Advanced and recent applications for floating borosilicate glasses

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Borosilicate glass shapes

Schott headquarters

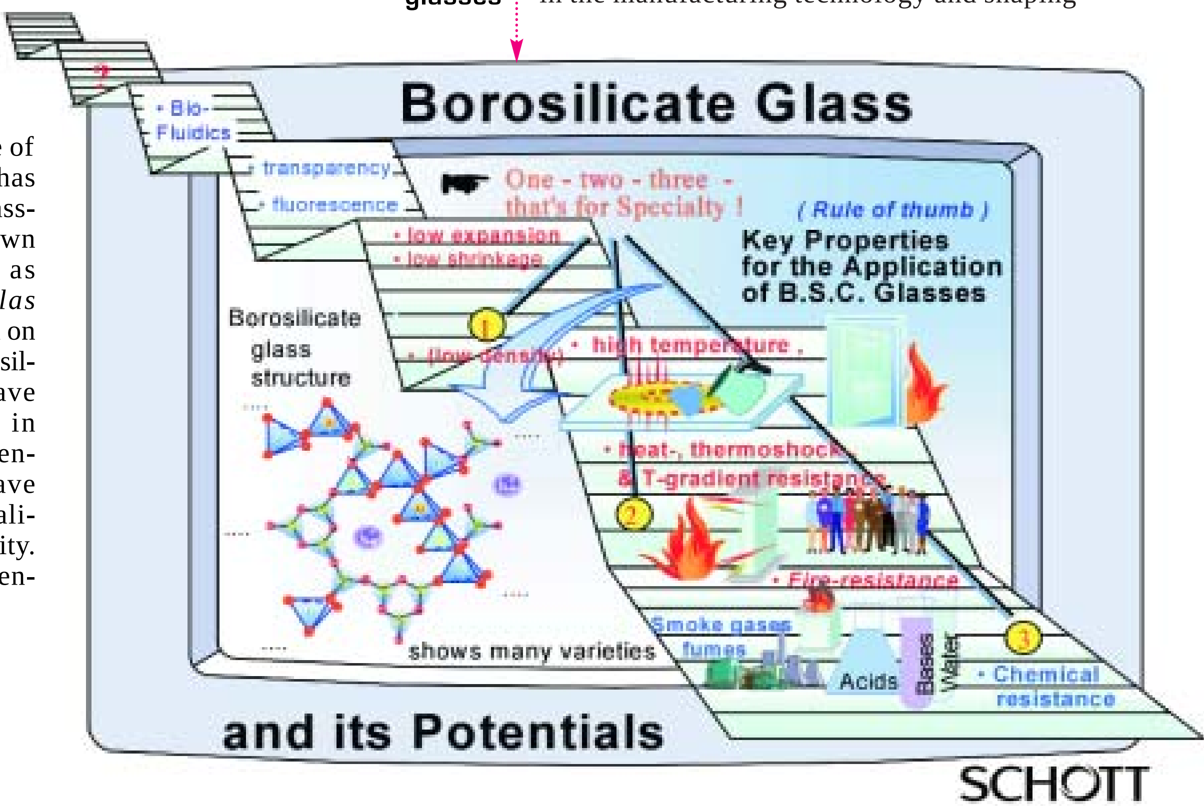
The major challenge of the future in the area of special flat glass is seen as the flexible availability of glass substrates, which can be produced to a high standard of quality yet at a favourable cost. Bigger, flatter, fault free, universally available from ultra-thin to ultra-thick, as inert as possible and able to withstand the rigours of processing in the widest range of demanding technical applications; these are the comprehensive requirements of modern special flat glasses. Schott's borosilicate float glasses have all the necessary prerequisites to meet these continually and rapidly growing needs.

Borosilicate glasses, nowadays, play an outstanding part in a wide variety of technically orientated glass applications. The range of chemically varied compositions for this family of glasses is almost inexhaustible, which means that they can be endowed with remarkable properties. The particular features of these glasses are their resistance to high temperatures, low thermal expansion and excellent resistance to chemical attack.

This complex, and at the same time very beneficial range of potential properties has made borosilicate glasses famous. Well-known brand names such as *Duran* and *Jena Glas* have made their mark on our perception of borosilicate glass. They have proved themselves in everyday use and generations of users have recognized their quality and lasting durability. Recently, greater attention has been drawn to borosilicate glasses of the type which can be produced without the inclusion of any alkali content or with only a very low alkali content.

Ever since Otto Schott's pioneering days in Jena, right up to the present day, the whole development of borosilicate glass at Schott has been marked by one particular motivation: how can continuous improvement and innovation in the manufacturing technology and shaping

Potentials of borosilicate glasses



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processes for borosilicate glass be applied to effectively raise the quality and wide range of forms of special glasses? New and demanding applications for special borosilicate glasses are constantly opening up in a whole range of advanced market areas.

