TENSILE PROPERTIES OF YTTRIUM IRON GARNET ($Y_3Fe_5O_{12}$) – THERMOPLASTIC NATURAL RUBBER (TPNR) COMPOSITES

ABDUL AZIZ MANSOR & SITI ATKAH ABDUL HAMID
Faculty of Applied Science
Universiti Teknologi MARA Cawangan Pahang,
26400 Bandar Jengka, Pahang.
MALAYSIA

ABSTRACT

$Y_3Fe_5O_{12}$ (YIG) - thermoplastic natural rubber (TPNR) magnetic composites with 0 - 30 weight percent of YIG filler were prepared via Brabender plasticorder internal mixer. Blending conditions at 170 ^{0}C with rotor speed of 50 rpm for 12 minutes. The microstructural and filler distribution in the PP/NR matrix were performed via X-ray diffractometer (XRD) and thermogravimetric analyzer (TGA). The result of X-ray diffraction (XRD) indicates that the structure of YIG in the composites does not change after mixing in PP/NR matrix. Thermogravimetric analysis confirmed the uniform dispersion of the YIG filler in the PP/NR matrix. The tensile properties were determined via a universal testing machine. The result shows that the Young Modulus increase, but the maximum strain and the strain at break decrease, with filler content. The tensile properties of the composite are influenced by the filler contents.

KEYWORDS: Tensile properties, Magnetic Composite, Thermoplastic Natural Rubber

INTRODUCTION

Thermoplastic composites made by incorporation of powdery metal fillers represent an important group of engineering materials that have a wide range of applications including electromagnetic-inferences shielding, discharging static electricity, heat conduction and conversion of mechanical to electrical signals (Ghosh & Maiti, 1996). These materials combine the advantageous properties of metal and plastics which offer cost effectiveness and rapid fabrication rate with a wide range of design flexibilities, light weight and noncorrosiveness.

The mechanical properties of highly filled composites are influenced by adhesion at the polymer filler interface, non-uniform straining due to the presence of filler particles and particles-particles interaction, to a greater extent than in composites containing lower filler level. It is known that the mechanical properties of filled polymers are dependent on the filler amount, particle size, shape, orientation and the extent of interfacial adhesion between filler and matrix (Saini et. al. 1987 ; Chow, 1980)

Natural rubber-polypropylene, so called TPNR blend system is the most widely studied. PP is considered to be the best choice for blending with NR due to its high softening temperature of about 150 °C and low glass transition temperature of about – 60 °C for the blend, giving rise to a very versatile thermoplastic applicable over a wide range of temperatures. NR/PP thermoplastic blend compositions can be varied to give materials of different mechanical properties ranging from a soft elastomer to a semirigid plastic (Ibrahim & Dahlan, 1998).

In the present paper, the effects of incorporating the ferrite into the matrix of the TPNR on the tensile characteristics of the composites is an important factors that determine the usefulness of the materials as electromagnetic field absorbers.

MATERIALS AND METHODS

The YIG used as magnetic filler was obtained from Cerac Incorporated, USA. It was supplied in a powder form of about ~ 200 mesh (75μm) with purity of 99.9%.The materials used as a matrix were polypropylene (PP) and natural rubber (NR) with liquid natural rubber (LNR) as a compatibilizer in the ratio of 70:20:10 (Sahrim et. Al. 1994,1995). The LNR was prepared by photosensitized degradation of NR in visible light. The matrix was prepared by melt-blending of the materials in a laboratory cam mixer (Brabender Plasticorder Model PL 200 and Mixer Model W 50E/2) at about 170°C and rotor speed of 50 r.p.m. The LNR was added into the mixer 1 min after introducing NR, then allowed to mix for about 2 min before PP was charged into the mixer. Once homogeneous mixing was assumed after about 12 min, the blend was removed from the mixer. The TPNR matrix was ground by a granulator (Granulator Model Ph 400 SS). TPNR – YIG composites were prepared by melt-blending of the materials in a laboratory cam mixer at 170°C and rotor speed of 50 r.p.m. The garnet content was varied from 0 to 30 weight percent. The powder was added into the mixer 2 min after introducing TPNR. The materials were allowed to mix for about 12 min. Once homogeneous mixing was assumed, the blend was removed and subsequently compressed at about 175°C and 7 kN pressure for about 2 min using a hot press (Carver Laboratory Press) into a thin sheet of about 1 mm thickness.

