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Composite materials based on wastes of flat glass processing

A.V. Gorokhovsky [a,*], J.I. Escalante-Garcia [a], G.Yu. Gashnikova [b], L.P. Nikulina [b], S.E. Artemenko [b]

[a] Department of Engineering Ceramics, CINVESTAV Unidad Saltillo, Carr. Saltillo-Monterrey km13, AP 663, Saltillo, CP25000 Coahuila, Mexico
[b] Department of Chemical Technology, Technological Institute of Saratov State Technical University, Pl. Svobody 17, Engels 413100, Russian Federation

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Abstract

Glass mirrors scrap and poly (vinyl) butiral waste (PVB) obtained from flat glass processing plants were investigated as raw materials to produce composites. The emphasis was on studying the influence of milled glass mirror waste contents on properties of composites produced with PVB. The characterization involved: elongation under rupture, water absorption, tensile strength and elastic modulus tests. The results showed that the composite containing 10 wt% of filler powder had the best properties among the compositions studied. The influence of the time of exposure in humid atmosphere on the composite properties was investigated. It was found that the admixture of PVB iso-propanol solution to the scrap of glass mirrors during milling provided stabilization of the properties of the composites produced.

1. Introduction

The use of industrial wastes to produce composite materials is one of the current problems of industry; this provides a means to decrease environmental contamination. Flat glass processing involves the generation of wastes, like scrap of glass mirrors as well as strips of poly (vinyl) butiral film (PVB), from the manufacture of automobile windscreens (Garner, 1996) and safety architectural glass (Lievens, 1995). Clean PVB waste can be recycled on the basis of well-known technological processes; however, about 5–20% of this waste contains contamination, which precludes its recycling. Moreover, in developing countries there is little efforts or possibility for the recycling of this type of waste. Additionally, waste from glass mirror production (scrap or mirrors not meeting standards) has to be disposed because of the lack of technological processes oriented towards its utilization (Foss, 1997). The amounts of such waste can reach 10–15% of commercial production in different plants.

Taking into account that the plants oriented to flat glass processing, usually produce both types of the aforementioned wastes or are located close by, it was of interest to investigate the possibility of producing glass-polymer composites based on the complex utilization of such wastes that are inapplicable for recycling. The production of composites based on PVB wastes is especially attractive in developing countries, where their collection as well as transportation into the plants specialized in PVB recycling is economically unprofitable.

The high adhesion properties of the PBV to the soda-lime-silicate glass surface (Garner, 1996; Gopal et al., 1997) make the composite, based on PVB waste and milled glass, a promising material useful for different applications. The best scheme is that for plants producing both wastes, for example in the manufacturing of different profiled rods, characterized with high mechanical properties stable in conditions of humid atmosphere and temperature changes. However, the presence of

* Corresponding author. Tel.: +52 844 438 9600; fax: +52 844 438 9610.
E-mail address: alexande@saltillo.cinvestav.mx (A.V. Gorokhovsky).

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metal particles on the glass surface of milled glass mirror scrap as well as the use of PVB waste could negatively influence the exploitation properties and thus must be investigated.

2. Methodology

Wastes of Saratovsteklo Inc. (Russia) were used for the experiments. The glass used to produce mirrors had the following chemical composition (wt%): 73.1 SiO_2; 1.1 Al_2O_3; 8.6 CaO; 3.6 MgO; 13.6 Na_2O. The mirror coating was formed by vacuum sputtering of stainless steel. PVB waste was obtained from the polymer film B-17 produced by Monsanto.

In Series 1 of the experiments, the filler was produced by dry ball milling of glass mirror scrap, in jars of alumina with balls of alumina, to reach a surface area of 4000 ± 100 cm^2/g (controlled by LHM-8MD Russian equipment). The ground glass was then added to PVB waste molten at 115 °C, the latter was previously admixed with 0.5 wt% of poly (ethyl) silane (PES-5, Volzhskii, Russia) to promote the blending of components and increase homogeneity of composition. The ratio of glass powder and molten PVB was varied in the range of 1–30 wt%. The mixtures obtained were used to produce films by quenching, as well as rods by extrusion.