The introduction of the microfloat technology for borosilicate glasses at Schott Jena Glas GmbH in 1994, was a unique innovation in the low thermal expansion flat glass sector. Particular physical and chemical properties, which can only be achieved with these glasses, open up access to new and sophisticated special glass applications (such as electro-phoresis, displays, photovoltaics, etc.). The microfloat process has made it possible to produce high quality float glass, which only a few years ago, was not even available as laboratory samples.

NEW AREAS OF APPLICATION FOR SPECIAL BOROSILICATE FLAT GLASSES

Display glass

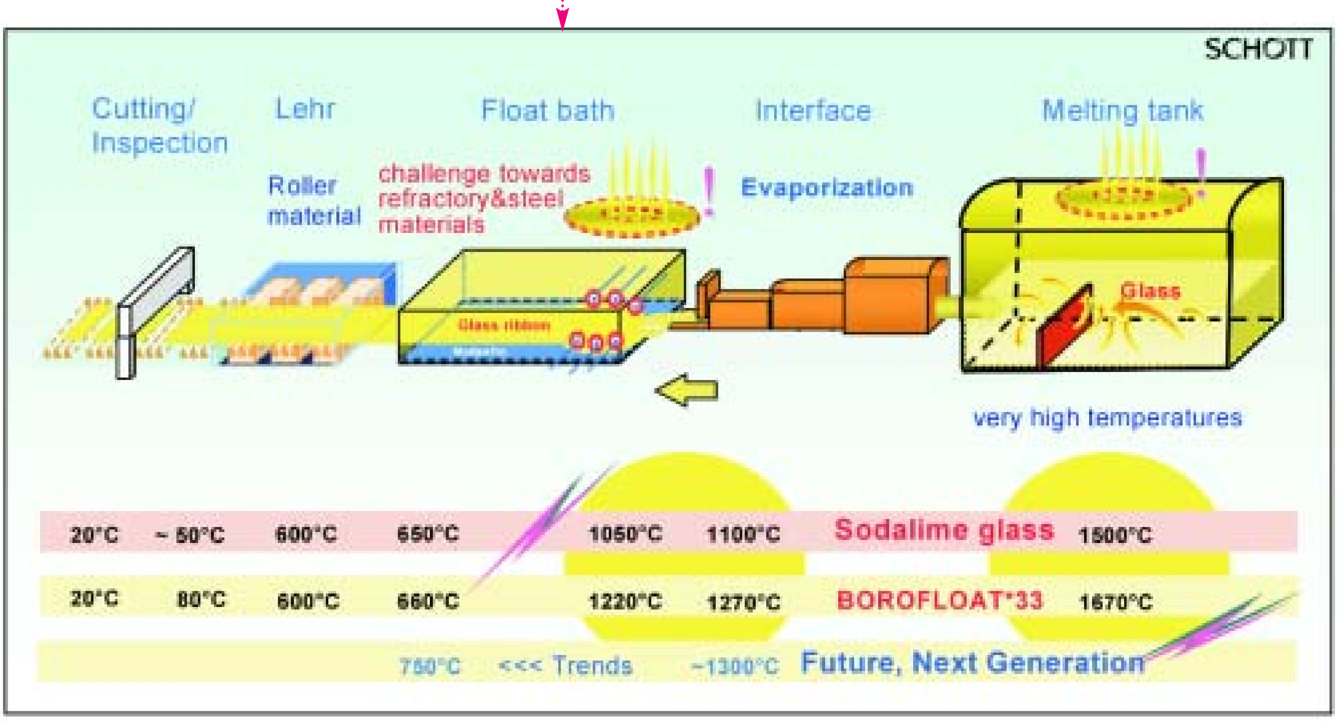
There has never been such a wealth of information available as there is today. Media increasingly rule people's everyday experiences. Analyses of trends show that new visualized and self-explanatory communications systems will be giving new impetus to lifestyles until well into this century. For these forward-looking communications systems, so-called key technologies are gaining increasing importance. One of these modern technologies is the flat-panel display.

