Hybrid Reinforcement in Nitrile Rubber Composites

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SUMMARY: Nitril rubber -PVC composites having carbon black and mica fillers in different compositions as hybrid reinforcements have been studied. The degree of replacement on static-dynamic mechanical , swelling behavior of resultant composites were all discussed. Results showed that increase in mica in total filler resulted in increase in toughness values , decrease in swelling in organic solvents together with increase in vibrational damping capacity of the resultant composites.

Introduction

Addition of filler materials to improve the mechanical, electrical, thermal, optical and processing properties of polymers while reducing their cost has become a popular field of research.

At the present time, the effects of individual fillers on the properties of components are relatively well known. For example as a general rule, tensile strength can usually be improved by fibrous fillers, provided that the adhesion is sufficient. Rigidity can be increased by sheet-like fillers and improvement depends on the aspect ratio of the filler [1]. Impact strength cannot usually be improved by mineral fillers [2].

Multicomponent compounding, on the other hand, where two or more different filler types are used, produces so-called hybrid structures where effects of the different components are combined. Recent investigations on composites having multicomponent filler systems are focused mainly on thermoplastics and thermosets such as spherical(glass beads), sheet-like (mica) or fibrous (wollastonite) reinforced polypropylene [3], fly-ash/glass fibre reinforced polyester composites [4] , sand / fly ash reinforced polyester mortar (PM) based on recycled poly(ethylene terephthalate) [5] and fly ash/mica reinforced unsaturated polyester composites both in uncured and cured state [6].

Studies on hybrid reonforcement in rubber composites are rather limited and needs to be studied in detail. Recently, the effect of mica addition to the swelling behaviour and static/dynamic mechanical properties of fumed silica reinforced PDMS composites has been investigated by our group [7].

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This paper reports a study on the nitril rubber -PVC composites having carbon black and mica fillers in different compositions as hybrid reinforcement. The degree of replacement with carbon black on both static-dynamic mechanical and swelling behavior of resultant composites are all discussed.

Experimental

Nitrile rubber blended with 30 % polyvinyl chloride (BAYER) has 34 % acrylonitrile content. Muscovite mica (30 μm) (Sabuncular) and carbon black -FEF N550 (44 nm and 12 m^2/g) (Continental Carbon) are used for this study as fillers.

All composites were prepared using mica and carbon black to give 0,30,47, 60, 75, 100 weight percentages of mica in total filler. Mixing was achieved on an open two-roll mill and vulcanization was done in an electrically heated press at 175 °C in 2 mm thick steel molds by using dicumyl peroxide as curing agent.

For the swelling experiments, strips (0.2 x 0.5 x 2 cm) were immersed in N-liquid (a mixture of 50 % isooctane and toluene) at room temperature for three days. The length changes were measured in the immersed state by a traveling microscope (Gaertner 7109-C-46) . Swelling degrees were reported in terms of swelling ratio $q = v_2^{-1}$ where v_2 is the volume fraction of polymer in the swollen network at a given time during the course of the experiment. v_2 is found from the ratio of the dry network volume to the swollen network volume at a given time.

Mechanical experiments were performed under two loading conditions: (1) Quasi-static mechanical tests, carried out at room temperature and cross-head speed of 50 cm/s in the static mode of a Zwick 1464 machine equipped with an incremental extansiometer and, (2) dynamic mechanical tests, carried out on a Polymer Laboratories Dynamic Mechanical Testing Analyzer, (DMTA), for a temperature range of $-60^{o}C < T < 120^{o}C$ at a frequency of 1 Hz.

Result and Discussion

The general effect of introducing mica is observed to decrease swelling. In Figure 1, swelling ratios as a function of mica content are shown. The straight lines are obtained by a least square fit to the data points. The increase in mica content in total filler induces further decrease in swelling .

