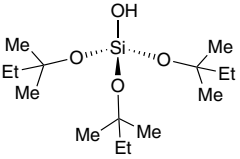
Technical Note:
1. See 14-7028 (page 39)

98-6025 **Tri-t-butoxysilanol (99.999%-Si) PURATREM 14-7015 contained in 50 ml Swagelok® cylinder (96-1077) for CVD/ALD** *(18166-43-3)* 25g
$[(CH_3)_3CO]_3SiOH$; FW: 264.43; white solid
moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1.

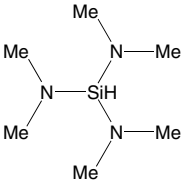
Technical Note:
1. See 14-7028 (page 39)

14-7925 **Trimethylsilane, 97%** *(993-07-7)* 100g
HAZ $(CH_3)_3SiH$; FW: 74.20; gas; m.p. -135.9°; b.p. 6.7°; f.p. <-4°F; d. 0.638 (6.7°)

14-7020 **Tri-t-pentoxysilanol (99.999%-Si) PURATREM** 1g 5g
(17906-35-3)
$[CH_3CH_2C(CH_3)_2O]_3SiOH$; FW: 306.51; colorless liq.
moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1.
Limited quantities available.



14-8750 **Tris(dimethylamino)silane, 99+%, 3DMAS (99.999%-Si) PURATREM** *(15112-89-7)* 5g 25g
HAZ $[(CH_3)_2N]_3SiH$; FW: 161.32; colorless to light yellow liq.; b.p. 145-148° (4°/16mm); f.p. 77°F; d. 0.84
Note: Available prepacked in ALD cylinder- see 98-4035.



Technical Note:
1. Silicon precursor for the atomic layer deposition (ALD) and CVD of silicon containing thin films.

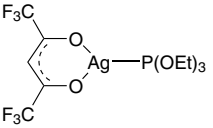
References:
1. *Nanoscale Research Letters*, **2017**, *12*, 370.
2. *Journal of the Korean Physical Society*, **2015**, *67(12)*, 2115.
3. *Journal of Materials Science: Materials in Electronics*, **2012**, *23*, 2075.

98-4035 **Tris(dimethylamino)silane, 99+%, 3DMAS (99.999%-Si) PURATREM, 14-8750, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(15112-89-7)* 25g
HAZ $[(CH_3)_2N]_3SiH$; FW: 161.32; colorless to light yellow liq.; b.p. 145-148° (4°/16mm); f.p. 77°F; d. 0.84
air sensitive, moisture sensitive

SILVER (Compounds)

47-2600 **2,2,6,6-Tetramethyl-3,5-heptanedionato silver(I) (99.9%-Ag) [Ag(TMHD)]** 1g
(79827-25-1) 5g
$AgC_{11}H_{19}O_2$; FW: 291.14; gray pwdr.; m.p. 178° dec. 25g

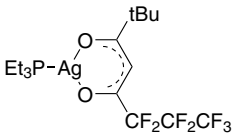
47-3010 **Triethoxyphosphine(trifluoroacetylacetonate)silver(I), min. 98%** *(783334-85-0)* 1g
$Ag(CF_3COCHCOCH_3)P(OCH_2CH_3)_3$; FW: 427.10; yellow solid 5g



Technical Note:
1. Precursor for the chemical vapor deposition of silver films.

References:
1. *Thin Solid Films,* **2005**, *478(1-2)*, 72

47-3025 **Triethylphosphine(6,6,7,7,8,8,8-heptafluoro-2,2-dimethyl-3,5-octanedionate)silver(I), min. 98%** 1g
(165461-74-5) 5g
$Ag(C_3F_7COCHCOC_4H_9)P(CH_2CH_3)_3$; FW: 521.20;
yellow liq. to low melting solid; d. 1.623
air sensitive, light sensitive, (store cold)



Technical Note:
1. Precursor for the chemical vapor deposition of silver films. Together with plasma-activated hydrogen, useful starting material for the atomic layer deposition of silver thin films at growth temperatures of 120-150°C.

References:
1. *Microelectronic Engineering,* **2005**, *82(3-4)*, 296.
2. *J. Phys.Chem.,* **1995**, *99*, 9230
3. *J. Am. Chem. Soc.,* **1995**, *117*, 4030
4. *Chem. Mater.*, **2011**, *23*, 2901.

47-3000 **Trimethylphosphine(hexafluoroacetylacetonato)silver(I), 99% (99.9%-Ag)** *(148630-66-4)* 1g
$Ag(CF_3COCHCOCF_3)P(CH_3)_3$; FW: 391.00; white to yellow xtl.; m.p. 140-142°; 5g
b.p. subl. 95°/0.1mm 25g

47-8000 **Vinyltriethylsilane(hexafluoroacetylacetonato)silver(I) (99.9%-Ag)** *(177279-28-6)* 1g
$Ag(CF_3COCHCOCF_3)(C_8H_{18}Si)$; FW: 456.45; yellow liq. 5g
air sensitive, (store cold)

Technical Note:
1. Precursor for the chemical vapor deposition of pure silver films.

STRONTIUM (Compounds)

38-1000 **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)strontium hydrate [$Sr(TMHD)_2$]** 1g
(199445-30-2) 5g
$Sr(C_{11}H_{19}O_2)_2 \cdot XH_2O$; FW: 454.16; light yellow pwdr.; m.p. 200-203°; b.p. dec. 250° 25g
(subl. 230°/0.05mm)

38-1010 **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)strontium tetraglyme adduct (99.99%-Sr)** 1g
PURATREM *(150939-76-7)* 5g
$Sr(C_{11}H_{19}O_2)_2 \cdot CH_3(OCH_2CH_2)_4OCH_3$; FW: 454.16 (676.44); white xtl.; m.p. 75°
Note: This compound is covered by U.S. Patent No. 5,225,561, and is manufactured and sold under license from Advanced Technology Materials, Inc., Danbury, CT.

38-1015 **Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)strontium triglyme adduct (99.99%-Sr)** 1g
PURATREM 5g
$Sr(C_{11}H_{19}O_2)_2 \cdot CH_3(OCH_2CH_2)_3OCH_3$; FW: 454.16 (632.39); white xtl.; m.p. 102°
Note: This compound is covered by U.S. Patent No. 5,225,561, and is manufactured and sold under license from Advanced Technology Materials, Inc., Danbury, CT.

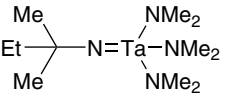
38-3838 **Strontium bis(N,N,N',N',N''-pentamethyldiethylenetriamine)bis[BREW] (99.99+%-Sr)** 1g
PURATREM 5g
$Sr(C_9H_{23}N_3)_2[C \cdot H_yC(O)CHC(O)C \cdot H_y]_2$ (x=3-4, y=2x +1); pale yellow liq.
moisture sensitive
Note: 9-11 wt% Sr, ***Limited quantities available. Will discontinue when stock gone***

Technical Note:
1. See 56-5656 (page 14)

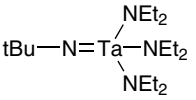
38-2000 **Strontium hexafluoroacetylacetonate** *(1245785-21-0)* 1g
$Sr(CF_3COCHCOCF_3)_2$; FW: 501.75; off-white pwdr.; m.p. dec. 260°; b.p. (subl. 220°/0.02mm) 5g
25g

TANTALUM (Compounds)

73-0490 **t-Amylimidotris(dimethylamino)tantalum(V) TAIMATA** *(629654-53-1)* — 1g, 5g
$C_{11}H_{29}N_4Ta$; FW: 398.32; colorless solid
air sensitive, moisture sensitive



73-0723 **(t-Butylimido)tris(diethylamino)tantalum(V), min. 98% (99.99%-Ta) PURATREM TBTDET** *(169896-41-7)* — 250mg, 1g, 5g
$C_{16}H_{39}N_4Ta$; FW: 468.45; colorless to pale yellow liq.; d. 1.252 g/ml@25°C
air sensitive, moisture sensitive

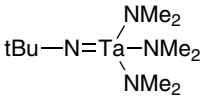


Technical Note:
1. Useful precursor for the atomic layer deposition of tantalum oxide and tantalum nitride.