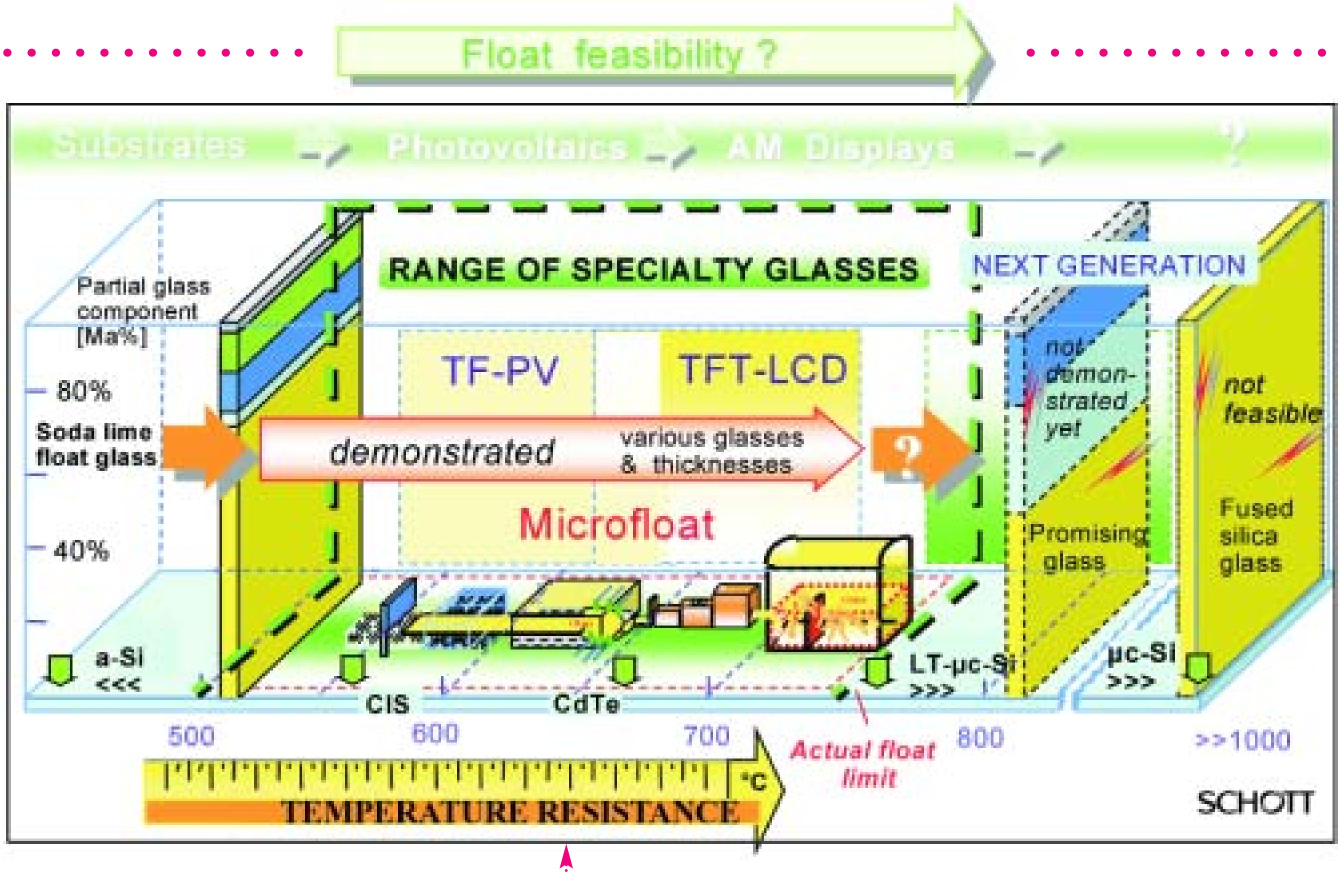
Flat displays are already part of everyday lives and it is difficult to imagine technology operating without them. They are used for the most varied of applications, starting from the wrist watch, simple temperature indicators and instrument displays via automotive applications and the communication terminals, such as facsimile machines and mobile telephones, through to lap-top computers and the television sets of the future.

This is why there is virtually no other market, that offers more interesting opportunities for special glass than the market for flat-panel display applications. Growth rates in excess of 20 per cent were expected for a worldwide market volume of DM 1-5 billion for display glass by the year 2000.

The liquid crystal display (LCD) is currently the best known type of flat display, although a great deal of money is being invested in many

Microfloat process for borosilicate glasses





Microfloat process feasibility potentials

other display technologies exploiting different physical principles for displaying the image (e.g. electroluminescence, plasma gas discharge, miniature light emitting diodes, etc).

All of these systems have one thing in common: they use specially developed glass substrates of very high quality, on which thin functional layers can be deposited very precisely. These are applied using temperature intensive processes and then structured or textured either by etching or using ultraviolet, visible or laser supported techniques. The quality of the substrates has a significant influence on the imaging properties of the system and, via the capabilities of glass specific processes, a display's yield and manufacturing costs.

Very high demands are made on the quality of the glass. Important criteria are, for example, practically fault-free glass (<50 µm) with excellent surface qualities (very good flatness), a thermal expansion coefficient matching that of the crystalline function layer, no alkali content in many cases, good chemical resistance and, above all, temperature resistance. As a rule, display cells are of the bi-glass type and the evenness of the glass substrate is extremely important to ensure that the distance between the glass is kept constant to µm accuracy which, in the final analysis, determines the contrast sharpness and image resolution qualities of the finished display.

Which flat glass manufacturing technology will satisfy the market demand in this century is hard to answer. A high-grade flat glass producing company would seem to be well prepared for the future, when focusing towards several optional technologies. Overflow fusion and down-draw processes dominate display glass manufacturing. However, the call for further cost reduction and larger sizes again may bring the microfloat process more strongly into the field, when more glass capacity in different thicknesses is in demand.

Photovoltaics

Photovoltaics used for renewable energy production will be one of the key technologies of the 21st century if mankind is going to safeguard continuously growing energy needs in an environmentally friendly manner.

At the present time, crystalline silicon wafers continue to retain a dominant position as the photovoltaic material in photovoltaic modules. Crystalline silicon is, however, a very expensive material; in the long term, it cannot be produced in sufficiently large quantities and sizes, and it can only be directly structured as "relatively thick compact wafer material".

