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Magnetoactive elastomeric composites: Cure, tensile, electrical and magnetic properties

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Abstract. **Magnetically active elastomer materials were prepared by incorporating nickel powder in synthetic elastomeric matrices, polychloroprene and nitrile rubber. Cure characteristics, mechanical, electrical and magnetic properties were experimentally determined for different volume fractions of magnetoactive filler. The cure time decreases sharply for initial filler loading and the decrease is marginal for additional loading of filler. The tensile strength and modulus at 100% strain was found to increase with increase in the volume fraction of nickel due to reinforcement action. The magnetic impedance and a.c. conductivity are found to increase with increase in volume fraction of nickel as well as frequency.**

Keywords. **Magnetoactive composites; magnetic impedance; a.c. conductivity.**

1. Introduction

Magnetoactive elastomers are the elastomers in which magnetically active materials are embedded. The embedded magnetic particles give potential magnetizability to the otherwise magnetically inert elastomers (Davis 1999). Metallic fillers provide stiffening and reinforcement also. These composites have many applications (Bedmarek 1999; Ginder *et al* 1999, 2000). Selection of right material requires a systematic study of tensile, electrical and magnetic properties. Hence, the present work was devoted to development and characterization of magnetically active elastomeric composites.

2. Experimental

2.1 *Preparation of magnetoactive composites*

The list of materials used in the preparation of magnetically active composites is shown in tables 1 and 2. The magnetically active nickel powder of average particle size 2–3 μm was obtained commercially and used as such without any treatment. Composites having nickel powder loadings of 20–100 phr (parts per hundred parts of rubber) were produced by incorporating nickel and other ingredients into the polychloroprene and nitrile rubber matrices in a two-roller mill.

2.2 *Preparation of test specimens*

Sample for evaluating the tensile and electrical properties are prepared by compression moulding method in accordance with ASTM D 3188. For evaluating the magnetic properties, rubber compounds were moulded into cylindrical discs.

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3. Evaluation of properties

Cure parameters were studied by using die rheometer at 150°C. Mechanical properties like tensile strength, modulus and elongation at break are evaluated using universal testing machine. Tensile test was carried out according to the ASTM D 412 standard. For measuring the magnetic impedance an indigenous experimental set up was used. The samples were kept between the poles of two d.c. magnets, which can generate the d.c. magnetic field up to 5 KOe. Electrical conductivity measurements were carried out using LCR Meter in the frequency range 500 Hz–1 MHz.

4. Results and discussion

4.1 *Cure characteristics*

The cure characteristics was evaluated in terms of change in cure time with change in filler loading. In the case of polychloroprene composites, the cure time was found to decrease sharply for initial filler loading (20 phr) and the change in the cure time is only marginal for additional loadings of the filler (figure 1). This shows that the processability will not get affected by the increase in the filler content (Malini *et al* 2003). In the case of nitrile rubber composites also the trend is similar but the initial decrease in cure time is significantly large. This may be due to the catalytic effect of nickel on the sulphur cure reac-

Table 1. Polychloroprene–nickel composites: Materials used.

Name of the material	Supplier
Polychloroprene (CR)	M/s Du Pont, USA
Stearic acid	M/s Godrej Soap Ltd, India
N-(1,3-dimethylbutyl)-N-phenyl-P-phenylenediamene	M/s Bayer India
1,2-Dihydro-2,2,4-trimethyl quinoline	M/s Bayer India
Carbon black, FEF N 550	M/s Philips Carbon Black Ltd, Kochi
Carbon black, HAF N 330	M/s Philips Carbon Black Ltd, Kochi
Lead oxide (red lead)	M/s Glaxo, Mumbai
2-Mercaptoimidazoline	M/s Du Pont, USA
Benzothiazyl disulphide	M/s Bayer India Ltd, Mumbai
Naphthenic oil	M/s Hindustan Petroleum Ltd
Microcrystalline wax	M/s SBM Chemicals, Mumbai
Nickel powder	M/s Grishma Special Materials, Mumbai

Table 2. Nitrile rubber–nickel composites: Materials used.