References:

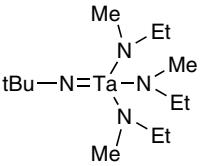
1. *Journal of Nanosci. and Nanotechno.,* **2013**, *13*, 4097.
2. *Semicond. Sci. Tech.,* **2012**, *27*, 074003.
3. *Chem. Vapor Depos.*, **2011**, *17*, 37.
4. *Electrochem. Solid St.,* **2010**, *13*, H426.
5. *J. Electrochem. Soc.,* **2010**, *157*, H652.
6. *J. Electrochem. Soc.,* **2009**, *156*, H852.

73-0700 **t-Butylimidotris(dimethylamino) tantalum(V), min. 98%** *(69039-11-8)* — 1g, 5g
$C_{10}H_{27}N_4Ta$; FW: 384.30; pale-yellow solid
air sensitive, moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4045.



98-4045 **t-Butylimidotris(dimethylamino)tantalum(V), min. 98%, 73-0700, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(69039-11-8)* — 10g, 25g
$C_{10}H_{27}N_4Ta$; FW: 384.30; colorless solid
air sensitive, moisture sensitive
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost.

73-0735 **(t-Butylimido)tris(ethylmethylamino)tantalum(V) (99.99%-Ta) PURATREM** *(511292-99-2)* — 1g, 5g, 25g
$C_{13}H_{33}N_4Ta$; FW: 426.38; yellow liq.
air sensitive, moisture sensitive



73-0800 amp HAZ **Pentakis(dimethylamino)tantalum(V), min. 98%** *(19824-59-0)* — 1g, 5g, 25g
$Ta[N(CH_3)_2]_5$; FW: 401.33; orange xtl.; m.p. >100° (dec.); b.p. subl. 100°/0.1mm
moisture sensitive

93-7303 amp HAZ **Tantalum(V) ethoxide (99.99+%-Ta) PURATREM** *(6074-84-6)* — 10g, 50g, 5 x 50g
$Ta(OC_2H_5)_5$; FW: 406.26; colorless to yellow liq.; m.p. 21°; b.p. 145°/0.1 mm; f.p. 87°F; d. 1.56
moisture sensitive

93-7325 HAZ **Tantalum(V) fluoride, 99.5%** *(7783-71-3)* — 5g, 25g
TaF_5; FW: 275.94; off-white pwdr.; m.p. 96.8°; b.p. 229.5°; d. 4.74
moisture sensitive
Note: Packaged in PFA/FET bottle.

93-7329 HAZ **Tantalum(V) methoxide (99.99+%-Ta) PURATREM** *(865-35-0)* — 2g, 10g
$Ta(OCH_3)_5$; FW: 336.12; white pwdr.; m.p. 50°; b.p. 189°/10 mm
moisture sensitive

73-5000 HAZ **Tantalum(V) (tetraethoxy)(acetylacetonate) (99.99+%-Ta) PURATREM** *(20219-33-4)* — 10g, 50g
$Ta(OC_2H_5)_4(CH_3COCHCOCH_3)$; FW: 460.30; yellow solid to liquid; m.p. 45°; b.p. 95°/0.5mm; d. 1.5
moisture sensitive

73-7373 **Tantalum(V) (tetraethoxy)[BREW] (99.99+%-Ta) PURATREM** — 1g, 5g
$Ta(C_2H_5O)_4[C_xH_yC(O)CHC(O)C_xH_y]_2$ (x=3-4, y=2x+1); pale brown liq.
moisture sensitive
Note: ***Limited quantities available. Will discontinue when stock gone***

TERBIUM (Compounds)

65-7000 amp — **Tris(i-propylcyclopentadienyl)terbium (99.9%-Tb) (REO)** *(312696-25-6)* — 1g, 5g
$(C_3H_7C_5H_4)_3Tb$; FW: 480.45; yellow solid
air sensitive

65-8000 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)terbium(III), 99% (99.9%-Tb) (REO) [Tb(TMHD)$_3$]** *(15492-51-0)* — 1g, 5g
$Tb(C_{11}H_{19}O_2)_3$; FW: 708.74; off-white xtl.; m.p. 155-156°; b.p. dec. 275°

THALLIUM (Compounds)

81-0305 HAZ — **Cyclopentadienylthallium, 99% (99.9%-Tl) sublimed** *(34822-90-7)* — 1g, 5g, 25g
C_5H_5Tl; FW: 269.47; yellow xtl.; m.p. subl. 75°/0.1mm
air sensitive, (store cold)

81-1000 HAZ — **2,2,6,6-Tetramethyl-3,5-heptanedionatothallium(I), 99% [Tl(TMHD)]** *(56713-38-3)* — 1g, 5g
$Tl(C_{11}H_{19}O_2)$; FW: 387.62; white to off-white pwdr.; m.p. 159-164°;
b.p. dec. 260° (subl. 110°/0.1mm)

93-8105 HAZ — **Thallium(I) ethoxide, min. 95%** *(20398-06-5)* — 5g, 25g
$Tl(OC_2H_5)$; FW: 249.43; cloudy, dense liq.; m.p. -3°; b.p. 130° dec.; d. 3.493 (20°)
moisture sensitive, (store cold)
Note: May contain a precipitate.

81-2500 HAZ — **Thallium(I) hexafluoroacetylacetonate, 99% (99.9%-Tl)** *(15444-43-6)* — 1g, 5g
$TlCF_3COCHCOCF_3$; FW: 411.42; yellow xtl.; m.p. 126-128°;
b.p. dec. 220° (subl. 140°/0.1mm)

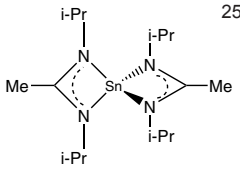
THULIUM (Compounds)

69-6000 amp — **Tris(cyclopentadienyl)thulium (99.9%-Tm) (REO)** *(1272-26-0)* — 1g, 5g
$(C_5H_5)_3Tm$; FW: 364.22; greenish yellow xtls.
air sensitive, moisture sensitive

69-7000 — **Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)thulium(III), 98% (99.9%-Tm) (REO) [Tm(TMHD)$_3$]** *(15631-58-0)* — 1g, 5g
$Tm(C_{11}H_{19}O_2)_3$; FW: 718.75; off-white xtl.; m.p. 169-172°; b.p. dec. 280°

TIN (Compounds)

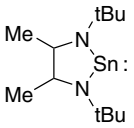
50-1170 amp — **Bis(N,N'-di-i-propylacetamidinato)tin(II), 99%** *(1421599-46-3)* — 250mg, 1g, 5g
$Sn(C_8H_{17}N_2)_2$; FW: 401.18; white xtls.
air sensitive, moisture sensitive
Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.



References:

1. *Chem. Mater.*, **2014**, *26*, 3065.
2. *Adv. Eng. Mater.*, **2011**, *1*, 1116

50-1150 amp — **N,N'-Di-t-butyl-2,3-diamidobutanetin(II), 98%** *(1268357-44-3)* — 250mg, 1g, 5g
$C_{12}H_{26}N_2Sn$; FW: 317.06; orange pwdr.
moisture sensitive, (store cold)
Note: ALD Precursor. US Patent Application 61/320,069 filed April 1, 2010. Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard3. Available prepacked in ALD cylinder- see 98-4052.



Technical Note:
1. Tin precursor for the ALD of tin sulfides, oxides and composites

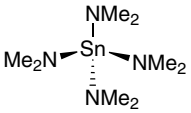
References:

1. *J.Phys.Chem. C.,* **2011**, *115*, 10277
2. *J. Mater. Chem.*, **2012**, *22*, 4599
3. *Chem. Mater.,* **2014**, *26*, 3065

98-4052 — **N,N'-Di-t-butyl-2,3-diamidobutanetin(II), 98%, 50-1150, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(1268357-44-3)* — 5g
$C_{12}N_{26}N_2Sn$; FW: 317.06; white to off-white pwdr.
air sensitive, moisture sensitive, (store cold)
Note: ALD Precursor. US Patent Application 61/320,069 filed April 1, 2010. Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard3.