For this type of solar cell, therefore, no glass substrate is needed, just a cover glass with the maximum possible solar transmission (soda-lime-silica glass, often with its reflection reduced by means of surface structuring or coating).

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The potential for reducing the costs and increasing the efficiency of this conventional solar cell technology has been largely exhausted. For this reason there is intensified international emphasis on the industrial implementation of the thin film photovoltaic technology with higher solar efficiency.

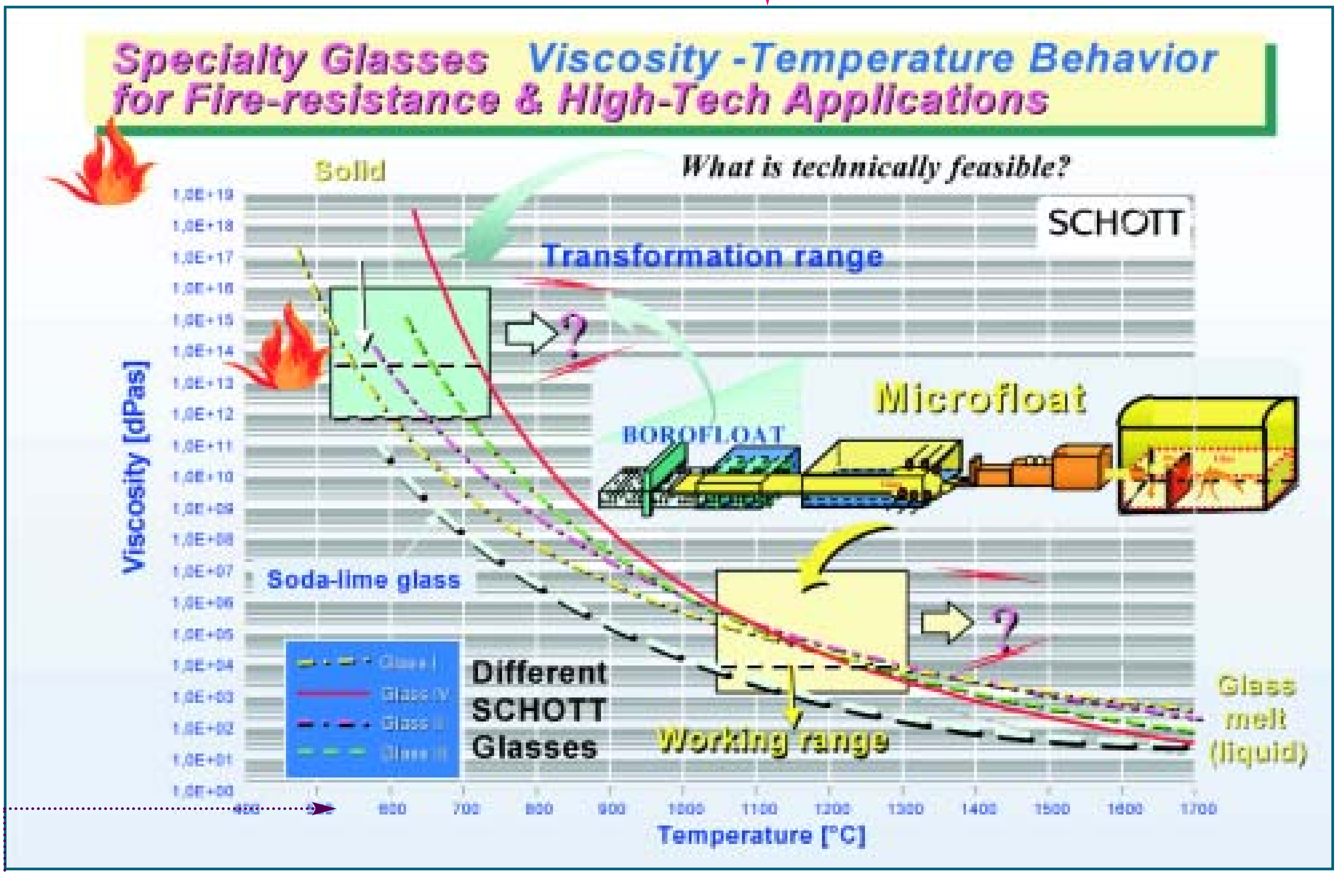
It can be established that, currently, (particularly in Japan and the United States), a general tendency can be seen in modern photovoltaics towards high efficiency thin-film solar cells (efficiency 12-16 per cent), with concurrent optimization of the modular solar cell construction, (reducing the number of layers and their thickness, cutting down the total cost of the modules by possibly dispensing with the cover glass: one-piece substrate and cover glass!), and optimization of the substrate glass properties. This calls for special substrate glasses, which can withstand, to some extent, relatively high