Name of the material	Supplier
Nitrile rubber KNB 35L	M/s Korean Synthetic Rubber Co.
Sulphur, S	M/s Godrej Soaps Pvt. Ltd
Stearic acid	M/s Godrej Soap Ltd, India
Zinc oxide	M/s Rubosynth Impex Pvt. Ltd, Mumbai
1,2-Dihydro-2,2,4-trimethyl quinoline	M/s Bayer, India
Carbon black, MT	M/s Cabot Corporation, USA
Naphthenic oil	M/s Hindustan Petroleum Ltd
2-Mercaptobenzothiazole	M/s ICI India Ltd, Risha
Zinc diethyldithiocarbamate	M/s ICI India Ltd, Risha
Tetra methylthiuramdisulphide	M/s Bayer India Ltd, Mumbai
Nickel	M/s Grishma Special Materials, Mumbai

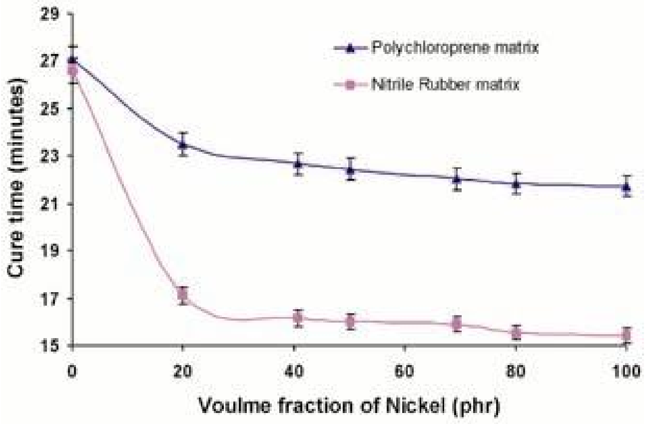

Figure 1. Cure time vs volume fraction.

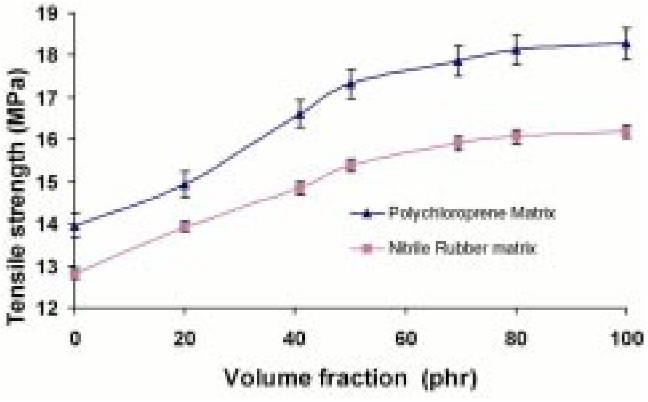

Figure 2. Tensile strength vs volume fraction.

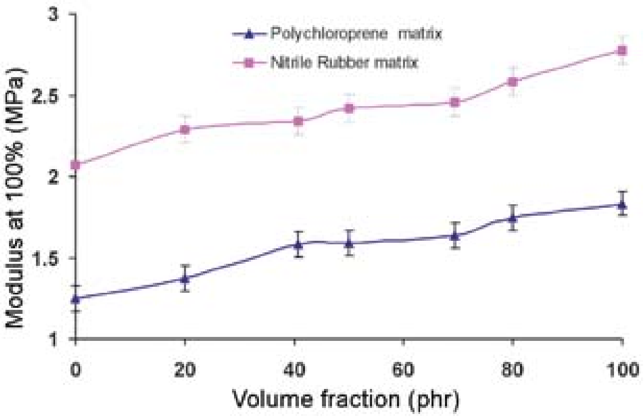

Figure 3. Modulus at 100% vs volume fraction.

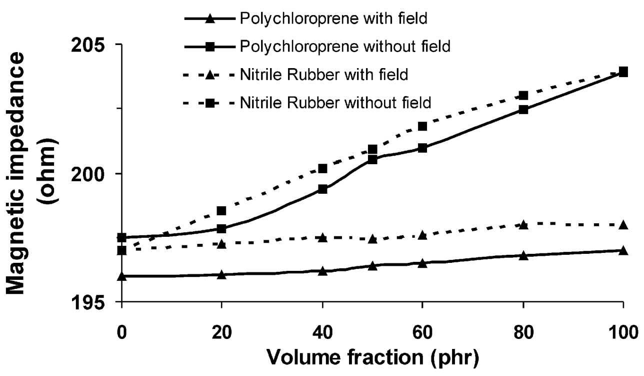

Figure 4. Magnetic impedance vs volume fraction at 5 kHz.