TIN (Compounds)

50-1815 — **Tetrakis(dimethylamino)tin(IV), 99% (99.99%-Sn)** — 1g, 5g, 25g
amp
HAZ
TDMASn PURATREM *(1066-77-9)*
$Sn[N(CH_3)_2]_4$; FW: 295.01; colorless to pale-yellow liq.; b.p. 51° (0.1mm); d. 1.169 g/cm³
moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4050.



Technical Note:
1. ALD precursor for tin.

References:
1. *Chem. Mater.,* **1992**, *4*, 68
2. *Chem. Mater.,* **1994**, *6*, 360
3. *Chem. Mater.,* **2014**, *26*, 2795

98-4050 — **Tetrakis(dimethylamino)tin(IV), 99% (99.99%-Sn) TDMASn PURATREM, 50-1815, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(1066-77-9)* — 10g, 25g
HAZ
$Sn[N(CH_3)_2]_4$; FW: 295.01; colorless to pale-yellow liq.; b.p. 51° (0.1mm); d. 1.169g/cm³
moisture sensitive

50-1900 — **Tetramethyltin, 98%** *(594-27-4)* — 5g, 25g
HAZ
$Sn(CH_3)_4$; FW: 178.83; colorless liq.; m.p. -54.8°; b.p. 76-78°; f.p. 9°F; d. 1.3149

50-1977 — **Tin(II) acetylacetonate, min. 98%** *(16009-86-2)* — 2g, 10g, 50g
$Sn(CH_3COCHCOCH_3)_2$; FW: 316.93; yellow liq.; b.p. 110°/0.1mm; d. 1.45
moisture sensitive

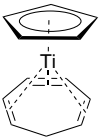
50-2100 — **Tin(IV) t-butoxide (99.99%-Sn) PURATREM** *(36809-75-3)* — 1g, 5g, 25g
$Sn(OC_4H_9)_4$; FW: 411.17; white solid to turbid colorless liq.; m.p. 45°; b.p. 65°/0.3mm; d. 1.06
moisture sensitive

50-5022 — **Tin(IV) chloride, anhydrous (99.99-Sn%) PURATREM** *(7646-78-8)* — 5g, 25g
HAZ
$SnCl_4$; FW: 260.50; colorless liq.; m.p. -33°; b.p. 114.1°C; d. 2.226
air sensitive, moisture sensitive

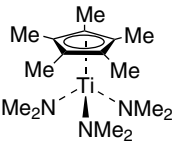
50-1980 — **Tin(II) hexafluoroacetylacetonate (99.9%-Sn)** *(51319-99-4)* — 5g, 25g
$Sn(CF_3COCHCOCF_3)_2$; FW: 532.81; yellow solid; m.p. 72°; b.p. 125°/2mm

TITANIUM (Compounds)

22-0450 — **Cyclopentadienyl(cycloheptatrienyl)titanium(II), 99%** *(51203-49-7)* — 500mg, 2g
HAZ
$Ti(C_5H_5)(C_7H_7)$; FW: 204.09; blue xtl.
air sensitive
Note: CVD Precursor.



22-6015 — **Pentamethylcyclopentadienyltris (dimethylamino) titanium(IV), 99%** *(154940-96-2)* — 250mg, 1g, 5g
HAZ
$[(CH_3)_5C_5]Ti[N(CH_3)_2]_3$; FW: 315.32; red xtl.
moisture sensitive



References:
1. *J. Organomet. Chem.,* **2010**, *696*, 235
2. *ECS Transactions* **2009**, *25(4, Atomic Layer Deposition Applications 5)* 217.
3. *J. Am. Chem. Soc.,* **2007**, *129*, 1776

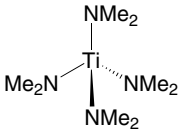
22-1050 — **Tetrakis(diethylamino)titanium(IV), 99%** *(4419-47-0)* — 5g, 25g
amp
HAZ
$Ti[N(C_2H_5)_2]_4$; FW: 336.40; yellow to orange liq.; b.p. 133°/1.2mm; f.p. -18°F; d. 0.938
moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4043.

98-4043 — **Tetrakis(diethylamino)titanium(IV), 99%, 22-1050, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(4419-47-0)* — 10g, 25g
HAZ
$Ti[N(C_2H_5)_2]_4$; FW: 336.40; yellow to orange liq.; b.p. 133°/1.2mm; f.p. -18°F; d. 0.938
moisture sensitive
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost.

TITANIUM (Compounds)

93-2240
amp
HAZ

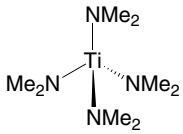
Tetrakis(dimethylamino)titanium(IV), 99% TDMAT
(3275-24-9)
$Ti[N(CH_3)_2]_4$; FW: 224.20; yellow to orange liq.; b.p. 50°/0.5 mm; f.p. -22°F; d. 0.96
moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4015, 98-4016.



1g
5g
25g

22-2240
HAZ

Tetrakis(dimethylamino)titanium(IV), 99% TDMAT
(99.99%-Ti) PURATREM *(3275-24-9)*
$Ti[N(CH_3)_2]_4$; FW: 224.20; yellow to orange liq.; f.p. -22°F
air sensitive, moisture sensitive



1g
5g
25g

98-4015
HAZ

Tetrakis(dimethylamino)titanium(IV), 99% TDMAT, 93-2240, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD *(3275-24-9)*
$Ti[N(CH_3)_2]_4$; FW: 224.20; yellow to orange liq.; b.p. 50°/0.5 mm; f.p. -22°F; d. 0.96
moisture sensitive
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost. See 98-4016.

25g

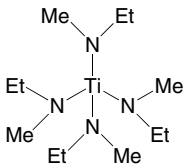
98-4016
HAZ

Tetrakis(dimethylamino)titanium(IV), 99% TDMAT, 93-2240, contained in high-temp 50 ml Swagelok® cylinder (96-1071) for CVD/ALD *(3275-24-9)*
$Ti[N(CH_3)_2]_4$; FW: 224.20; yellow to orange liq.; b.p. 50°/0.5 mm; f.p. -22°F; d. 0.96
moisture sensitive

25g

22-1060
amp
HAZ

Tetrakis(ethylmethylamino)titanium, 99% (99.99%-Ti) PURATREM *(308103-54-0)*
$C_{12}H_{32}N_4Ti$; FW: 280.28; yellow to orange liq.; b.p. 80°/1 mm
moisture sensitive



2g
10g

93-2204

Titanium(IV) n-butoxide, 98+% *(5593-70-4)*
$Ti(OC_4H_9)_4$; FW: 340.35; colorless liq.; m.p. -55°; b.p. 312° (206°/10mm); f.p. 170°F; d. 0.994 (25°)
moisture sensitive

500g
2kg

22-1170

Titanium(IV) t-butoxide (99.95%-Ti) *(3087-39-6)*
$Ti(OC_4H_9)_4$; FW: 340.35; colorless liq.; b.p. 70°/0.2mm; d. 0.89
moisture sensitive

5g
25g

22-1150
HAZ

Titanium(IV) chloride, 99% *(7550-45-0)*
$TiCl_4$; FW: 189.73; pale yellow liq.; m.p. -25°; b.p. 136°; d. 1.726
moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4033.

250g
1kg

98-4033
HAZ

Titanium(IV) chloride, 99%, 22-1150, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD *(7550-45-0)*
$TiCl_4$; FW: 189.73; pale yellow liq.; m.p. -25°; b.p. 136°; d. 1.726
moisture sensitive
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost.