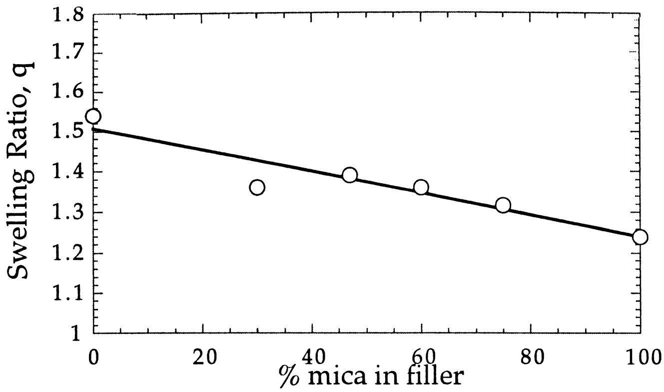

Fig. 1: Plot of swelling ratios of NBR composite as a function of mica in total filler.

Figure 2 shows the variation of tensile strength as a function of filler composition of nitrile rubber composites. The straight lines are obtained by a least square fit to the data points. The general effect of increasing mica content in the filler is to decrease the tensile srength.

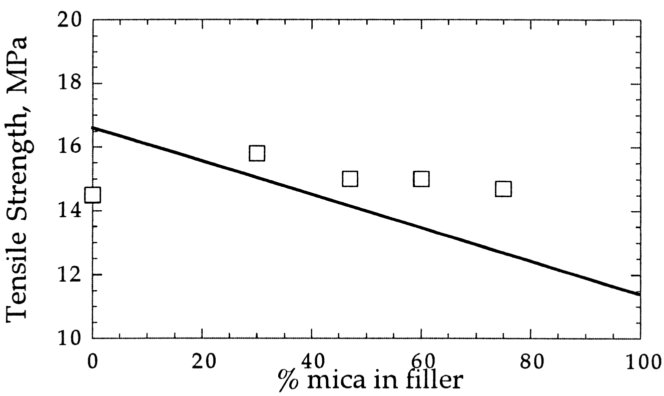

Fig. 2: Variation of ultimate tensile strength with concentration of mica in total filler for NBR composite.

Figure 3 presents elongation at break values of the composites . Similar to the behaviour observed for the polybutadiene composites [8] addition of mica increases the ductility of the samples. Similar to our observations, Khanh et al. [9] observed that with the addition of two-dimensional fillers such as mica in polypropylene matrix, mica-reinforced polypropylene becomes more and more ductile leading to higher elongation.

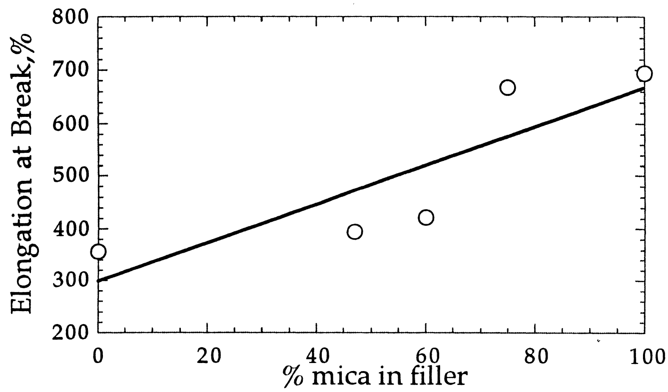

Fig. 3: Variation of elongation at break with concentration of mica in total filler for NBR composite.

The stress-strain curves of the 3470 NBR composites with only carbon black, and optimum compositions are given in Figure 4.

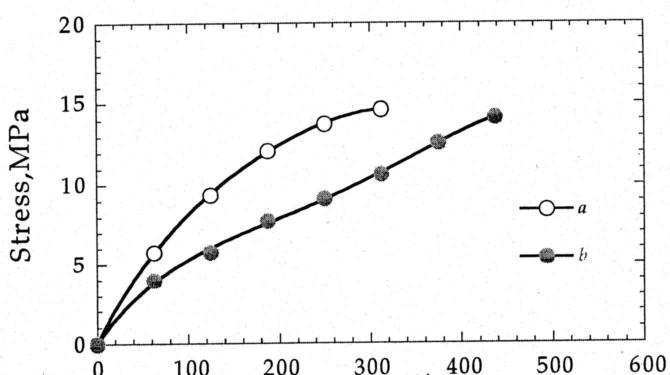

Fig. 4: Stress strain diagrams for composites having a) only carbon black, b) 47 % mica in total filler.