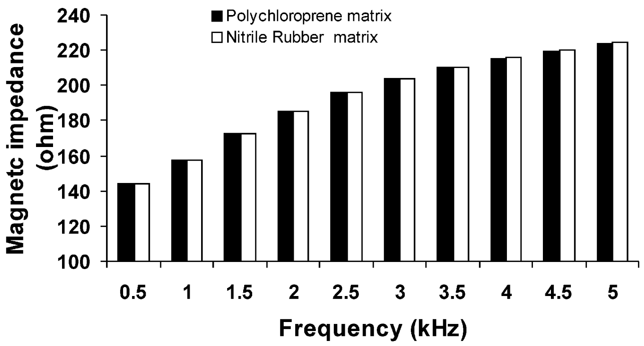

Figure 5. Magnetic impedance vs frequency.

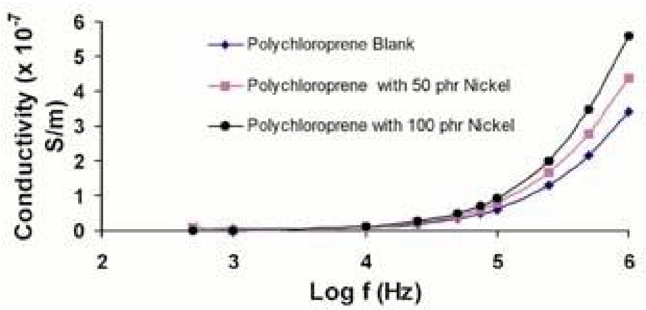

Figure 6. Conductivity of polychloroprene–nickel composites.

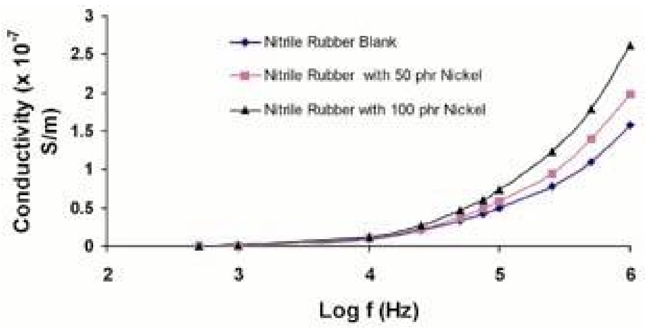

Figure 7. Conductivity of nitrile–nickel composites.

tion. The conclusion is made by comparing the cure time of polychloroprene rubber–nickel composites, which are cured by metal oxide cure system and nitrile rubber–nickel composites, which are cured by sulphur cure system.

4.2 *Tensile properties*

Tensile properties evaluated are tensile strength (figure 2) and 100% modulus (figure 3). Both properties show an increasing trend with increase in the volume fraction of nickel. This is due to the reinforcing action of the filler (Blow and Hepburn 1985; Shah 1998). The modulus at 100% is higher for nitrile rubber composites compared to neoprene rubber composites.

4.3 *Magnetic properties*

The magnetic impedance (Ozlem *et al* 2005) of the samples was measured as a function of volume fraction (figure 4). The magnetic impedance increases with the metal content of the composite. The volume fraction value has little effect on the magnetic impedance in presence of a magnetic field. It is due to the saturation effect of applied magnetic field (Kamruzzaman Md *et al* 2001). The magnetic impedance as a function of frequency in the absence of magnetic field is shown in figure 5. As the frequency increases the magnetic impedance increases in both the matrices. The increase in the magnetic impedance at higher frequencies is attributed to the increase in the stiffness of the material.

4.4 *Electrical properties*

Electrical conductivity of the magnetoactive composites under various volume fractions was determined in the frequency range 500 Hz–1 MHz. The conductivity increases with increase in the frequency as well as volume fraction (figures 6 and 7). The increase in conductivity at higher frequency is due to the hopping of charge carriers (Papathanassiou 2002).

5. Conclusions

Magnetoactive composites containing nickel in polychloroprene and nitrile matrices have been prepared. The cure characteristics reveal that the processability and flexibility of the matrix is not affected much even up to a maximum loading of 100 phr of the filler in the case of polychloroprene rubber. However, the effect of filler on the cure time is significant in the case of nitrile rubber composites. The mechanical properties show that the magnetoactive filler acts as a reinforcing agent also. The magnetic impedance values show that the applied magnetic field has saturation effect on the magnetic impedance of samples having different volume fractions of magnetoactive filler. But in the absence of magnetic field the volume fraction of filler has significant influence on the magnetic impedance. For a fixed volume fraction and magnetic field, the magnetic impedance becomes frequency dependent one and increases with increase in frequency.

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