25g

22-2222

Titanium(IV) (di-i-propoxide)bis[BREW] (99.99+%-Ti) PURATREM
$Ti(OC_3H_7)_2[C_xH_yC(O)CHC(O)C_xH_y]_2$ (x=3-4, y=2x + 1); red-orange liq.
moisture sensitive
Note: 8-11 wt% Ti, ***Limited quantities available. Will discontinue when stock gone***

1g
5g

22-2209
amp
HAZ

Titanium(IV) ethoxide (99.99%-Ti) PURATREM *(3087-36-3)*
$Ti(OC_2H_5)_4$; FW: 228.14; xtl. to pale orange liq.; m.p. 54°; b.p. 138°/5mm; f.p. 84°F; d. 1.088
moisture sensitive

5g
25g

93-2222
HAZ

Titanium(IV) fluoride, 98% *(7783-63-3)*
TiF_4; FW: 123.89; white pwdr.; m.p. > 400°; b.p. 284° subl.; d. 2.798
moisture sensitive

10g
50g

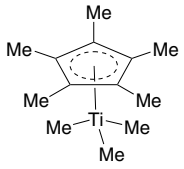
TITANIUM (Compounds)

93-2216 HAZ
Titanium(IV) i-propoxide, min. 98% *(546-68-9)*
$Ti[OCH(CH_3)_2]_4$; FW: 284.25; colorless to pale yellow liq.; m.p. 20°; b.p. 58°/1 mm; f.p. 81°F; d. 0.9550
moisture sensitive
Note: Available prepacked in ALD cylinder- see 98-4030.
250g 1kg

98-4030 HAZ
Titanium(IV) i-propoxide, min. 98%, 93-2216, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD *(546-68-9)*
$Ti[OCH(CH_3)_2]_4$; FW: 284.25; colorless liq.; m.p. 20°; b.p. 58°/1mm; f.p. 81°F; d. 0.9550
moisture sensitive
Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost.
25g

22-1155 NEW HAZ
Titanium(IV) chloride, (99.99+%-Ti) PURATREM *(7550-45-0)*
Cl_4Ti; FW: 189.73; pale yelloq liq.; m.p. -25; b.p. 136; d. 1.726
air sensitive, moisture sensitive
50g

22-5500 amp HAZ
(Trimethyl)pentamethylcyclopentadienyltitanium(IV), min. 97% *(107333-47-1)*
$(CH_3)_5C_5Ti(CH_3)_3$; FW: 228.22; yellow xtl.
air sensitive, light sensitive, moisture sensitive, (store cold)

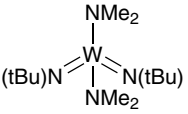


250mg 1g 5g

22-6000 amp
Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)titanium(III), min. 97% $[Ti(TMHD)_3]$ *(181418-64-4)*
$Ti(C_{11}H_{19}O_2)_3$; FW: 597.70; purple xtl.; b.p. subl. 75°/0.1mm
air sensitive, moisture sensitive
1g 5g 25g

TUNGSTEN (Compounds)

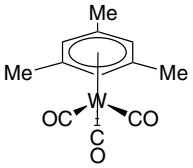
74-1225
Bis(t-butylimido)bis(dimethylamino)tungsten(VI), min. 97% BTBMW *(406462-43-9)*
$C_{12}H_{30}N_4W$; FW: 414.23; yellow to orange liq.; b.p. 81°C (0.02mm); d. 1.305
air sensitive, moisture sensitive



1g 5g

References:
1. *J. Am. Chem. Soc.,* **2009**, *131*, 2772

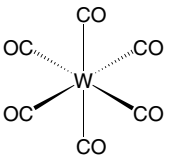
74-1350
Mesitylene tungsten tricarbonyl, 98% *(12129-69-0)*
$C_9H_{12}W(CO)_3$; FW: 388.08; yellow xtl.; m.p. 165° dec.



1g 5g

74-2201
Tungsten carbonyl, 99% (<0.1%-Mo) *(14040-11-0)*
$W(CO)_6$; FW: 351.92; white to off-white pwdr.; m.p. 169-170° dec.
5g 25g

74-2200
Tungsten carbonyl, 99% (<0.3%-Mo) *(14040-11-0)*
$W(CO)_6$; FW: 351.92; white xtl.; m.p. 169-170° dec.



5g 25g 100g

Technical Notes:
1. Volatile starting material used for the atomic layer deposition of tungsten oxide and nitride.

References:
1. *Chem. Vapor Depos.,* **2012**, *18*, 245
2. *Phys. Chem. Chem. Phys.,* **2015**, *17*, 17445

74-2202
Tungsten carbonyl, 99% (99.9+%-W) sublimed *(14040-11-0)*
$W(CO)_6$; FW: 351.92; white xtl.; m.p. 169-170° dec.
5g 25g

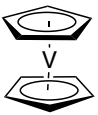
TUNGSTEN (Compounds)

74-2350 amp HAZ
Tungsten(VI) chloride (99.9%-W) *(13283-01-7)*
WCl_6; FW: 396.57; purple xtl.; m.p. 275°; b.p. 346.7°
moisture sensitive
25g 100g 5 x 100g

74-3180
Tungsten(VI) oxychloride, 98% *(13520-78-0)*
$WOCl_4$; FW: 341.65; orange needles
air sensitive, moisture sensitive
1g 5g 25g

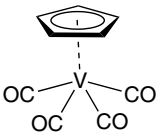
VANADIUM (Compounds)

23-0180 amp HAZ
Bis(cyclopentadienyl)vanadium, sublimed, 95% (Vanadocene) *(1277-47-0)*
$(C_5H_5)_2V$; FW: 181.13; purple xtl.; b.p. (subl. 200°/0.1mm)
air sensitive, moisture sensitive



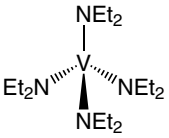
1g 5g

23-0350 amp
Cyclopentadienylvanadium tetracarbonyl, min. 97% *(12108-04-2)*
$C_5H_5V(CO)_4$; FW: 228.08; orange to red xtl.; m.p. 138°; b.p. (subl. 80-110°/0.1mm)
air sensitive, (store cold)



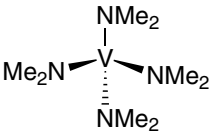
1g 5g

23-0515 HAZ
Tetrakis(diethylamino)vanadium(IV), min. 95% TDEAV *(219852-96-7)*
$V[N(CH_2CH_3)_2]_4$; FW: 339.46; green liq.
air sensitive, moisture sensitive, (store cold)



250mg 1g 5g

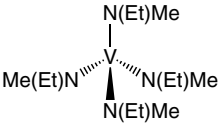
23-0500 HAZ
Tetrakis(dimethylamino)vanadium(IV), min. 95% TDMAV *(19824-56-7)*
$V[N(CH_3)_2]_4$; FW: 227.25; dark solid; m.p. 55-60°
air sensitive, moisture sensitive, (store cold)



250mg 1g 5g

References:
1. *Inorg. Chem.,* **2014**, *53*, 5438

23-0365
Tetrakis(ethylmethylamino)vanadium(IV), 98% TEMAV *(791114-66-4)*
$C_{12}H_{32}N_4V$; FW: 283.35; dark green liq.
air sensitive, moisture sensitive



250mg 1g 5g

23-2250 HAZ
Vanadium(III) acetylacetonate, 98% *(13476-99-8)*
$V(CH_3COCHCOCH_3)_3$; FW: 348.27; brown xtl.; m.p. 178°; b.p. subl. (170°/0.05mm)
air sensitive, moisture sensitive
25g 100g

93-2305 HAZ
Vanadium(V) trichloride oxide, min. 99% *(7727-18-6)*
$VOCl_3$; FW: 173.30; orange liq.; m.p. -77°; b.p. 126.7°; d. 1.829
moisture sensitive
100g 500g

23-5000 HAZ
Vanadium(V) tri-i-propoxy oxide, 98+% VTIP *(5588-84-1)*
$VO(OC_3H_7)_3$; FW: 244.20; light yellow to light green liq.; b.p. 60-61°/0.5mm; f.p. 113°F; d. 1.035
moisture sensitive
5g 25g 100g

XENON (Compounds)

54-1500 HAZ
Xenon(II) fluoride, 99.5% *(13709-36-9)*
XeF_2; FW: 169.30; white xtl.; m.p. 128-130°; d. 4.32
moisture sensitive, (store cold)
Note: Packaged in PFA/FET bottle.
2g 10g