The area under these curves is a measure of the toughness and is equal to the energy absorbed by the specimen up to fracture. Our results are similar to results on polypropylene-mica composites 9). Here, toughness is maximum for the composition having 47 % mica in total filler.

Dynamic mechanical spectra of only carbon black (Figure 5a), and 47 % mica in total filler reinforced composite (Figure 5b) showed that the glass transition temperature (T_g) of the sample with carbon black reinforcement only is 17 ° C whereas in the presence of about 47 % mica as a replacer, the Tg of the composite increases to 22 ° C and the damping peak becomes broader.

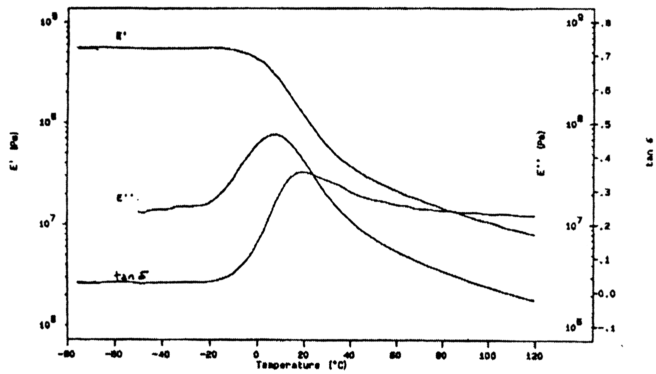

Fig. 5 a: Dynamic mechanical spectrum of nitrile rubber composite having only carbon black as reinforcer.

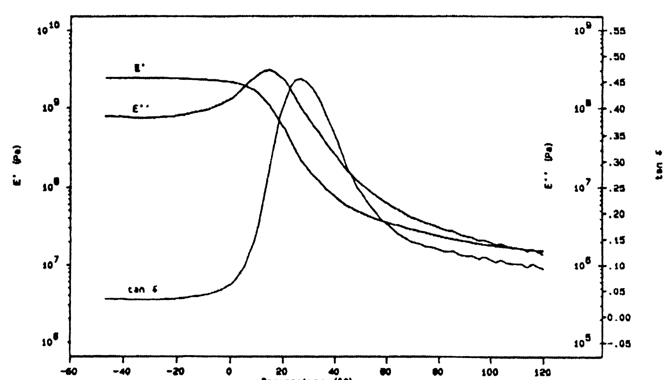

Fig. 5 b: Dynamic mechanical spectrum of nitrile rubber composite having 47% mica in total filler as reinforcer as reinforcer.

Although the mica is inert over this temperature range, the dynamic mechanical properties of composite are different from those of the carbon black reinforced polymer due to the effect of mica-matrix interphase. We believe that the slight upshift of the glass transition temperature and the broadenning the damping peak are due to the optimum packing of the two different sized and shaped fillers. Tan d values , measured over a large temperature range (-60-120 ° C) and at a frequency of 1 Hz , have a maximum increasing from 0.35 to 0.45 for the composites having only carbon black and 47 % mica in total filler, respectively.

Conclusion

It has been found that replacement of mica by carbon black marginally decreases the swelling of the composites in organic solvents and increases toughness values. Dynamic mechanical properties show that composite can act as a better vibration damper over wider temperature range.

The results presented in this study invited attention to a possible statistical thermodynamic approach to the cosolvent effect of one filler to the other in hybrid reinforcement, to find the optimum composition both theoretically and experimentally in terms of final performance of the composite. The related theory is currently under investigation .

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