The homogeneity of the samples was confirmed using a termogravimetric analyzer (Model Shimadzu TGA – 50) (Daniels, 1973). The morphology of all composite samples were examined using a scanning electron micrographs (Model Philips XL30) where the samples were harden in liquid nitrogen and fractured. The fracture ends of the samples were mounted on an aluminium stubs and sputter- coated with thin layer of gold to avoid electrical charging during examination. Structures of the ferrite and composites were studied using Siemen D5000 diffractometer with $Cuk_{\alpha 1}$ radiation (λ = 1.541Å).

Samples in the dumb bell shaped were cut from the compressed sheet based on the ASTM standard. All tensile measurements were carried out on an Instron Machine Testometric (Model Micro 350) at extension rate of 50 mm/min by using 1000 kg load cell at room temperature.

RESULTS AND DISCUSSION

The homogeneity of YIG filler composition in the TPNR matrix are confirmed from the data in Table 1. This result indicates that the time, temperature and rotor speed that been used in preparing the composites are suitable and optimum (Sahrim et al. 1995 ; sahrim et al. 1994).

X-ray diffractograms for the pure YIG ferrite, PP/NR matrix and the composites PP70NR30/YIG varies from 5 to 30 weight percent of YIG filler are shown in Figure 1. The results confirmed the formation of the single-phase cubic spinel structure of pure YIG crystal. The lattice parameter (a) calculated from the XRD data is (12.38 ± 0.01) Å. The main planes with miller indices of (400), (420), (422), (521), (611), (444), (640), (642) and (800) are located in the range of 2θ = 30 - 60 degree. The same result was obtained by Standley, Geller and Gilleo, Wolf and Rodrigue with lattice parameters are 12.37Å, 12.38 Å, and 12.36 Å respectively (Gilleo, 1980). Figure 1 shows that the microstructure of pure YIG ferrite filler in the PP/NR matrix for all the composites were remain unchanged.

Fillers are normally used to modify various properties of polymers. The incorporation of filler into a polymer might increase or decrease the tensile and bending strength of the resulting composite (Zzaini et. el. 1996) The results for the maximum strain and the strain at break are shown in Figure 2 and Figure 3. The result showed that the maximum stress and strain at break decrease with increasing filler content.

The Young Modulus for all samples are shown in Figure 4. The Young Modulus increases almost linearly with YIG filler contents and reaching a highest value at 30 weight percent filler content. The experimental data presented above is a composition-dependent trend of tensile properties (Ghosh & Maiti, 1996; Saini et.al. 1987; Tavman 1996). Syehlova Poloucek have shown that a better filler dispersion leads to a greater modulus. This development is explained by a percolation theory described by He and Jiang. There is a matrix zone around each particle, affected by a stress concentration. If the distance between particles is small enough, these zones join together and form a percolation network, which increases the modulus (Mareri et. al. 1998).

CONCLUSION

The microstructure of pure YIG ferrite filler in the PP/NR matrix for all the composites were remain unchanged. The mechanical properties of PP/NR/YIG composites were observe to be affected by the filler loading. Modulus increases, while the maximum stain and strain at break decreases with filler content.

REFERENCES

Ghosh, K and Maiti, S. N. (1996). Journal of Applied Polymer Science, **60**; 323 – 331.

Saini,D. R, Nadkarni, V. M, Nigam, K. D. P. and Grover, P. D. (1987). Journal of Composite Materials, **21**; 782-797.

Chow, T. S. (1980). Journal of Materials Science, **15**; 1873 – 1888

Ibrahim, A. and Dahlan, M. (1998). Prog. Polymer Science, **23**; 665 – 706.

Sahrim, A., Ibrahim, A. and Che Som, S. (1995). Journal of Applied Polymer Science, **58**; 1125 – 1133.

Sahrim, A., Ibrahim, A., Che Som, S., Kohiya, S. and Yoon, S. R. (1994). Journal of Applied Polymer Science, **51**; 1357 – 1363.