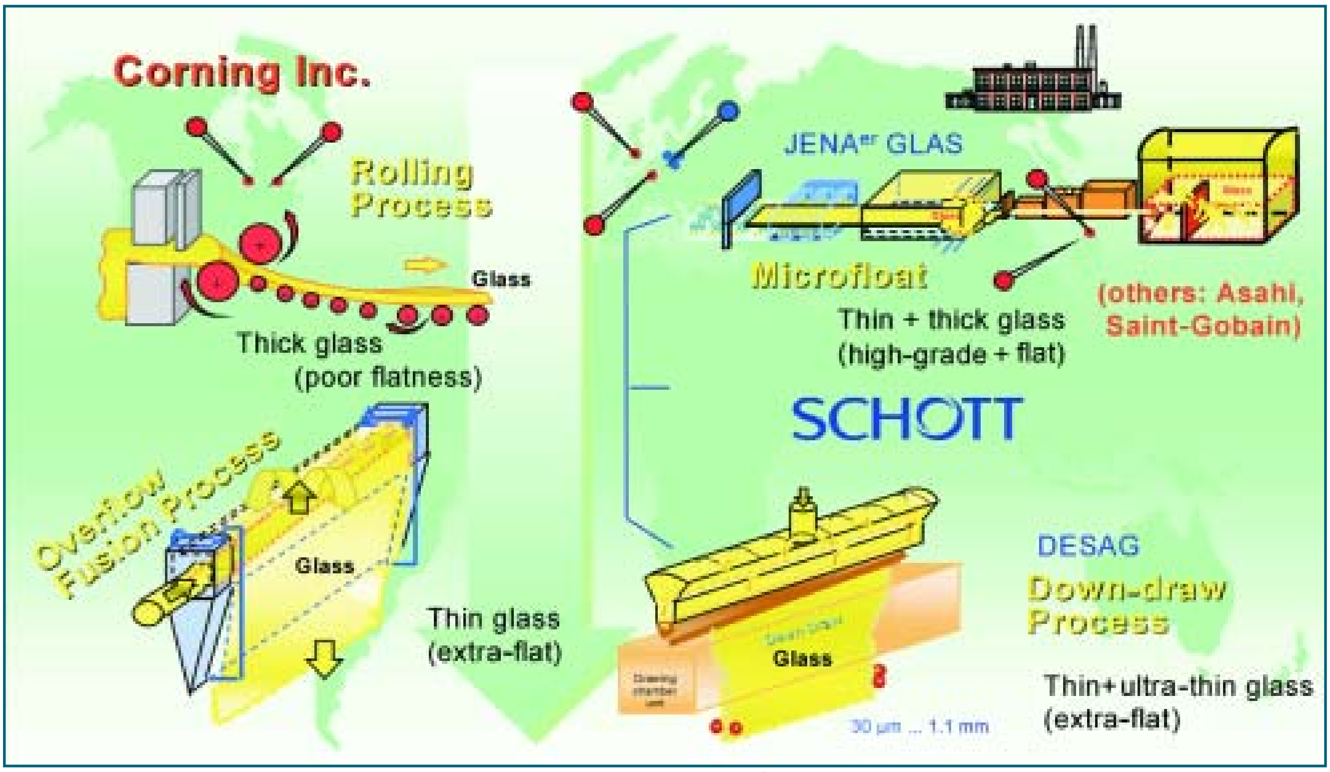
Application of borosilicate glass in photovoltaics

thermal loadings (550-630°C), resist chemical attacks and, in addition, meet the requirements as regards mechanical strength.

Microfloat process feasibility potentials

The development of cost-saving single glass multi-functional substrates in the 3 to 4 millimetres thickness range could supersede the versions used up to now, comprising thin substrate glass and 4 millimetres thick (soda-lime-silica) cover glass, and would simplify the





Specialty flat glass manufacturing methods

whole manufacturing process in modern photovoltaics technology.

There are possible applications for Borofloat 33 as a high-efficiency substrate material for aSi thin film solar cells, since it is the best match for amorphous silicon as regards thermal expansion, and has excellent thermal resistance. At the present time, because of the low temperature requirements, soda-lime-silica glass is still generally used, although thermally toughened glass is required together with additional barrier layers (SiO^2) to prevent alkali migration into the a-Si layer. In the case of solar cell types with crystalline semi-conductor junctions ($CuInSe(Ga)^2(C1S)$, CdTe, GaAs and other chalcopyrites), the Borofloat family of glasses has significantly better opportunities because of the (to some extent) very high thermal loadings involved during the coating application and the crystallization process, if it is possible to achieve, in the medium term, marketable prices of the order of about DM 20 - 40 per square metre.

Over a period of a few short years microfloat technology at Schott has been consistently developed to a high technical level so that it is now possible in principle to go as far as the limits of what is technologically feasible. Because of their outstanding and optimized process technology (glass melting and conditioning), the products covered by the Borofloat brand have resulted in superior physical properties and quality, this breathing new life into the market for special borosilicate glasses, and providing fresh impetus for modern product areas.