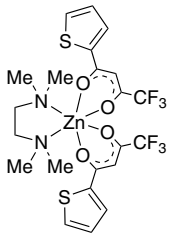
YTTERBIUM (Compounds)

70-0075 amp HAZ	**Tris(cyclopentadienyl)ytterbium (99.9%-Yb) (REO)** *(1295-20-1)* $(C_5H_5)_3Yb$; FW: 368.33; green xtl.; m.p. 273°; b.p. subl. 150° (vac.) *air sensitive, moisture sensitive*	1g 5g
70-1000	**Tris(N,N'-di-i-propylacetamidinato)ytterbium(III), 99%** $Yb(C_8H_{17}N_2)_3$; FW: 596.74; white to off-white pwdr. *air sensitive, moisture sensitive* Note: ALD precursor. Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.	250mg 1g 5g
70-0100	**Tris(2,2,6,6-tetramethyl-3,5-heptanedionato) ytterbium(III), 99% (99.9%-Yb) (REO) [Yb(TMHD)$_3$]** *(15492-52-1)* $Yb(C_{11}H_{19}O_2)_3$; FW: 722.86; off-white xtl.; m.p. 167-169°; b.p. dec. 300° Note: Volatile precursor for the ALD, CVD and MOCVD deposition of ytterbium oxide.	1g 5g
70-2500	**Ytterbium(III) hexafluoroacetylacetonate dihydrate (99.9%-Yb) (REO)** *(81849-60-7)* $Yb(CF_3COCHCOCF_3)_3{\cdot}2H_2O$; FW: 794.19 (830.22); white to off-white solid	1g 5g

YTTRIUM (Compounds)

39-1500 amp	**Tris[N,N-bis(trimethylsilyl)amide]yttrium(III), min. 98% (99.9%-Y) (REO)** *(41836-28-6)* $\{[(CH_3)_3Si]_2N\}_3Y$; FW: 570.06; white to off-white pwdr.; m.p. 180-184°; b.p. subl. 105°/10^{-4}mm *air sensitive, moisture sensitive* Note: Available prepacked in ALD cylinder- see 98-4018.	1g 5g 25g
98-4018	**Tris[N,N-bis(trimethylsilyl)amide]yttrium(III), min. 98% (99.9%-Y) (REO), 39-1500, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(41836-28-6)* $\{[(CH_3)_3Si]_2N\}_3Y$; FW: 570.06; white to off-white pwdr.; m.p. 180-184°; b.p. subl. 105°/10^{-4}mm *air sensitive, moisture sensitive*	10g
39-4950 amp	**Tris(butylcyclopentadienyl)yttrium (99.9%-Y) (REO)** *(312739-77-8)* $(C_4H_9C_5H_4)_3Y$; FW: 452.52; yellow liq. *air sensitive*	1g 5g
39-5000 amp HAZ	**Tris(cyclopentadienyl)yttrium (99.9%-Y) (REO)** *(1294-07-1)* $(C_5H_5)_3Y$; FW: 284.20; off-white pwdr.; m.p. 295°; b.p. subl. 200° (vac.) *air sensitive, moisture sensitive*	1g 5g
39-1550 amp	**Tris(N,N'-di-i-propylformamidinato)yttrium(III), 97%** $C_{21}H_{45}N_6Y$; FW: 470.53; light beige-yellow solid *air sensitive, moisture sensitive* Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2	250mg 1g 5g
39-5100 amp HAZ	**Tris(n-propylcyclopentadienyl)yttrium (99.9%-Y) (REO)** *(329735-73-1)* $(C_3H_7C_5H_4)_3Y$; FW: 410.44; yellow solid *air sensitive, moisture sensitive*	1g 5g
39-1000	**Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)yttrium(III), 98+% (99.9%-Y) (REO) [Y(TMHD)$_3$]** *(15632-39-0)* $Y(C_{11}H_{19}O_2)_3$; FW: 638.72; white to off-white xtl.; m.p. 170-173°	1g 5g 25g
39-1015	**Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)yttrium(III) triglyme adduct (99.9%-Y) (REO)** $Y(C_{11}H_{19}O_2)_3{\cdot}CH_3(OCH_2CH_2)_3OCH_3$; FW: 638.72 (816.94); white xtl.; m.p. 77°; b.p. 100°/0.1mm	1g 5g
39-2500	**Yttrium(III) hexafluoroacetylacetonate, hydrate (99.9%-Y) (REO)** *(18911-76-7)* $Y(CF_3COCHCOCF_3)_3{\cdot}XH_2O$; FW: 710.10; white xtl.; m.p. 166-170°; b.p. dec. 240° (subl. 100°/0.2mm)	1g 5g 25g

ZINC (Compounds)

30-0500	**Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)zinc, 99% [Zn(TMHD)$_2$]** *(14363-14-5)* $Zn(C_{11}H_{19}O_2)_2$; FW: 431.93; white xtl.; m.p. 144°; b.p. dec. 250°	1g 5g 25g
30-3055	**Bis[4,4,4-trifluoro-1-(2-thienyl-1,3-butanedionato]zinc TMEDA adduct, 99%** *(873585-38-7)* $C_{22}H_{24}F_6N_2O_4S_2Zn$; FW: 623.95; white pwdr. *hygroscopic* Note: Useful reagent for the MOCVD of zinc oxide. 	1g 5g
93-3030 HAZ 	**Diethylzinc, min. 95%** *(557-20-0)* $Zn(C_2H_5)_2$; FW: 123.49; colorless liq.; m.p. -28°; b.p. 124°; f.p. -1°F; d. 1.18 *moiture sensitive, pyrophoric* Note: Available prepacked in ALD cylinder- see 98-4000, 98-4005.	100g
98-4000 HAZ 	**Diethylzinc, min. 95%, 93-3030, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(557-20-0)* $Zn(C_2H_5)_2$; FW: 123.49; colorless liq.; m.p. -28°; b.p. 124°; f.p. -1°F; d. 1.18 *moiture sensitive, pyrophoric* Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost. See 98-4005.	25g
98-4005 HAZ 	**Diethylzinc, min. 95%, 93-3030, contained in high-temp 50 ml Swagelok® cylinder (96-1071) for CVD/ALD** *(557-20-0)* $Zn(C_2H_5)_2$; FW: 123.49; colorless liq. *moiture sensitive, pyrophoric*	25g
97-4525 HAZ 	**Diethylzinc, elec. gr. (99.9998%-Zn) PURATREM** *(557-20-0)* $Zn(C_2H_5)_2$; FW: 123.49; colorless liq.; m.p. -28°; b.p. 124°; f.p. -1°F; d. 1.18 *moiture sensitive, pyrophoric*	100g
97-5061 HAZ 	**Dimethylzinc, 99%** *(544-97-8)* $Zn(CH_3)_2$; FW: 95.44; colorless liq.; m.p. -42°; b.p. 46°; f.p. -1°F; d. 1.386 (20°) *moiture sensitive, pyrophoric* Note: Available prepacked in ALD cylinder- see 98-4001.	5g 25g 100g
98-4001 HAZ 	**Dimethylzinc, 99%, 97-5061, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(544-97-8)* $Zn(CH_3)_2$; FW: 95.44; colorless liq.; m.p. -42°; b.p. 46°; f.p. -1°F; d. 1.386 (20°) *moiture sensitive, pyrophoric*	25g
97-5060 HAZ 	**Dimethylzinc, elec. gr. (99.999%-Zn) PURATREM** *(544-97-8)* $Zn(CH_3)_2$; FW: 95.44; colorless liq.; m.p. -42°; b.p. 46°; f.p. -1°F; d. 1.386 (20°) *moiture sensitive, pyrophoric* Note: Available prepacked in ALD cylinder- see 98-4002.	50g 100g
98-4002 HAZ 	**Dimethylzinc, elec. gr. (99.999%-Zn) PURATREM, 97-5060, contained in 50 ml electropolished Swagelok® cylinder (96-1077) for CVD/ALD** *(544-97-8)* $Zn(CH_3)_2$; FW: 95.44; colorless liq.; m.p. -42°; b.p. 46°; f.p. -1°F; d. 1.386 (20°) *moiture sensitive, pyrophoric*	10g
30-3095	**Zinc i-propoxide, 99%** *(13282-39-8)* $Zn(OC_3H_7)_2$; FW: 183.56; white pwdr. *moiture sensitive*	1g 5g