Daniels, T. (1973). Thermal Analysis. Kogan, London, Chap. 3, p 53.

Gilleo, M. A. (1980). Ed. Wohlfarth, E. P. Ferromagnetic Materials : A Handbook on the Properties of Magnetically Ordered Substances, Vol. 2. North-Holland Publishing, London.

Zaini, M. J., Fuad, M. Y. A., Ismail, Z., Mansor, M. S. and Mustaffa, J. (1996). Journal of Polymer International, **40**; 51-55.

Tavman, I. H. (1996). Journal of Applied Polymer Science, **62**; 2161 – 2167.

Mareri, P., Bastide, S., Binda, N. and Crespy, A. (1998). Journal of Composites Science and Technology, **58** ; 747 – 752.

Nominal YIG content (%wt)	YIG content from TGA at three different locations (wt %)	Average YIG content (wt %)
5	5.59, 5.68, 5.48	5.58
10	12.51, 12.37, 12.50	12.46
15	15.29, 15.36, 15.83	15.49
20	20.36, 21.25, 20.36	20.32
25	25.45, 25.65, 25.76	25.62
30	31.36, 31.86, 32.06	31.78

Table 1 Percentage of YIG in the PP/NR matrix.

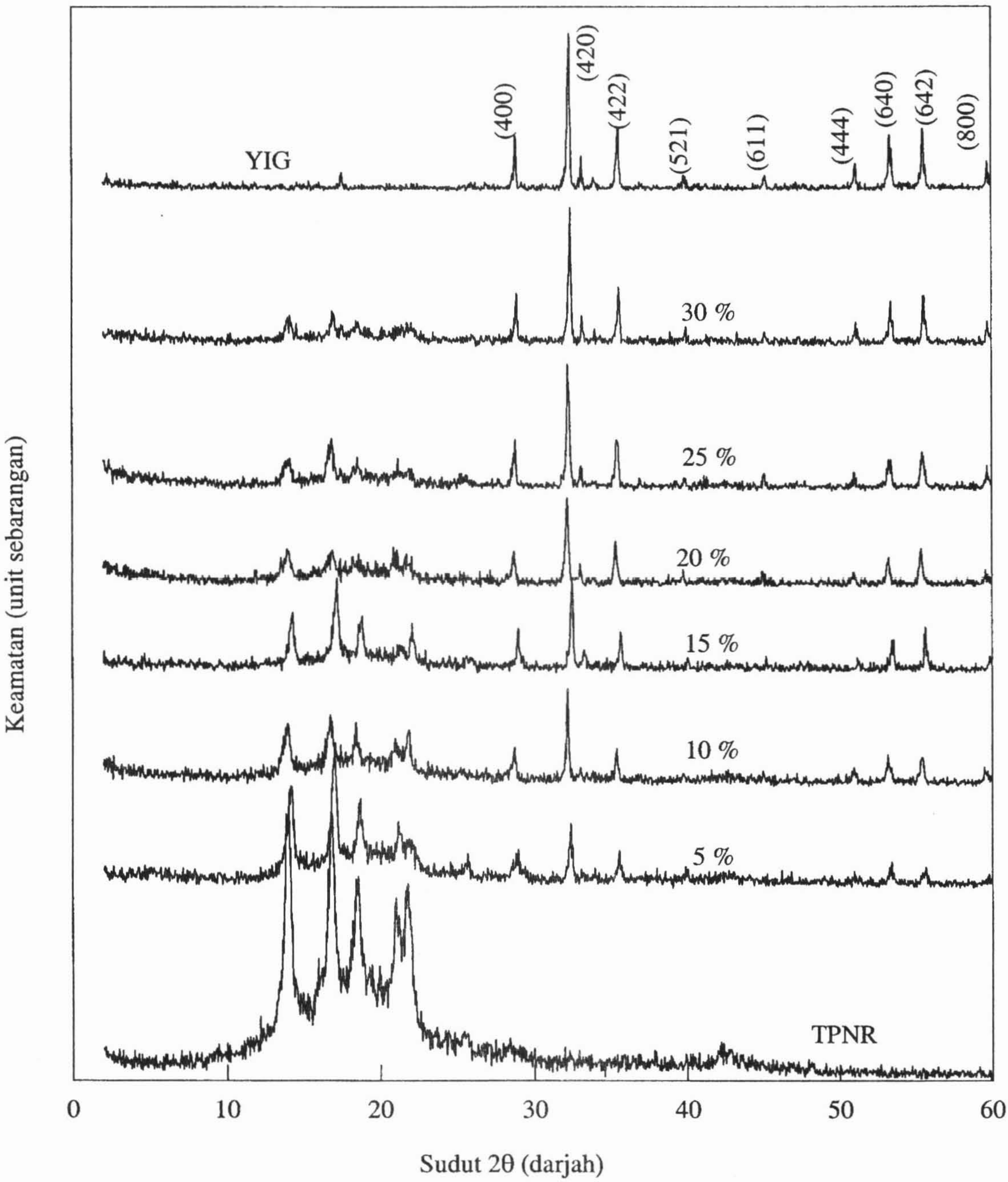

Figure 1 X-ray diffractogram at room temperature for the pure YIG ferrite, PP/NR matrix and the composite of PP70NR30 that contain 5 to 30 weight percent of YIG ferrite filler.

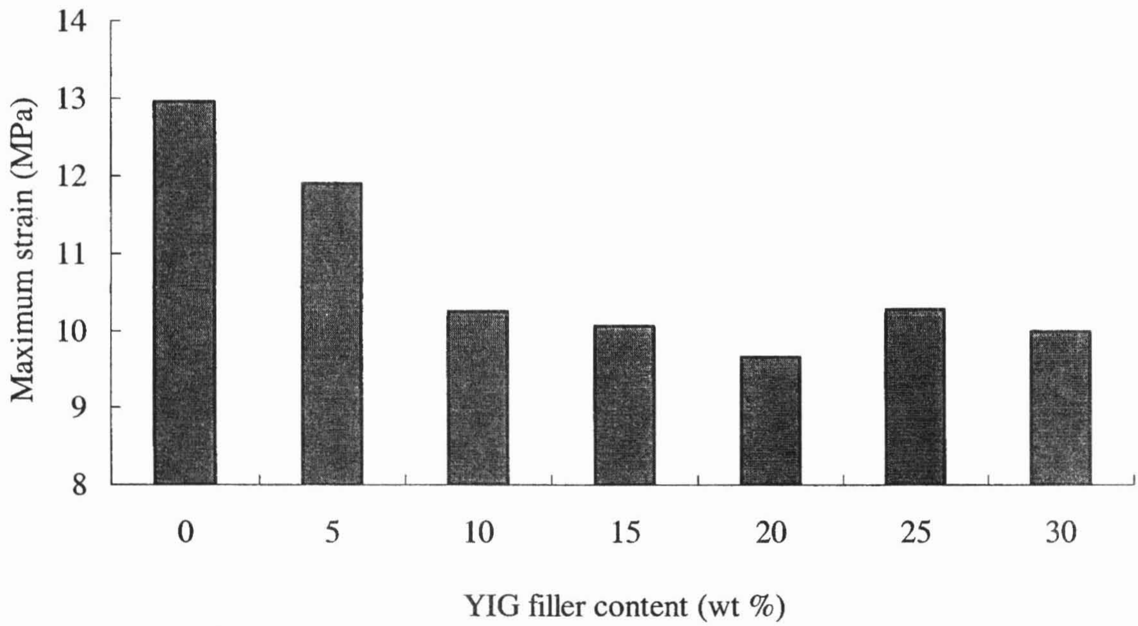

Figure 2 The variation of maximum strain for all composites as a function of filler content

