JOURNAL OF MATERIALS SCIENCE **40** (2005) 4391 – 4393 LETTERS

Flexural and tribological properties of polyester-clay nanocomposites

P. JAWAHAR
Composites Technology Center, Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Madras, Chennai – 600036, India

R. GNANAMOORTHY
Department of Mechanical Engineering, Indian Institute of Technology, Madras, Chennai – 600036, India

M. BALASUBRAMANIAN*
Composites Technology Center, Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Madras, Chennai – 600036, India
E-mail: mbala@iitm.ac.in

Polymer nanocomposites have received considerable attention since the discovery that polymer properties can be greatly improved by the presence of nanosized particles. Polymer-layered silicate nanocomposites show high stiffness, strength and excellent barrier properties with far less filler content compared to conventionally glass or mineral filled polymers [1–3]. Unsaturated polyester is a thermosetting polymeric material, widely used because of its good mechanical and thermal properties. The nanoclay reinforcement influences the tensile and fracture toughness of the polyester nanocomposites [4]. In this work, the flexural and tribological behavior of composites has been studied for the clay content of 1 wt.%.

Inorganic bentonite clay (Emerck India Pvt Ltd.) was sodium activated. It is modified with dodecylamine (SRL Pvt Ltd., Bombay, India) according to the method reported elsewhere [5] to obtain organo modified clay. Isopthalic a polyester resin (Vasavibala resins Pvt Ltd, Chennai, India) was mechanically mixed with 1 wt.% organically modified clay. Catalyst and accelerator was added to effect curing reaction. Conventionally clay-filled composites were prepared using inorganic clay as the filler. Change in interlayer spacing of clay was studied by X-ray diffractometer (SHIMADZU XD-DI) at a scanning rate of 2°/min with Cu-Kα radiation. Flexural and tribological performance of nanocomposites, conventional clay-filled composites and pristine polyester was evaluated. Three-point flexural tests were conducted at room temperature using Instron 4301 UTM at a crosshead speed of 5 mm/min. Three samples were tested for each batch, and the average values were reported. The specific wear rate as reported by Wetzl *et al.* [6] and coefficient of friction of pristine polyester, conventional composite and nanocomposite were found by conducting pin on disc wear testing (pin on disc tribometer, locally fabricated according to ASTM G-99). Two pins of 8 mm diameter were tested at constant pressure of 0.5 MPa and sliding velocity of 0.5 m/s for the sliding distance of 3600 m. The disc used is EN31 (tool steel) of surface roughness 1 μm. Wear surfaces were observed using scanning electron microscope (JEOL JSM–840 A).

TABLE I Flexural properties of composites

Property	Pristine Polyester	Conventional clay-filled composite	Nanocomposite
Flexural strength[a] (MPa)	101	102	108
Flexural modulus[a] (GPa)	2.8	2.9	3.5

[a] Variation with in 10%.

X-ray diffraction patterns of inorganic clay and organo modified clay show peak at 6.98° and 5° and the corresponding intergallery spacing is 12.63 and 17.7 Å, respectively (Fig. 1). Composites containing inorganic clay do not show any significant change in intergallery spacing. The inorganic clay just remains as microtactoids and forms conventionally filled composites. But there is no peak in the composites containing organo clay and this indicates that clay platelets are dispersed uniformly throughout the polyester matrix and confirms the formation of exfoliated nanocomposites.

Nanocomposite has better flexural strength and flexural modulus compared to conventional clay-filled composite and pristine polyester (Table I). The uniformly distributed nanosize clay platelets throughout the matrix effectively reinforce the matrix and act as crack arrestor by increasing the mean effective path of the crack to propagate.

Nanocomposites show better tribological performance. The specific wear rate and coefficient of friction are found to be significantly less compared to conventionally clay-filled composite and pristine polyester (Table II). SEM photographs also show deep wear out surfaces on both pristine polyester and conventionally clay-filled composite (Figs 2 and 3), whereas the surface of nanocomposite is smooth with very fine scratches (Fig. 4). The hard and nanoscale clay platelets

---

*Author to whom all correspondence should be addressed.