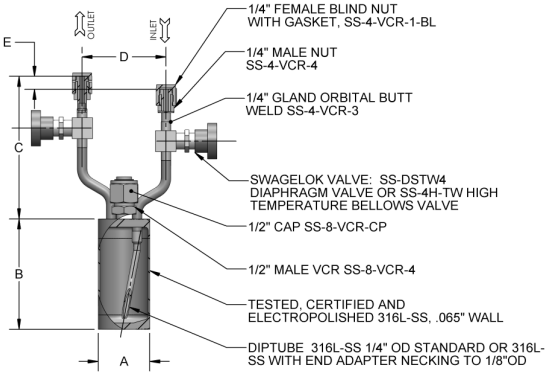
ZIRCONIUM (Compounds)

40-1000	**Bis(cyclopentadienyl)dimethylzirconium, min. 97%** *(12636-72-5)* $(C_5H_5)_2Zr(CH_3)_2$; FW: 251.48; white xtl. *air sensitive, (store cold)*	1g 5g
40-1110	**Dimethylbis(t-butylcyclopentadienyl)zirconium, min. 98%** *(68193-40-8)* $[(C_4H_9)C_5H_4]_2Zr(CH_3)_2$; FW: 363.70; pale yellow pwdr. *air sensitive, moisture sensitive*	250mg 1g 5g
93-4040 amp HAZ	**Tetrakis(diethylamino)zirconium, 99%** *(13801-49-5)* $Zr[N(CH_2CH_3)_2]_4$; FW: 379.74; yellow liq.; b.p. 112°/0.1mm; d. 1.026 *moisture sensitive, (store cold)*	5g 25g
40-4100 HAZ	**Tetrakis(dimethylamino)zirconium(IV), 99% TDMAZ** *(19756-04-8)* $Zr[N(CH_3)_2]_4$; FW: 267.53; white to light yellow xtl.; m.p. 57-60°; b.p. 80°/0.1mm *moisture sensitive, (store cold)* Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1. Available prepacked in ALD cylinder- see 98-4012.	1g 5g 25g
98-4012 HAZ	**Tetrakis(dimethylamino)zirconium(IV), 99% TDMAZ, 40-4100, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(19756-04-8)* $Zr[N(CH_3)_2]_4$; FW: 267.53; white to light yellow xtl.; m.p. 57-60°; b.p. 80°/.01mm *moisture sensitive, (store cold)* Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1.	25g
40-4115 amp HAZ	**Tetrakis(dimethylamino)zirconium(IV), 99% (99.99%-Zr) PURATREM TDMAZ** *(19756-04-8)* $Zr[N(CH_3)_2]_4$; FW: 267.53; light-yellow xtl.; m.p. 57-60°; b.p. 80° (0.1mm) *moisture sensitive, (store cold)* Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1.	1g 5g 25g
98-4042 HAZ	**Tetrakis(dimethylamino)zirconium(IV), 99% (99.99%-Zr) TDMAZ, 40-4115, contained in 50ml Swagelok® cylinder (96-1070) for CVD/ALD** *(19756-04-8)* $Zr[N(CH_3)_2]_4$; FW: 267.53; light yellow xtl. *moisture sensitive, (store cold)* Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1	25g
40-1710 amp HAZ	**Tetrakis(ethylmethylamino)zirconium(IV), 99% TEMAZ** *(175923-04-3)* $Zr[N(CH_3)(CH_2CH_3)]_4$; FW: 323.63; light yellow liq.; d. 1.0499 *moisture sensitive* Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1. Available prepacked in ALD cylinder- see 98-4039.	1g 5g 25g
98-4039 HAZ	**Tetrakis(ethylmethylamino)zirconium(IV) 99% TEMAZ, 40-1710, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(175923-04-3)* $Zr[N(CH_3)(CH_2CH_3)]_4$; FW: 323.63; light yellow liq. *moisture sensitive* Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost. Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1	10g 25g
40-5000	**Tetrakis(2,2,6,6-tetramethyl-3,5-heptanedionato) zirconium(IV), 99% [Zr(TMHD)$_4$]** *(18865-74-2)* $Zr(C_{11}H_{19}O_2)_4$; FW: 824.30; white xtl.; m.p. 318-320°; b.p. subl. 180°/0.1mm	1g 5g 25g
40-1749 amp	**Zirconium(IV) t-butoxide, 99%** *(2081-12-1)* $Zr(OC_4H_9)_4$; FW: 383.68; slightly yellow liq.; b.p. 90°/5mm; f.p. 185°F; d. 0.96 *moisture sensitive, (store cold)*	5g 25g 4 x 25g

ZIRCONIUM (Compounds)

40-1750 amp	**Zirconium(IV) t-butoxide (99.99%-Zr) PURATREM** *(2081-12-1)* $Zr(OC_4H_9)_4$; FW: 383.68; slightly yellow liq.; b.p. 90°/5mm; f.p. 185°F; d. 0.96 *moisture sensitive, (store cold)*	2g 10g 2 x 25g
93-4043 HAZ	**Zirconium(IV) ethoxide, 99+%** *(18267-08-8)* $Zr(OC_2H_5)_4$; FW: 271.47; white pwdr.; m.p. 171-173° *moisture sensitive*	5g 25g
40-3000	**Zirconium(IV) hexafluoroacetylacetonate** *(19530-02-0)* $Zr(CF_3COCHCOCF_3)_4$; FW: 919.47; white to off-white xtl.; m.p. 41-43°; b.p. 225° *hygroscopic*	5g 25g
93-4026	**Zirconium(IV) trifluoroacetylacetonate, 99%** *(17499-68-2)* $Zr(CF_3COCHCOCH_3)_4$; FW: 703.54; white pwdr.; m.p. 125-128°; b.p. dec. 235° (subl. 130°/0.05mm)	1g 5g 25g

STAINLESS STEEL BUBBLERS:
Vertical, Electropolished with ill-port, DOT4B Stamped



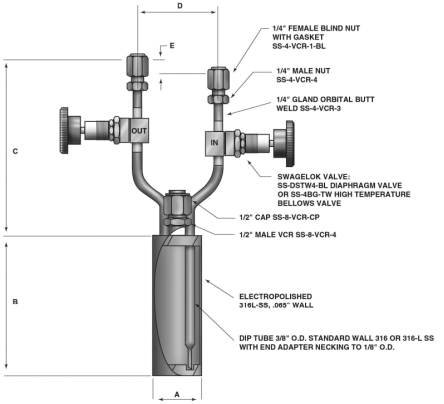
Stainless Steel Bubblers, vertical, electropolished with fill-port, PCTFE valve stem tip (121°C), DOT 4B stamped

Catalog #	Vol. (mL)	A mm	B mm	C mm	D mm	E mm	Temp. Valve	Special Configuration
95-4151	150	51	108	143	83	13	Standard	
95-4290	300	51	187	143	83	13	Standard	
95-4598	600	76	164	143	83	13	Standard	
95-4998	1000	76	254	143	83	13	Standard	
95-5002	1200	102	184	143	83	13	Standard	
95-5003	1500	102	223	143	83	13	Standard	
95-5001	2000	102	292	143	83	13	Standard	
95-5011	3000	152	213	140	83	13	Standard	
95-3000	150	51	108	140	83	13	Standard	replaceable-seat valves with rotated handles
95-4153	150	51	108	143	83	13	Standard	with rotated handles

Stainless Steel Bubblers, vertical, electropolished with fill-port, high temperature valves (315°C), DOT 4B stamped