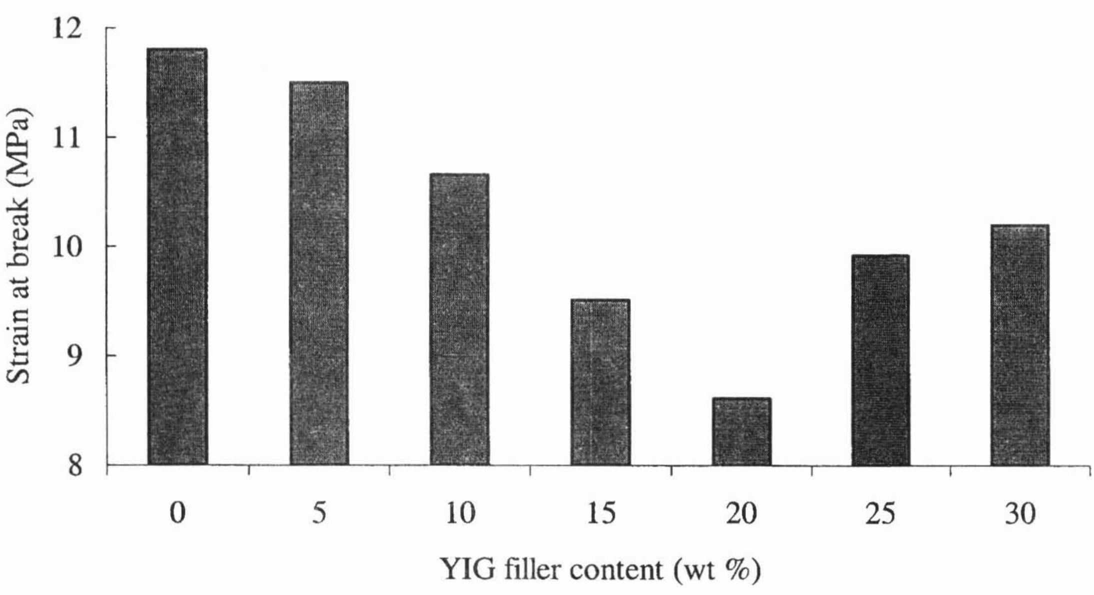

Figure 3 The variation of strain at break for all composites as a function of filler content

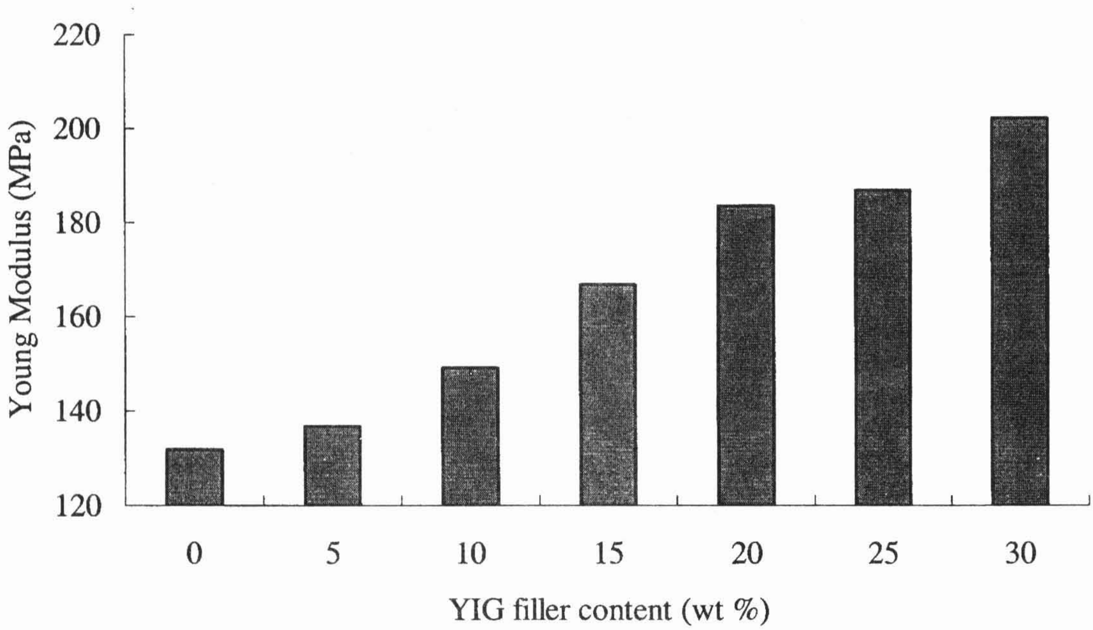

Figure 4 The variation of young modulus for all composites as a function of filler content