It is well known that water vapor adsorption onto the surface of soda-lime-silicate glasses influences their adhesion to polymers (Kawaguchi and Pearson, 2003; Gu et al., 2000; Radhakrishnan and Unde, 1999). It has been shown (Soshko et al., 1989) that the admixtures of some organic polymers into the glass scrap during milling promoted the modification of the glass surface by the products of their thermo-mechanical destruction (Dhaliwal and Hay, 2000). For this reason, an additional batch of Series 2 was prepared using composites made from the resulting material obtained after joint ball milling of glass mirrors scrap admixed with PVB waste dissolved at room temperature in iso-propanol (15% solution); the weight ratio of glass scrap and PVB–alcohol solution was 0.05. It was expected that the glass powder thus obtained would have enhanced hydrophobic properties and improved adhesion to PVB. To characterize such surface modification, the obtained fillers were investigated by TGA/DTGA (Perkin Elmer/Seiko Instruments, Japan) for the following types of glass powder: (a) "fresh" dry milled, (b) dry milled and exposed to a humid atmosphere for a month, (c) milled with PVB alcohol solution and exposed to a humid atmosphere for a month.

The average tensile mechanical strength of the composite articles was measured by testing 18 specimens of each system using the ER-5046-5 Russian equipment. The Young modulus was measured following the E1875-00e1 ASTM standard using UZIS equipment (LETI, Russia).

Taking into account the influence of environmental factors on the properties of materials produced, specimens of the two composites, prepared with the fillers of Series 1 and 2, were exposed for three months at 25 °C in air (40% humidity); and the same mechanical tests, as previously described, were repeated to determine the range of variation in the main characteristics during exploitation.

3. Results and discussion

The main characteristics of composites with different contents of glass powder for Series 1, measured immediately after their production, are presented in Table 1. The introduction of 1–10 wt% of glass powder into the matrix of PVB waste increased the mechanical strength of the composite (by 1.6 times) and decreased its relative elongation under the rupture (by 1.3 times). Further increase of glass powder contents decreased the exploitation properties.

The influence of exposure to a humid atmosphere on the exploitation properties of the composite, made from Series 1 with 10 wt% of glass powder (highest mechanical properties), is presented in Figs. 1 and 2. All the tested properties decreased only during the first two months of exposure and then stabilized. The same effect was displayed by the results presented in Table 2, showing the properties of composites obtained with the "fresh" and "old" (exposed in air for a month) glass powder. Such reduction in the exploitation properties observed, in agreement with published results (Keller and Mortelmans, 1999), can be attributed to the processes taking place on the surface of glass filler before the production of composites: adsorption (condensation) of water vapor from the atmosphere, leaching of sodium ions, and crystallization of Na_2CO_3 and NaH-

Table 1
The properties of composites obtained by extrusion of samples made of separate dry milling of glass

Properties	Contents of glass powder (wt%)								
	0	1	3	5	10	15	20	25	30
Young module (MPa)	2.3	2.5	2.7	2.9	4.3	3.8	2.7	2.5	2.3
Tensile strength (MPa)	6.8	5.2	7.4	7.9	11.2	8.4	8.5	7.0	5.4
Relative elongation under rupture (%)	318	345	288	271	237	328	295	286	142

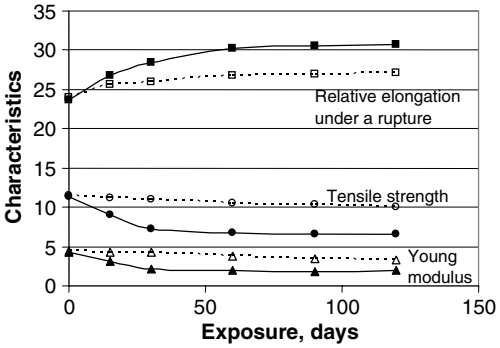

Fig. 1. Influence of exposure to humid atmosphere on properties of composites produced with powder obtained from Series 1 (continuous lines) and Series 2 (dashed lines): relative elongation under a rupture (%×10^{-1}), tensile strength (MPa), Young modulus (MPa).