Catalog #	Vol. (mL)	A mm	B mm	C mm	D mm	E mm	Temp. Valve	Special Configuration
95-0271	150	51	108	140	83	13	High	
95-0270	300	51	187	140	83	13	High	
95-4599	600	76	164	140	83	13	High	
95-4002	1200	102	184	143	83	13	High	
95-4155	150	51	108	140	83	13	High	with rotated handles
95-0276	150	51	108	140	83	13	High	with short dip tube, cut to 1 inch from top of bubbler
95-4157	200	51	150	140	83	13	High	with rotated handles
95-0280	300	51	187	140	83	13	High	with rotated handles
95-4295	300	51	187	140	83	13	High	with rotated handles, **no dip tube**
95-4610	600	76	164	127	83	13	High	with rotated handles, **no dip tube**, stems same height

STAINLESS STEEL BUBBLERS:
Vertical, Electropolished with fill-port



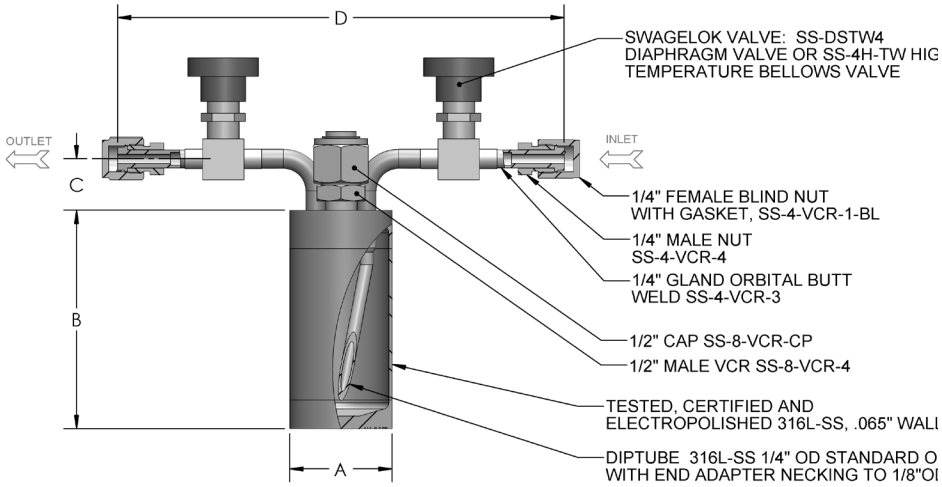
Stainless Steel Bubblers, vertical, electropolished with fill-port, PCTFE valve stem tip (121°C)

Catalog #	Vol. (mL)	A mm	B mm	C mm	D mm	E mm	Temp. Valve	Special Configuration
96-4151	150	51	108	140	83	13	Standard	
96-4290	300	51	187	140	83	13	Standard	
96-4598	600	76	163	140	83	13	Standard	
96-4998	1000	76	254	140	83	13	Standard	
96-5002	1000	102	165	140	83	13	Standard	
96-5003	1400	102	203	140	83	13	Standard	
96-5001	1800	102	254	140	83	13	Standard	
96-5011	2750	152	188	140	83	13	Standard	
96-4149	150	51	108	140	83	13	Standard	with short dip tube, cut 5cm from top of bubbler
96-4153	150	51	108	140	83	13	Standard	with rotated handles

Stainless Steel Bubblers, vertical, electropolished with fill-port, high temperature valves (315°C)

Catalog #	Vol. (mL)	A mm	B mm	C mm	D mm	E mm	Temp. Valve	Special Configuration
98-0271	150	51	108	140	83	13	High	
98-0270	300	51	187	140	83	13	High	
96-4599	600	76	163	140	83	13	High	
96-4996	1000	76	254	140	83	13	High	
98-0276	150	51	108	140	83	13	High	with short dip tube, cut to 1 inch from top of bubbler
98-0280	300	51	187	140	83	13	High	with rotated handles
96-4295	300	51	187	140	83	13	High	with rotated handles, **no dip tube**
96-4610	600	76	163	140	83	13	High	with rotated handles, **no dip tube,** stems same height

STAINLESS STEEL BUBBLERS:
Horizontal, Electropolished with ill-port, DOT4B Stamped



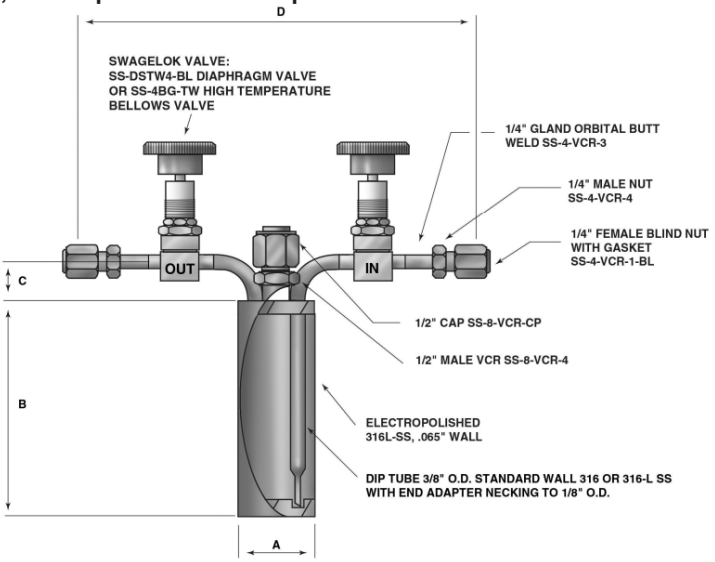
Stainless Steel Bubblers, horizontal, electropolished with ill-port, PCTFE valve stem tip (121°C) DOT 4B stamped

Catalog #	Vol. (mL)	A mm	B mm	C mm	D mm	Temp. Valve	Special Configuration
95-5151	150	51	108	24	222	Standard	
95-5298	300	51	187	24	222	Standard	
95-5599	600	76	164	24	222	Standard	
95-5998	1000	76	254	24	222	Standard	
95-5004	2000	152	152	24	222	Standard	
95-0273	150	51	108	24	222	Standard	with reversed handles

Stainless Steel Bubblers, horizonal, electropolished with ill-port, high temperature valves (315°C) DOT 4B stamped

Catalog #	Vol. (mL)	A mm	B mm	C mm	D mm	Temp. Valve	Special Configuration
95-0272	150	51	108	24	222	High	
95-5006	300	51	187	24	222	High	
95-5007	600	76	164	24	222	High	
95-5008	1000	76	254	24	222	High	
95-5009	1000	76	254	24	222	High	**no dip tube**

STAINLESS STEEL BUBBLERS:
Horizontal, Electropolished with fill-port



Stainless Steel Bubblers, horizontal, electropolished with fill-port, PCTFE valve stem tip (121°C)

Catalog #	Vol. (mL)	A mm	B mm	C mm	D mm	Temp. Valve	Special Configuration
96-5151	150	51	108	24	222	Standard	
96-5298	300	51	187	24	222	Standard	
96-5599	600	76	163	24	222	Standard	
96-5998	1000	76	254	24	222	Standard	
96-5004	1800	102	254	24	222	Standard	
98-0273	150	51	108	24	222	Standard	with reversed handles
98-0275	150	51	108	24	222	Standard	with rotated handles

Stainless Steel Bubblers, horizonal, electropolished with fill-port, high temperature valves (315°C)

Catalog #	Vol. (mL)	A mm	B mm	C mm	D mm	Temp. Valve	Special Configuration
98-0272	150	51	108	24	222	High	
96-5006	300	51	187	24	222	High	
96-5007	600	76	163	24	222	High	
96-5008	1000	76	254	24	222	High	

ALD CYLINDERS

Standard Assembly

96-1070 **Swagelok® Cylinder Assembly, 50ml with ¼" VCR Male Ball Valve and Female Nut for CVD/ALD**

¼" VCR Male Ball Valve rated to 300°F or 148°C

High-Temp Valve Assembly

96-1071 **Swagelok® Cylinder Assembly, 50ml with ¼" VCR Male Bellows-Sealed Valve (High Temp) and Female Nut for CVD/ALD**

¼" VCR Male Bellows-Sealed Valve (High Temp/EP) rated to 600°F or 315°C

Electropolished (EP) Assembly with Ball Valve or High-Temp Valve (Optional)