0022–2461

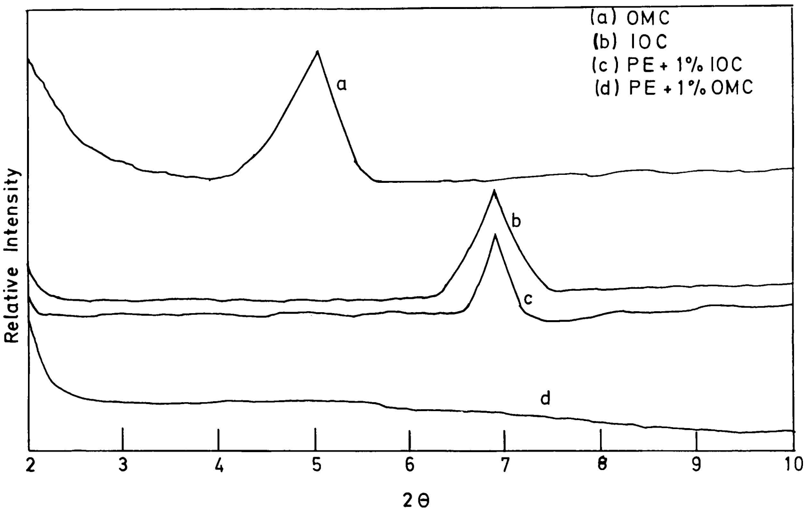

Figure 1 X-ray diffraction pattern of (a) organo modified clay, (b) inorganic clay, (c) conventional clay filled composite and (d) nanocomposite.

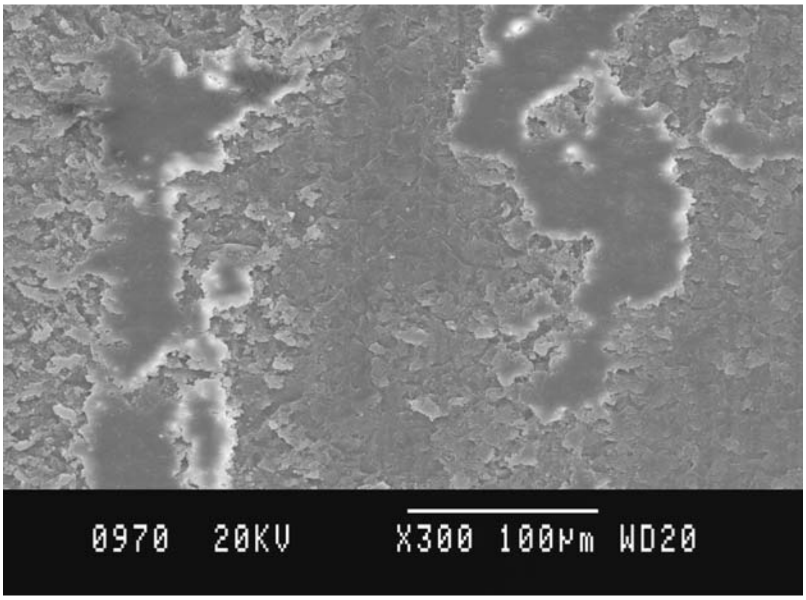

Figure 2 Wear surface of pristine polyester.

