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The effect of Sawdust loading as natural short fiber on NBR/NRL-G compounds

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ABSTRACT

In this study, sawdust (SD) has used as a short natural fiber to reinforce acrylonitrile butadiene rubber / recycled natural latex glove (NBR/NRL-G) compound. Sawdust fiber (SD) has been grinded and screened to form (300µm-700µm) size. Different loading of (SD) (5,10,15 and 20 phr) has been used and prepared by two-roll mill machine at room temperature. Several tests were used to study characteristics and properties of this compound. The testing such as cure characteristics, morphology, tensile and physical properties are determined. The scorch time (t_{s2}), cure times (t_{90}), minimum torque (M_L) and the maximum torque (M_H) of NBR/NRL-G/SD increased with increasing of the sawdust content in the compound. This was contributed to the increase the time for crosslinking initiation and increases the adhesion bonding between matrix and filler. The 5phr loading of (SD) which filled the NBR/NRL-G compound was the higher tensile properties than other (SD) loading.

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INTRODUCTION

In general, Rubber is used as the base material to the products that need the elasticity and flexibility as a requirement. In certain applications, the products of rubber need to be stiff along with flexibility. This case can be accomplished by filling rubbers by specific kinds of filler.

There are many researches that studied the filler effect on the polymer properties such as silica, carbon black, calcium carbonate (CaCo3) and other. These studies have focused on the efficiency of the matrix/filler reinforcement depending on many limitations such as the shape, the size, the surface and the nature of the filler (M. Morton, 1995). Lately, the interest of using of natural and renewable reinforcing fiber especially short natural reinforcing fibers from several sources for nature has attracted the attention of the worldwide and increased rapidly (De, D., De, D., and Adhikari, B., 2006). This is due to the low cost, easy processability and environment friendly materials. In addition, most of the natural filler with rubber matrix compounds have exhibited the both behavior of the elastic rubber matrix and the stiff fibrous reinforcement. This combination showed a several processing advantages in industrial fields such as the high level of strength, stiffness, modulus and other properties (Arumugam, N. *et al*, 1989). It has also been observed that a small amount of natural fibers could reduce the growth of crack and scaling for rubbers (Geethamma, V. G *et al*, 1998).

The development of natural fiber which reinforced rubber compound has made available polymers that are harder than aluminum and stiffer than steel (Jacob, M. *et al*, 2004). It has been effectively used in many applications, such as V-belts (Goettler, L. A. *et al*, 1979), hoses, tyre tread, and complex-shaped mechanical goods production (Geethamma, V. G. *et al*, 1998). Several researchers have studied different types of natural fibers to reinforce the natural and synthetic rubber. Jasso-Gastinel, C. F. *et al*, (1992) were studied the effects of different cellulosic materials (wood sawdust, Lignin, Sugar cane waste Pulp, Pine chips, Henequen, Coconut husk, Henequen and Coconut husk) on the mechanical and rheological properties of Butadiene acrylonitrile rubber (NBR). It was observed that all cellulosic materials have showed

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promising results and remarkable performance for reinforcing rubber at low strains.

Addition of recycled natural latex gloves (NRL-G) in NBR has gave many processing advantages and lowered the cost of the rubber compounds (Zulkepli, N. N. *et al*, 2009). The 20 Phr of NRL-G that filled NBR has been utilized as a control in the present study with different short natural sawdust fiber loading.

Sawdust fiber represented the one of the most abundant natural and renewable reinforcing material. It has many desirable properties for reinforcement that spread widely in the world.

The aim of the current investigation is to assess the ability of the sawdust (SD) as a short natural fiber to reinforce the NBR/NRL-G compound.

Experimental:

Materials:

Acrylonitrile-Butadiene Rubber (NBR) which containing 33% of Acrylonitrile has supplied by RRIM Guthrie Sdn. Bhd. – Malaysia, while Sawdust was supplied as a short natural fiber by Perlis Sawmill Sdn. Bhd – Malaysia. It was grinded by Crusher model RT34 (Chyun Industrial Co. Ltd.) to reach to the desired size. The examination gloves are scraps from Top Glove Sdn Bhd. As rejected gloves that have pinholes and tears defects were prepared by the same Crusher which grinded Sawdust filler and used Mastersizer Instrument (Type E) to form (300 – 700 micron) as a fine size. Each of vulcanizing agent (sulfur), activator (zinc oxide), accelerator (stearic acid), homogenizing agent (struktol) and N-cyclohexyl-2-benzothiazole sulfonamide (CBS) have been supplied by Anchor Chemical Co.(M) Ltd. – Malaysia and used in this study.