96-1075 **Swagelok® Cylinder Assembly, 50ml with ¼" VCR Male Ball Valve (SC-11 cleaned) and Female Nut, electropolished for CVD/ALD**

¼" VCR Male Ball Valve (EP) rated to 300°F or 148°C

96-1076 **Swagelok® Cylinder Assembly, 50ml with ¼" VCR Male Bellows-Sealed Valve (High Temp) and Female Nut, electropolished for CVD/ALD**

¼" VCR Male Bellows-Sealed Valve (High Temp/EP) rated to 600°F or 315°C

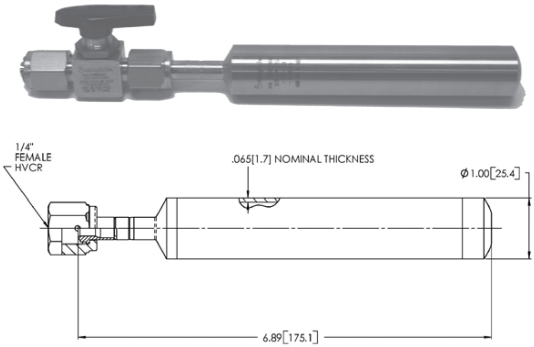
DP Valve Assembly

96-1077 **Swagelok® Cylinder Assembly, 50ml with ¼" VCR Male DP Valve (Ultra High Purity) and Female Nut, electropolished for CVD/ALD**

¼" VCR Male DP high pressure diaphragm Valve (Ultra High Purity/EP) rated to 50-320°F or 10-148°C

96-1078 **Swagelok® Cylinder Assembly, 50ml with ¼" VCR Male DP High Pressure Valve (High Purity), PCTFE seat, VCR Metal Gasket Seal Fitting, Round Handle**

¼" VCR Male DP high pressure diaphragm Valve (High Purity/EP) rated to 250°F or 121°C



- Drawing is not to scale
- Dimensions are in inches [millimeters in brackets]
- Drawing subject to change without notice

New Cylinders for ALD

95-4154 **Stainless steel cylinder, 200ml, single vertical stem, electropolished with fill-port, PCTFE valve stem tip, DOT 4B stamped**

PCTFE valve stem tip, ½" MVCR fill-port, SS-DSTW4 outlet valve, D.O.T specification: 4B-300

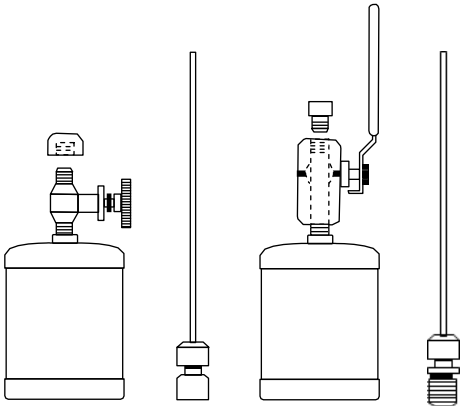
95-0281 **Stainless steel cylinder, 125ml, horizontal in line, with angled Bellows valve (150°C), DOT 4B stamped**

Angled bellows valve, Fujikin, FUB-81-6.35-PI inlet valve, rated to -10 to 150°C, D.O.T. specification: 4B-260

Equipment: Cylinders and Adapters

Caution!

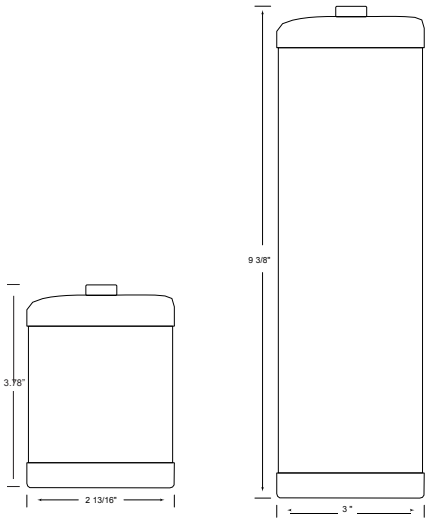
Due to the hazardous nature of many of the materials packaged in metal cylinders, we strongly recommend that all users read the technical note associated with the catalog numbers below posted at strem.com carefully before using the product. The cylinders and valves are used primarily for the safe transport and storage of pyrophoric materials. As with any air-sensitive compound, the cylinder should be taken into an inert atmosphere bag or box to remove the product. If you are unsure of the handling procedures and need assistance, please contact the Operations & Logisitics Manager at (978) 499-1600 (All countries) or (800) 647-8736 (USA & Canada only).



TYPE I SYSTEM | **TYPE I ADAPTER 96-8500** | **TYPE II SYSTEM** | **TYPE II ADAPTER 96-8501**

Cat #	Description
96-8500	Swagelok® Type I Adapter
96-8501	Swagelok® Type II Adapter
96-8105	Brass needle valve (Type I)
96-8100	Brass ball valve (Type II)
96-8000	Cylinder, carbon steel, 275 ml
96-8005	Cylinder, carbon steel, 900 ml

For instruction details on Type I or Type II systems please visit strem.com



96-8000 **96-8005**

96-8000	
Contents:	275 ml
Design Pressure:	240 psig
Outlet Fitting:	1/4 NPTF pipe thread size
Weight:	0.7 lbs
Dimensions:	2 13/16” dia x 3 7/8”
D.O.T. Specs:	DOT-4 B240

96-8005	
Contents:	900 ml
Design Pressure:	240 psig
Outlet Fitting:	1/4 NPTF pipe thread size
Weight:	1.5 lbs
Dimensions:	3” dia x 9 3/8”
D.O.T. Specs:	DOT-4 B240ET

IMPORTANT ANNOUNCEMENT!

We were acquired by Ascensus Specialties

Quote from Michael Strem, founder & former President of Strem Chemicals, “We thoughtfully chose Ascensus as the partner for the next phase of Strem’s growth. Our employees’ interests and well-being have been my top priority, and the strong cultural fit will provide opportunities for our team. The additional resources and global reach of Ascensus will deliver Strem’s strong capabilities to an even broader audience of customers."

About Ascensus Specialties

For over 70 years, Ascensus Specialties has been one of the world’s leading providers of sodium borohydride, specialty alcoholates, and boranes for a variety of industries.

Our specialty chemistries improve the way our clients create their products by making what they do easier, more efficient, safer, and more selective. From our world-class production plants in Elma, Washington, Evans City, Pennsylvania, and Newburyport, Massachusetts, we have a global reach that ensures our clients can consistently manufacture their products to the highest standards. What does all this mean? Our clients can make the best possible products to change people’s lives for the better, and we are able to make the world a better place with chemistry made for what matters.

Our Expanded Product Lines

We offer an unparalleled range of high-quality specialty reagents that enable complex transformations so you can continue to create the products that matter. Our products are available in sample, intermediate, and bulk packages.

Borohydrides | Boranes | Specialty Alcoholates | Boronic Acids & Esters | Alkali Metals | APIs | Custom Synthesis | Catalysis | Thin Film Deposition

ASCENSUS™

CHEMISTRY MADE FOR WHAT MATTERS

MOCVD, CVD & ALD Precursors

Our Product Offerings

APIs
BORANES
BOROHYDRIDES
CATALYSTS & LIGANDS
CVD/ALD PRECURSORS
FINE CHEMICALS
INTERMEDIATES
OTHER SPECIALTY CHEMICALS
SPECIALTY ALCOHOLATES
STREM CATALOG

Strem Catalog by Ascensus Specialties

7 Mulliken Way
Dexter Industrial Park
Newburyport, MA 01950-4098
U.S.A

Office Tel: (978) 499-1600
Office Fax: (978) 465-3104

Toll-free (U.S. & Canada)
Tel: (800) 647-8736
Fax: (800) 517-8736

Email: info@ascensusspecialties.com
www.strem.com

Ascensus Specialties
Global Headquarters

2821 Northup Way, Suite 275
Bellevue, WA 98004 U.S.A.

Office Tel.: (725) 538-1200

Email: ask@ascensusspecialties.com
www.ascensusspecialties.com

Visit us and view our blogs on strem.com