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Short Communication

Novel Quantitative Nanomechanical Property Mapping and In-Situ SPM Imaging of Polyetherimide Nanocomposite Materials

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Abstract

Determination of mechanical properties of modern nanocomposite materials through conventional macroscale test methods is always challenging and questionable. Nanoparticles interact with polymer molecules at a micron to nanoscale, and hence to precisely determine the properties of these composites, micron level test methods such as nanoindentation need to be utilized. In this work, we have used the nanoindentation techniques combined with a recently developed novel Accelerated Property Mapping (XPM) technique to study the statistical quantification of mechanical properties such as hardness and modulus, and the variance of these properties across the phases of Polyetherimide (PEI) nanocomposites reinforced with Zinc titanate ($ZnTiO_3$) nanoparticles.

Keywords: Zinc titanate; Polyetherimide; Nanoindentation; XPM

Materials, Processing and Characterization

PEI is a high-performance thermoplastic polymer with excellent mechanical and tribological properties even at elevated temperature due to its high glass transition temperature [1]. In this study, PEI pellets with a melt index of 18g/10min (337°C) and density of 1.27g/mL at 25°C purchased from Sigma-Aldrich was used. Zinc titanate (ZnTiO3) nano powder with a molecular weight of 161.26g/mol and a <100nm particle size (BET), 99% trace metals basis and along with N, N-Dimethylacetamide also purchased from Sigma-Aldrich were used.

At first, 15gm of PEI pellets were mixed with 100ml of N, N-Dimethylacetamide (1000 rpm at 150°C) for three hours until all the pellets were completely dissolved. The solution was then poured in Aluminum pans and placed on the hot plate for curing at 140°C for 72 hours. Finally, the samples were removed and carefully polished using alumina suspension and mounted on a circular metallic puck of 13mm in diameter using a cyanoacrylate glue.

Quantitative mapping of hardness and modulus were determined by Accelerated Property Mapping (XPM) technique using Hysitron TI-980 Tribonanoindenter with a diamond Berkovich tip. XPM is a recently developed technique through which the distribution of mechanical properties along the phases of material at nano level can be determined and mapped [2-3]. To acquire the XPM maps, a constant force of 200μN with an indent spacing of 1000nm was used over a 20x20μm area. Several tests were carried out with 100 indents in each test for quantitative hardness and modulus maps. The EDS spectrum was acquired using Field Emission Scanning Electron Microscope (JSM-7200F) equipped with Energy Dispersive X-Ray Analyzer, EX-37001.

Results

The hardness maps of PEI neat and 5 wt. % samples showed an average value of 0.48 GPa (Figure 1c) and 0.55GPa (Figure 2c), respectively. A significant increase of 14.59% was found in 5 wt. % PEI samples compared to its neat counterpart. Similarly, the modulus map of 5 wt. % PEI/ZnTiO3 showed 6.38GPa in comparison to 5.64GPa observed in neat PEI samples with an improvement of 13.12% in modulus. The EDS spectrum of PEI-$ZnTiO_3$ nanocomposites shows the elemental composition of PEI/$ZnTiO_3$ and the presence of $ZnTiO_3$ nanoparticles in the PEI polymer (Figure 1b). Similar results were also reported by Yildiz, K et al., [4] (Figure 1& 2).

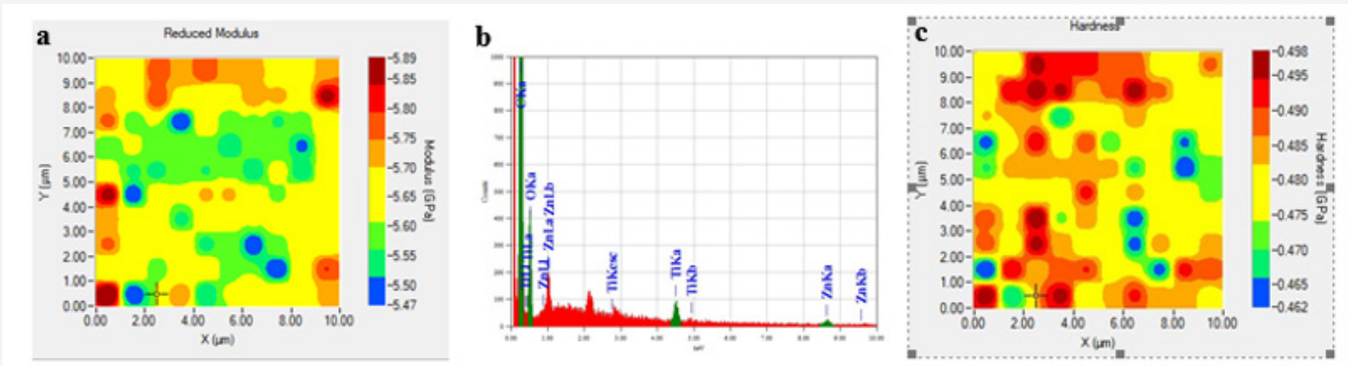

Figure 1: Images showing, a) modulus of a neat sample, b) EDS Spectrum of PEI- ZnTiO3, and c) hardness of neat sample.

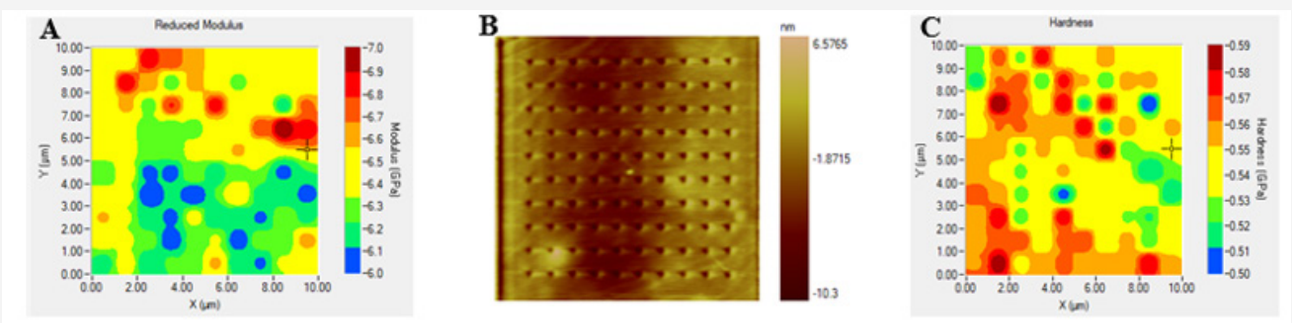

Figure 2: Images showing, A) modulus of a 5 wt. % sample, B) SPM of indents, and C) hardness of a 5% sample.

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Conflict of Interest

No conflict of interest.

References

1. Kumar S, Ratha T, Mahalinga RN, Reddy CS, Das CK, et al. (2007) Study on mechanical, morphological and electrical properties of carbon nanofiber/polyetherimide composites. Materials Science and Engineering: B, 141(1-2): 61-70.
2. Hintsala ED, Hangen U, Stauffer DD (2018) High-Throughput Nanoindentation for Statistical and Spatial Property Determination. JOM 70(4): 494-503.
3. Li D (2015) FASTMAP: High Speed Nanoindentation Mapping.
4. Yildiz K, N Karaku, N Toplan, HÖ Toplan (2007) Densification and grain growth of TiO2-doped ZnO. Materials Science-Poland 25(4).