Preparation, Cure Characteristics and Vulcanization of NBR/RL-G/SD compound:

Table 1. NBR/NRL-G compound as control with four different loading (0, 5, 10, 15 and 20 Phr) of Sawdust (SD) were added as a short natural fiber to the compound. According to American Society for Testing and Materials (ASTM D 3184-89), two roll mill model-X (S) K - 160 X 320 was used to mix and pre-blend the compounding at room temperature. After 24 hour of preservation, about 4 g samples were prepared and Monsanto Moving Die Rheometer device model - (MDR 2000) was used at 160 °C to study the cure characteristic of the compound based on ASTM D 2240-93. Vulcanization was performed in a laboratory press at 30 tonn and 160 °C for their optimum cure time t_{90} (Table 2).

Table 1: Formulation of NBR/NRL-G/SD compound.

Ingredients	(Phr)				
	R0	R5	R10	R15	R20
Acrylonitrile butadiene rubber (NBR)	100	100	100	100	100
Recycled natural latex gloves (NRL-G)	20	20	20	20	20
Zinc oxide (ZNO)	5	5	5	5	5
Stearic Acid	2	2	2	2	2
N-cyclohexyl-2-benzothiazole sulfonamide (CBS)	1	1	1	1	1
Homogenizing agent (Struktol)	1	1	1	1	1
Vulcanizing agent (Sulphur)	2	2	2	2	2
Sawdust (SD)	0	5	10	15	20

Physical and mechanical properties:

After samples compressed to a radial shape and 6 mm thickness, hand- held Shore-A Durometer has been used to calculate the hardness values of samples. The dumbbell cutter was used to cut the molded rubber sheets and form dumbbell-shaped specimens for the measurement of tensile properties (Tensile strength, break elongation and modulus 100%). It has been done according to ASTM D412 by universal testing machine (Instron 5582) at room temperature.

Swelling test:

Toluene was used as a solvent for swelling test according to ASTM D471-79. Cured rubber compound were cut to (30 x 5 x 2) cm dimension. Samples were weighed by electrical balance to calculate the initial weight (m1) and immersed in a close vessel containing toluene (30mL) at room temperature. After two days, the swollen samples were weighed again to calculate the weight after swelling (m2). The degree of swelling has been calculated by using the following equation.

$$Swelling\% = \frac{m2 - m1}{m1} \times 100 \quad (1)$$

Scanning electron microscopy (SEM):

The fracture surfaces of samples which obtained by tensile test have been studied by scanning electron microscope (SEM) – model JSM 620 LE JOEL. An extremely thin layer of palladium (1.5 - 3 nm) has coated samples by sputter coater machine to avoid the poor resolution of the image and to prevent the electrostatic charging during examination.

RESULT AND DISCUSSIONS

Cure characteristic:

Table 2 presented the influence of the different sawdust (SD) content as a natural fiber on the curing characteristics of NBR/NRL-G/SD compound. It can bee seen clearly the scorch time (t_{s2}) and the cure times (t_{90}) of the compound are slightly increased with increasing of the sawdust content into the compound. This increasing contributed to the increase the time for crosslinking initiation which increase the stiffness of the compound when the sawdust added. The strong adhesion bonding between the NBR matrix and the sawdust particles has restricted the deformation and made the compound harder and stiffer. This led to increase the value of the minimum torque (M_L) and the maximum torque (M_H) of the compound (Ichazo, M. N. *et al*, 2006).

Table 2: The cure characteristic of NBR/NRL-G/SD compound.