Alternative special fire-resisting glasses by Schott

Low thermal expansion glasses with low alkali content, such as Borofloat 33; still have the drawback that they cannot be thermally toughened to safety glass standards for use in modern fire resistant glazing (Pyran). Surprisingly, it was only necessary to make a slight but effective modification to the composition of the glass (resulting in Borofloat 40), to achieve an improved viscosity-temperature relationship (higher transformation and softening point). This, combined with the use of a new toughening concept, which is very balanced as regards the heating and cooling technology, and appropriate frame designs, resulted in the new Pyran S fire safety system.

The higher viscosity of this new glass contributes to an improvement in long-term fire resistance in the event of fire, and, at the same time, also meets the requirements in modern building technology for large area monolithic glazing with higher safety for occupants and other users.

FURTHER BENEFICIAL PHYSICAL AND CHEMICAL PROPERTIES

Optical properties

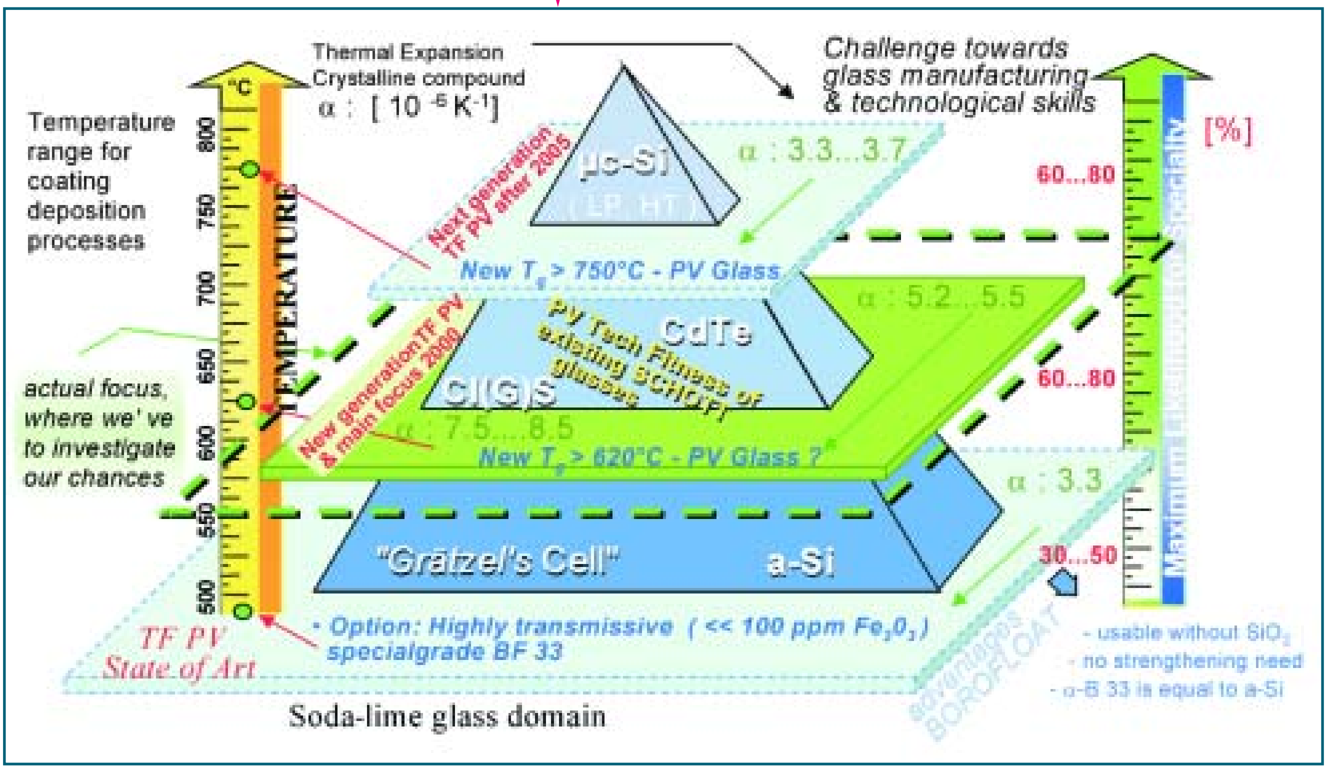
The outstanding transmission behaviour of Borofloat glasses can be attributed to the careful selection of the low impurity raw materials used and the optimized batch mixing and glass manufacturing process.

The good transmission characteristics of Borofloat glass, which is permanently colourless (<200 ppm Fe_2O_3), and its surface quality and smoothness combined with a significantly lower fluorescence behaviour are opening up new avenues to special applications in bioflu-idics (electrophoresis), optics, photonics and opto-electronics. The fluorescence intensity of Borofloat 33 is, for example, very low, lower than that of white B 270 soda-lime-silica glass over the whole of the visible range of the spectrum.