CO_3 as a result of the sodium ions interaction with dissolved CO_2. The presence of these crystals and adsorbed water onto the surface of glass filler decreased adhesion with PVB. At the same time, modification of the glass powder surface during the milling of glass mirrors scrap with PVB alcohol solution (Series 2) can increase the hydrophobic properties of the glass powder and stabilize the structure of the composite. A comparison of properties for composites from Series 1 and 2 is shown in Figs. 1 and 2; an improvement and increased stability of properties of the composite produced in Series 2 can be noted.

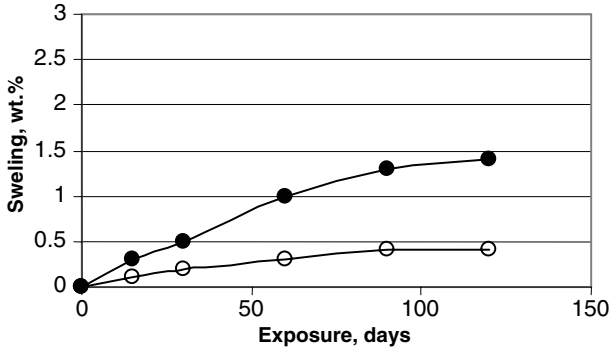

Fig. 2. Influence of exposure in humid atmosphere (dashed lines) and water (continuous lines) on weight of composite rods produced from Series 1 (●) and Series 2 (○).

Table 2
Properties of composites, made from Series 1 and with 10 wt% of glass powder, produced immediately after the milling and after one month of glass powder storage in air

Property	Type of glass powder applied	
	One month after milling	"Fresh" powder
Young modulus (MPa)	3.8	4.3
Tensile strength (MPa)	8.2	11.2
Relative elongation before the rupture (%)	281	237

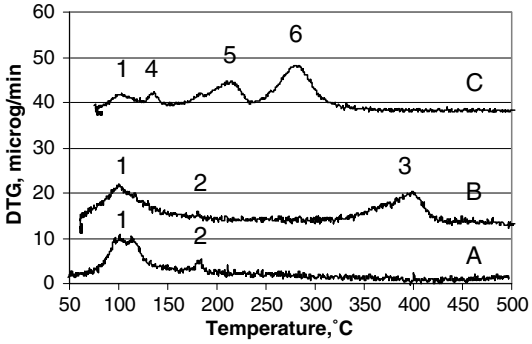

Fig. 3. DTGA data obtained for different types of filler: A – "fresh" dry milled, B – "old" dry milled, C – "old" milled with PVB alcohol solution. 1, 2 – desorption of condensed water, 3 – desorption of chemically adsorbed water, 4 – melting of PVB; 5, 6 – thermal decomposition of PVB and its derivatives formed by milling.

The obtained data of DTGA (Fig. 3) indicates that the "old" glass filler, in comparison with the "fresh" filler obtained by dry ball milling, is characterized by the additional intensive peak at 350–420 °C, related to the desorption of chemically adsorbed water (Hench, 1978; Gorokhovsky, 1988). At the same time, this peak is absent for the filler milled jointly with the PVB solution in iso-propanol; moreover, the quantity of condensed water is much less. The additional peaks in the thermogram of this filler are related to the melting and thermal decomposition of PVB (Dhaliwal and Hay, 2000). Thus, it is possible to propose that the effect of stabilization of the mechanical properties, obtained for the composite produced on the base of glass powder with modified surface (Series 2), was achieved due to a decreased adsorption of water vapor.

The composite rods of different profiles, produced by extrusion of the batch based on the PVB wastes and glassy filler (10 wt%), obtained by joint ball milling of glass mirrors scrap with PVB waste, dissolved at room temperature in iso-propanol (15% solution), were applied in Salavatsteklo Co. (Salavat, Russia) to manufacture the double glazing blocks, as well as bases for the storage and transportation of glass sheets of high thickness (weight).

4. Conclusions

Composite materials with attractive exploitation properties can be produced on the basis of typical wastes of flat glass processing: poly (vinyl) butiral ribbons and glass mirror scrap. The contents about of 10 wt% of glass powder results in composites with high and stable mechanical properties. The introduction of PVB alcohol solution resulted in the stabilization of properties of the composites in the case of exposure to humid atmospheres.

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