NBR/NRL-G/SD	t_2 (min)	t_{90} (min)	M_L (dNm)	M_H (dNm)
R0	2.06	24.2	5.56	25.88
R05	2.70	6.34	5.94	29.8
R10	3.10	14.50	6.10	31.9
R15	3.20	23.10	6.67	34.0
R20	3.90	24.34	7.20	37.4

Hardness:

Hardness Shore A values of the compound were improved when sawdust added to the NBR (Figure 1). The gradual increasing of the hardness values, passing from 51.30 at 5 Phr and reach to the last and higher value 60.4 at 20 Phr explained the increasing of the compounds rigidity. This behavior might be due to the reduction of the volume fraction of the rubber matrix into the compound and increase the filler percentage (Ismail, H. *et al*, 2002).

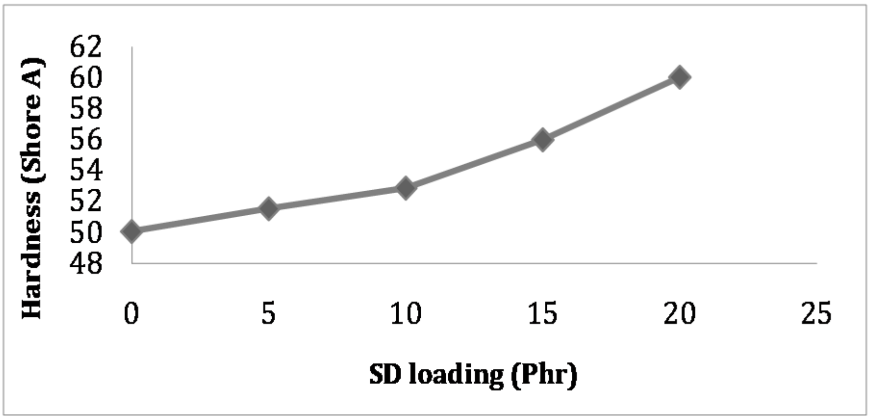

Fig. 1: Hardness values of NBR/NRL-G/SD compound.

Swelling test:

The swelling percentages of the sawdust (SD) filled the vulcanized rubber were displayed in (Figure 2). It was found that the swelling values of NBR/NRL-G/SD compound have been continuously decreased with increasing the sawdust loading. The rise of sawdust fiber content on the rubber compound has restricted the penetration of toluene inside the rubber compound, which in turn reduces the swelling percentage of rubber compounds.

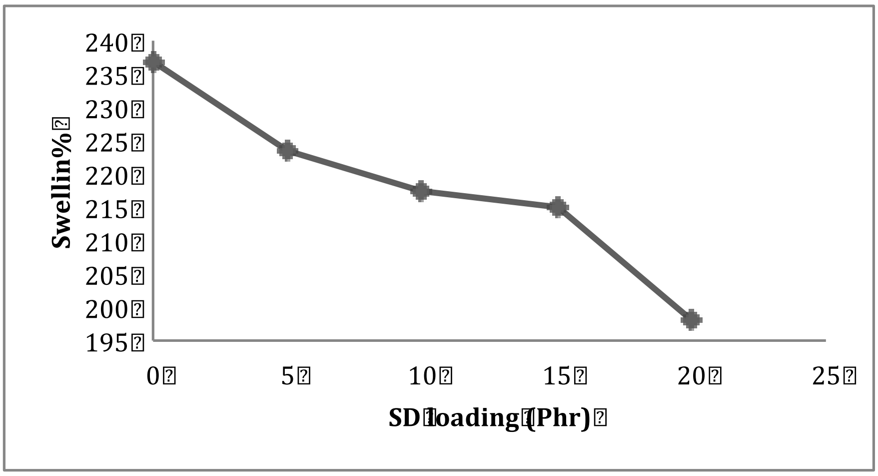

Fig. 2: The swelling percentage of NBR/NRL-G/SD compound.

Tensile properties:

The effect of several loading of the sawdust fiber on the tensile strength of the compound is shown in Figure 3.1. As mentioned earlier, the increasing of sawdust content in the compound led to increase the stiffness and the rigidity of the vulcanizates. Hence the value of the tensile strength decreased with increase of sawdust content into the compound. This drop of tensile strength contributed to the increase of filler concentration in the compound that increased the difficulty of the stress transmission from rubber matrix to the filler (Ismail, H. *et al*, 1997).

This matter corroborated by the SEM section (Figure 4).