Mechanical properties

The specific gravity of Borofloat glasses (density of Borofloat 33=-2.22 g/cm^3 and Borofloat 40=2.35 g/cm^3) is significantly lower than that of soda-lime-silica glass (up to 12 per cent). This represents an important and, for many applications, highly valued weight advantage, especially in the case of multilayer laminated glass units (e.g. bullet-proof safety glazing and armoured glass of all types). In addition, the unique combination of complex properties, such as outstanding optical transparency, low specific gravity, high bonding strength in the most extensively networked basic glass structure, modulus of elasticity, and so on,

Thin film photovoltaic glass substrate trends



makes it possible to develop new and less bulky laminates with significantly improved application potential. Also, the reduced sensitivity to scratching (surface hardness) of borosilicate glasses is highly valued by many customers.

Chemical properties

In addition to the excellent resistance to acids and alkalis of borosilicate glasses mentioned earlier, (e.g. Borofloat 33 is, of course, practically identical to the long established Duran laboratory glass or, if you will, the famous Jena Glas processed to high grade flat glass), their extraordinarily good hydrolytic resistance is also worth noting, (soda-lime-silica glasses have a hydrolytic resistance two classes poorer). This has the benefit that fluid acid or basic substances dissolved in water generally have no adverse effect on the glass and, as regards long-term stability, the ageing resulting from H_20 attack (water vapour in the atmosphere), which can often be observed on the surface of flat soda-lime-silica glass, is much less of a problem. In particular, any minute cracks which may be present in the surface of the glass are not expanded by molecules of water from the moisture in the atmosphere "docking" in them, as happens in the case of soda-lime-silica glass. This too, is a positive point in favour of the basic mechanical strength of Borofloat 33 from the viewpoint of long-term stability.

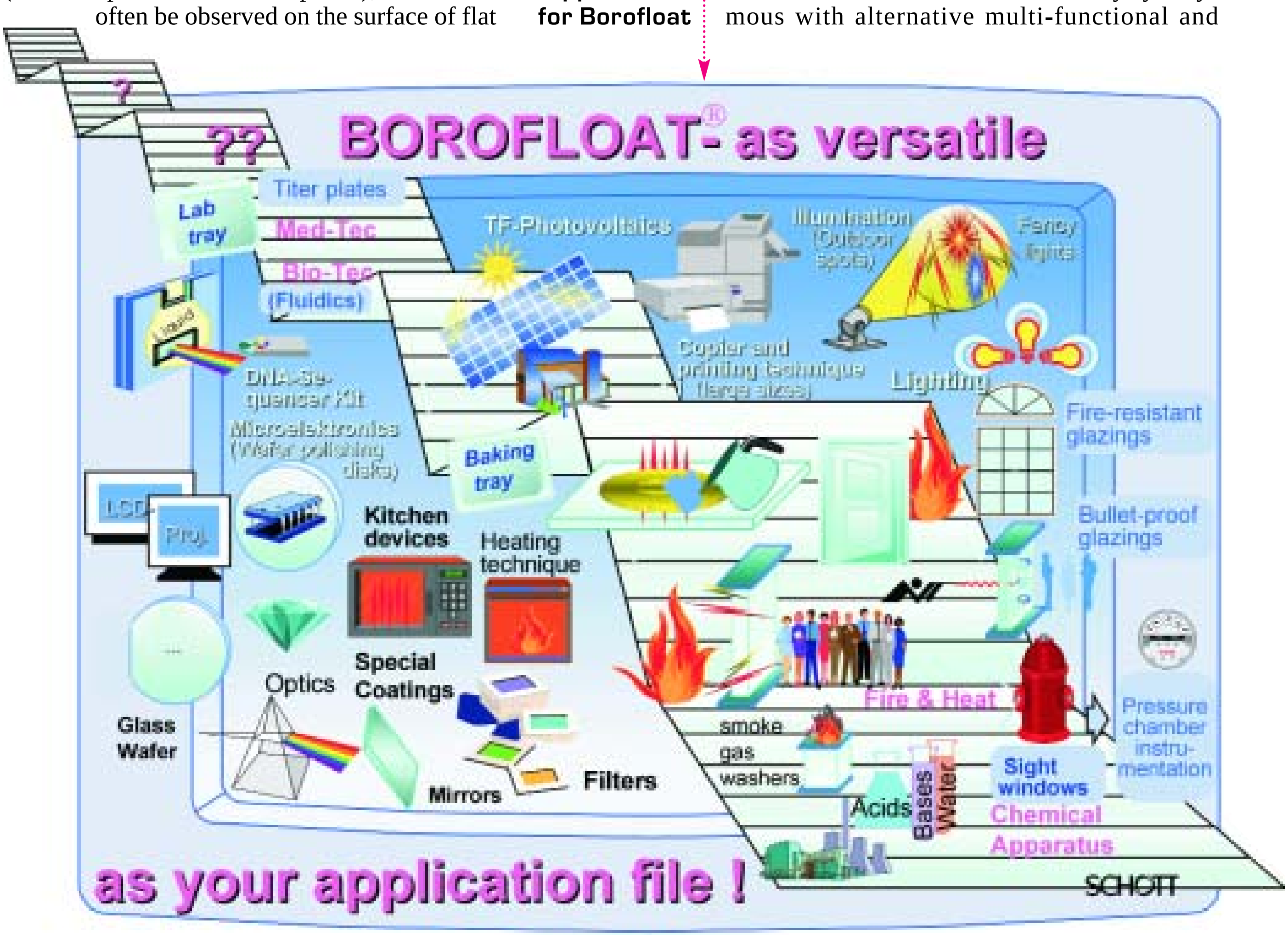
PROSPECTS AND SUMMARY

Expert opinion is uniformly agreed that every avenue in the advanced flat glass market is open to new high-quality, and, at the same time, extreme temperature resistant borosilicate flat glass substrates with improved chemical resistance.