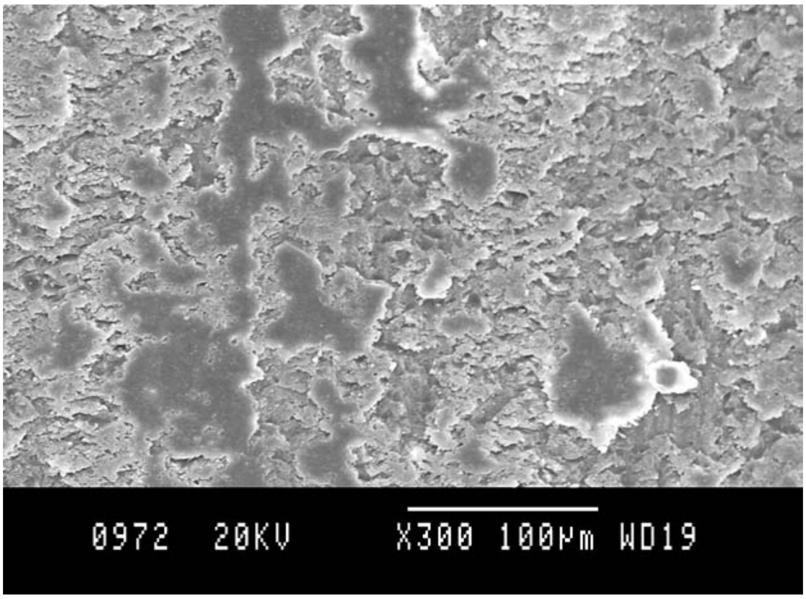

Figure 3 Wear surface of conventionally clay filled composite.

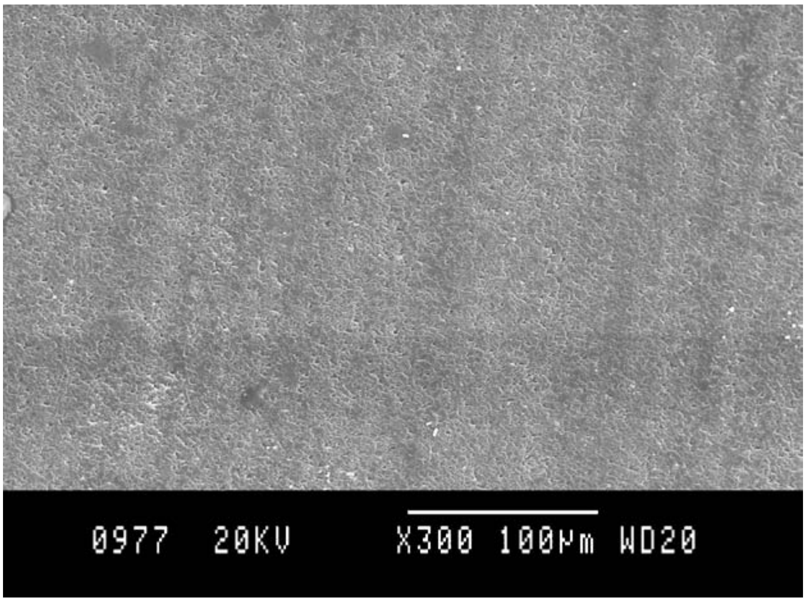

Figure 4 Wear surface of nanocomposite.

of organic clay in the matrix restrict the material removal. Organic modification of the clay and the large surface area of the nanoscale clay platelets lead to better bending with the polyester matrix. In the conventional clay-filled composite, the inorganic clay remains as microtactoid in polymer matrix. So, it is removed easily and also paves the way for additional material removal. Pristine polyester, being the soft material, is easily removed by the frictional force.

TABLE II Tribological properties of composites

Property	Pristine polyester	Conventional clay-filled composite	Nanocomposite
Specific wear rate[a] (X 10^{-6} mm^3/Nm)	0.458	0.449	0.066
Coefficient of friction[a]	0.45	0.44	0.1438

[a] Variation with in 5%.

In conclusion, the nanocomposites possess good flexural and tribological properties. The wear resistance of polyester is improved up to 85% by the addition of organically modified clay. The nanocomposite shows 20% improvement in flexural modulus than pristine polyester.

References

1. Y. KOJIMA, A. USUKI, M. KAWASUMI, Y. FUKUSHIMA, A. OKADA, T. KURAUCHI and O. KAMIGAITO, *J. Mater. Res.* **8** (1993) 1179.
2. *Idem.*, *ibid.* **8** (1993) 1185.
3. E. P. GIANNELIS, *Adv. Mater.* **8** (1996) 29.
4. X. KORNMANN, L. A. BERGLUND, J. STERTE and E. P. GIANNELIS, *Polym. Eng. Sci.* **38** (1998) 1351.
5. R. MAHARAPHAN, W. LILAYUTHALERT, A. SIRIVAT and J. W. SCHWANK, *Compos. Sci. Technol.* **61** (2001) 1253.
6. B. WETZL, F. HAUPERT and M. Q. ZHANG, *ibid.* **63** (2003) 2055.

Received 9 September 2004
and accepted 22 February 2005