The values of the elongation at break in Figure 3.2 have decreased with increasing of sawdust content causing decrease the resilience and toughness of the compound, which in turn reduce the mobility of the chain inside the compound. This made the compound stiffer and harder (Ismail, H., and Jaffri, R. M., 1999)

Furthermore, all elongation at break values after sawdust addition were lower values compared to the compound before sawdust addition.

From Fig3.3, it can be stated that the value of modulus of 100% elongation increased continuously with increasing the sawdust content in the compound. This might contribute to the increase of the adhesion bonding between the rubber matrix and sawdust particles. This high adhesion bonding was caused a high stiffness.

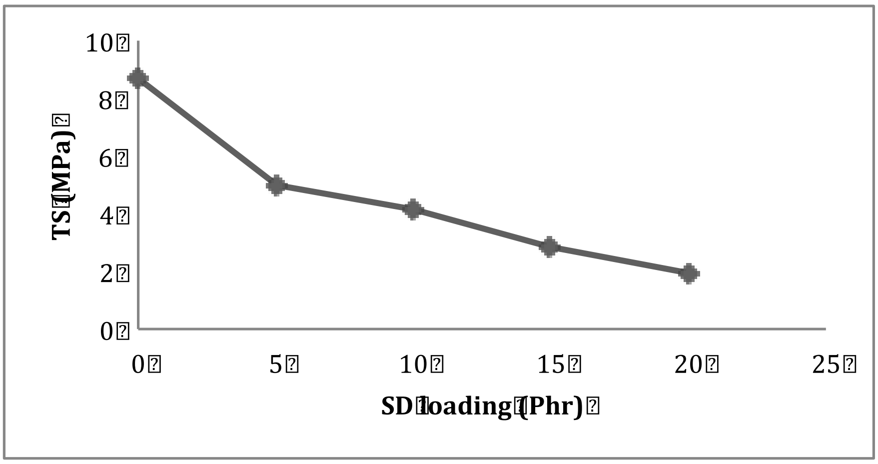

Fig. 3.1: The tensile strength of NBR/NRL-G/SD compound.

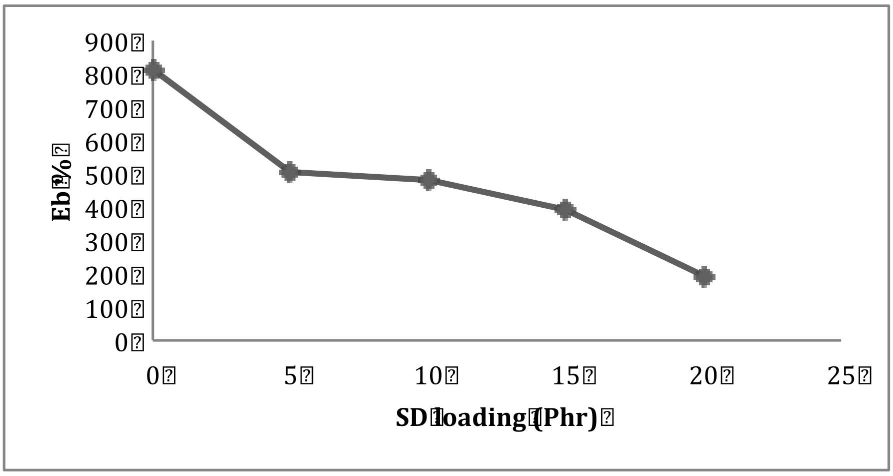

Fig. 3.2: The elongation at break of NBR/NRL-G/SD compound.

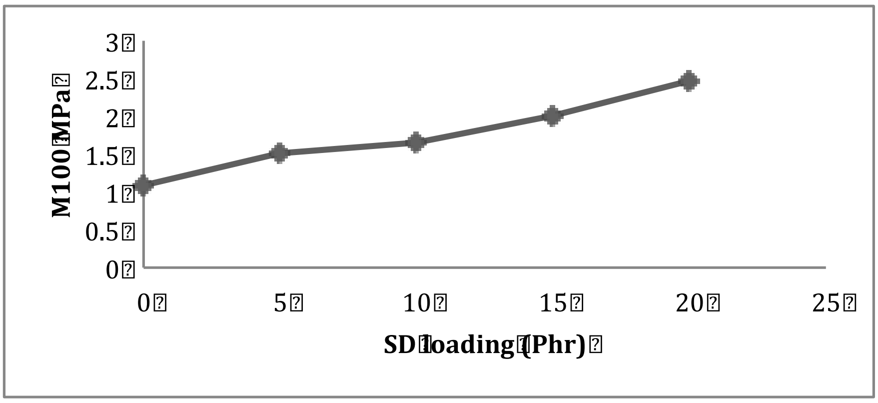

Fig. 3.3: The 100% modulus of NBR/NRL-G/SD compound.