As an alternative, with borosilicate float glasses, the areas of application start at the point where conventional soda-lime-silica glasses are being stretched to their limits.

The Borofloat brand name is today synonymous with alternative multi-functional and

A wide range of different applications for Borofloat



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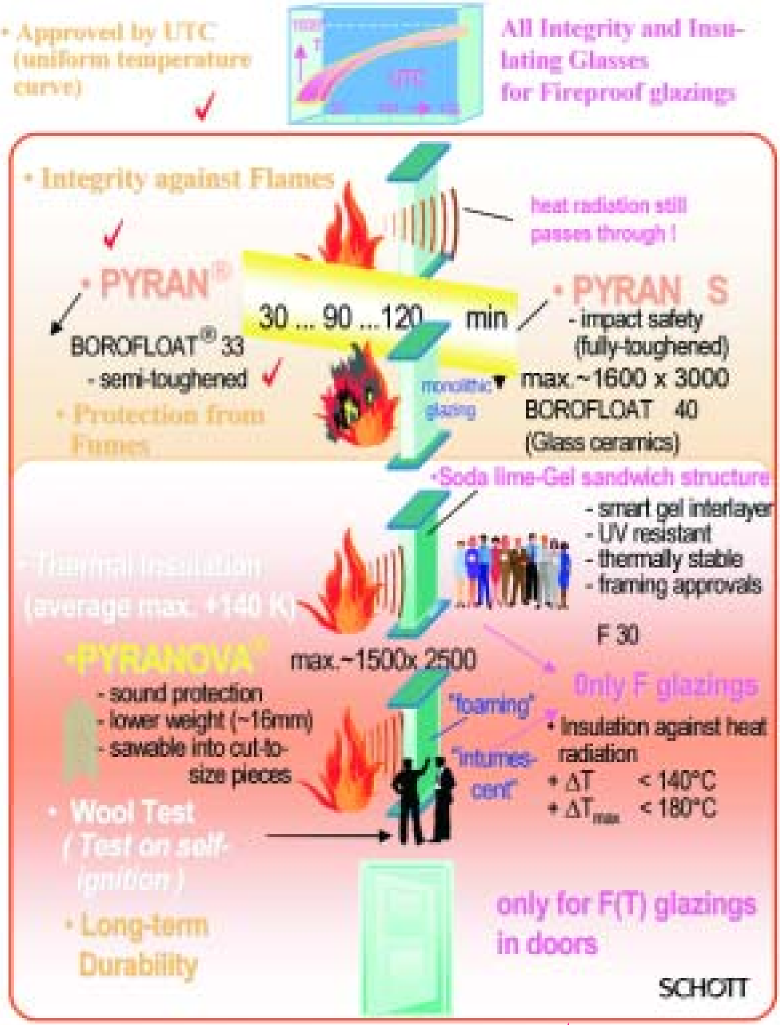

Fire-resistant glasses for integrity and insulating glazings

high quality borosilicate float glasses, which prove themselves when faced with fire and heat and from cold to hot in many applications.

Borofloat glasses demonstrate clear benefits when faced with especially difficult or extreme thermal and/or chemically aggressive conditions of use.

The range of applications is wide. Covering such diverse products as special fire resisting glass (Pyran S., Pyranova) and safety glass, glass doors for household appliances, aesthetic glass ovenware, cover panels for special lamps, sight glasses for pressure valves, analytical instruments for healthcare and biotechnology, microsystem engineering, simple optical components, photoactive and other functional coatings on glass, plus the relevant applications and processing technologies.

With the standard of technology that has now been reached there is great potential for the innovative microfloat technology to do justice to virtually all the major development and application trends in the modern glass sector. The high quality which can be achieved in a broad spectrum of thicknesses, from very thin to ultra-thick, the possibility of manufacturing very flat borosilicate glass with a constant thickness distribution across the whole width of the glass, in sizes typical, of float glass and comparable to plate glass, plus the high productivity and efficiency of microfloat compared to other technologies in the manufacture of special flat glass: all these factors form a solid basis for competitivity in the high-technology borosilicate glass substrate market.

Larger, very flat and smooth, high quality, extremely fault free flat glasses are increasingly set to play a decisive role over the next few decades in the special glass market, which is moving forward at a rapid pace. Competition between suppliers of high quality flat glasses, produced using different manufacturing technologies, is set to become even more intense and even more varied.

Microfloat technology in conjunction with Schott's glass and technology development, which has traditionally always been innovative in the borosilicate glass sector, provides a very good basis for it to assert its leading position in this development process, which is rapidly advancing technologically on an international scale.

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