Scanning electron microscopy (SEM):

The SEMs of the tensile fractured surface of sawdust 5 Phr and 20 Phr loading filled NBR/NRL-G compound have been illustrated by Figures 4a and Figure 4b respectively.

The 5 phr of sawdust in the compound had several tearing lines on the tensile fracture surface, which need more energy to break the matrix (Figure 4.a1 and a.2). This phenomenon contributed to the high surface area of the sawdust, which strongly bonded with the rubber matrix and caused a high adhesion bonding (Figure a.3).

However, at high level of sawdust loading particularly at 20 Phr in the rubber compound as shown in (Fig 2.b1, b2, and b3) led to agglomerate the sawdust inside the rubber compound and formed a rough surface. This agglomeration was reduced the sawdust surface area which caused the breakage and pull out of the sawdust particles and holes occurred.

These micrographs have explained clearly the decrease of the tensile strength level with increasing the loading sawdust fiber filled NBR/NRL-G compound.

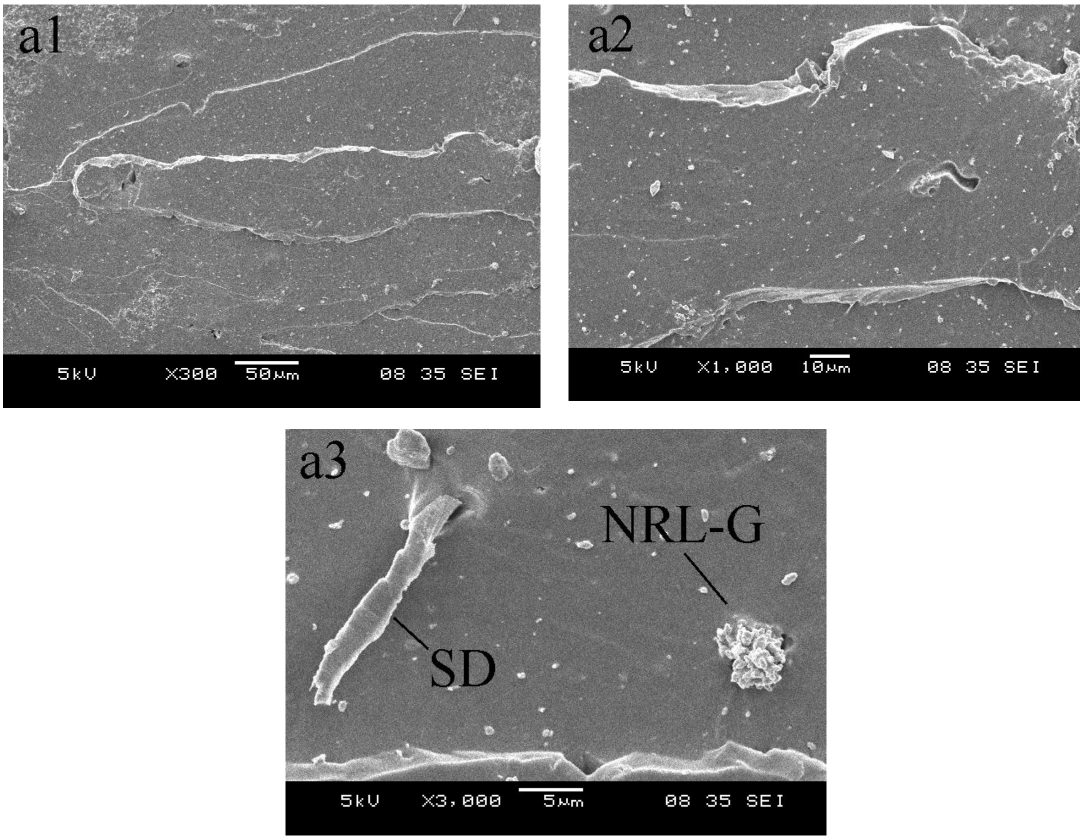

Fig. 4,a: The SEM on tensile fracture surfaces of 5 Phr SD filled NBR/NRL-G compound at X300, X1000 and X3000 magnification.

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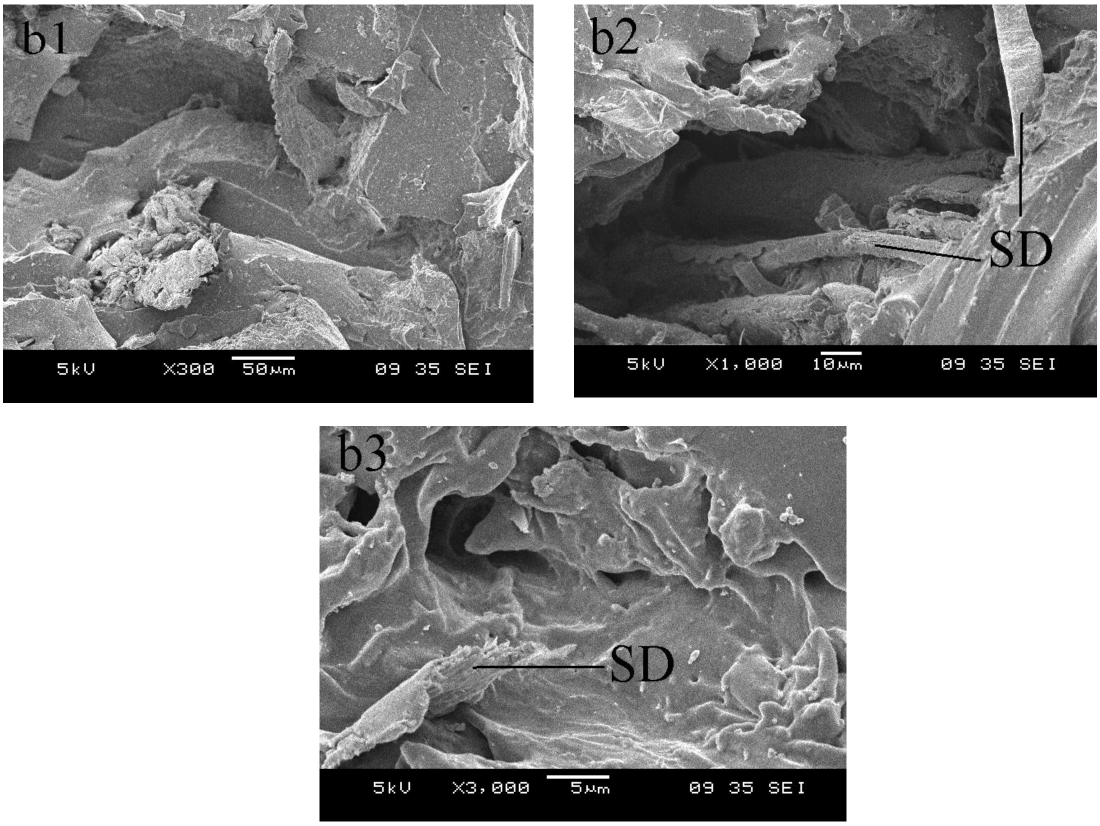

Fig. 4,b: The SEM on tensile fracture surfaces of 20 Phr SD filled NBR/NRL-G compound at X300, X1000 and X3000 magnification.

Conclusion:

The influence of short sawdust fiber content on NBR/NRL-G/SD rubber compound has been evaluated. Results revealed that the addition of short sawdust fiber to Acrylonitrile butadiene rubber/ Recycled natural latex gloves compound has increased the cure characteristic (t_2, t_{90}, M_L and M_H) of the rubber and produced an improvement in modulus at 100% strain. Despite the decrease of tensile properties of the rubber compound, The 5 Phr / sawdust fiber filled NBR/NRL-G compound has showed the best overall balance of tensile properties compared to higher sawdust loading, which involved tensile strength and elongation at break. This contributed to the high adhesion bonding between the matrix and the fiber. This bonding was proved by SEM section.

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