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Effects of single and binary fillers of hexagonal boron nitride in polyurethane foam

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Abstract
Adding nano fillers is an effective way to enhance the mechanical behaviour of polymer materials. Polyurethane (PU) foams are used widely in various applications due to their low density, however, they have poor mechanical properties. In this study, modified hexagonal boron nitride (h-BN) in combination with Multi-walled carbon nanotubes (MWCNTs) and graphene nanoplatelets (GNPs) were added to PU matrix both singly and binary to study their effect on mechanical properties. We demonstrated that even with small amount of fillers (%0.25 wt) there is an increase in tensile strength by 28% with annealed hBN.

Polyurethene, hybrid nanocomposites, boron nitride, carbon nanotubes

1. Introduction

Polyurethane foams, which are economic due to their low density, are frequently used in a widespread range of applications, such as insulation goals, automotive and electronic industries. However, their applications are limited because of their poor mechanical properties. It seems attractive to modify PUs using nanoparticles to modify their mechanical properties [1-6]. h-BN possess high mechanical, physical, and thermal properties, having a wide band gap (electrical insulator) and better thermal stability due to high phonon effect [7-9]. Nanocarbon fillers such as MWCNT and GNP owing to their lightweight, high thermal conductivity and high aspect ratio are receiving significant attention. Improving the mechanical and thermal properties of PU could be achieved by structuring a proper 3D network in the polymere matrice via the mentioned nanofillers [10]. An effective approach for improving dispersion states of nanofiller can be hybrid inclusion of them in polyurethane matrix to further enhance mechanical properties.

2. Experimental

PU is thermoset polymer obtaining via mixing its two components; polyol and isocyanate in a certain weight ratio (1:1.2, respectively; as supplyer suggestion). Nanofillers were added to the matrix during the polymerization process.

2.1. Materials

The hBN that is used as nanofiller has a 790 nm dimension with purity of 99.7% . MWCNTs have an average diameter of 8–10 nm, the length of 1–3 µm and purity of more than 92%. GNPs have 1.5 µm diameter and 3 nm thickness with purity of 99.9%.

2.2. Modification of nanofillers

Nano materials generally need to be modified before mixing with polymer in order to prevent agglomeration and well-dispersing throught the matrice. MWCNTs were functionalized with hydrogene peroxide (H_2O_2) as reported elswere [11]. hBN were surface-modified in order to attach hydroxide groups onto BN surfaces and obtain hydroxylatd BN (BN-OH). This modofocataion were done with three different methods to compare the effectivity of them. In first method, the modification were done with H_2O_2 in the way were accomplished for MWCNTs (H-hBN). In second method, a 5M sodium hydroxide (NaOH) solution was used to introduce OH groups to BN surface (N-hBN). In third method, hBN were placed in a furnace and heated up to 1000 °C and waited for 2 hours as done elsewere (A-hBN) [12]. After each of modification processes, the obtained modified hBN rinsed with DI water and filtered with vacuum filtering for several times to ensure that no chemicals remained on the surface of hBN. After that, hBNs were dryed in a 70 °C vacuum furnace. GNPs were not modified as it was not needed [10].

2.3. Preparation of nanocomposites

As shown in Fig. 1 firstly, nanofillers were dispersed in polyol in three stages. In first stage nanofillers were mixed with polyol mechanically for 5 minutes; then the mixture was placed in ultrasonic bath for another 5 minutes and then mechanically stirred for 5 minutes again. After dispersion of nanofillers in polyol, isocyanate was added and the mixture poured into a mold and left to cure. The amount of the nanofillers in both singular and binary mixtures was fixed at 0.25% wt. The obtained nanocomposites then were cut to extract tensile test specimens.

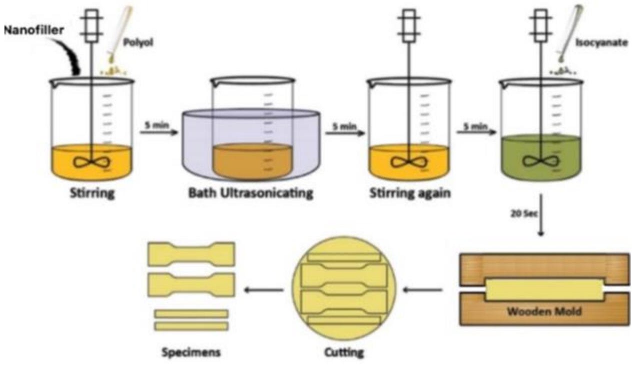

Figure 1. The scheme of the nanocomposites fabrication steps.

2.4. Characterization and instruments

The specimens were cut in a CNC machine according to ISO 1926 for tensile tests of rigid cellular plastics. Tensile properties were performed on at least five samples of each nanocomposite using Shimadzu, UTS machine equipped with a 1 kN load cell under a strain rate of 5 mm/min at room temperature [11].

3. Results and discussion

The results obtained from tensile tests are shown in Fig. 2. Note that hBN, H-hBN, N-hBN and A-hBN stand for unmodified, H_2O_2 modified, NaOH modified and Annealing modified hBN respectively. As could be seen from the results, all of the fillers have a positive impact on the tensile strength of PU.

Amoung the singular hBN composites, Annealed hBN demonstrated the best result showing that the annealing modification had better effect than NaOH and H_2O_2. This was also visible during the washing process in DI water that the annealed hBN was the most dispersed one and almost no precipitation happened. Although, the annealing process had the least yield than others as some of the hBN was oxidized or broke apart in high temperatures and passed through the filteration membrane with porous size of 450 nm. After annealed hBN, NaOH modified hBN follows it with higher results. Again NaOH modification showed good dispersability in DI water. H_2O_2 modification showed no improvement in results as it was near the unmodified hBN composite. The composites of GNP and CNT showed similar results to unmodified hBN.

For binary composites, it could be clearly seen that no synergic effect happened between the fillers as there is no increase in comparison to singular ones. The result with MWCNT and H_2O_2 modified hBN was slightly higher as both of them were modified with hydrogen peroxide.

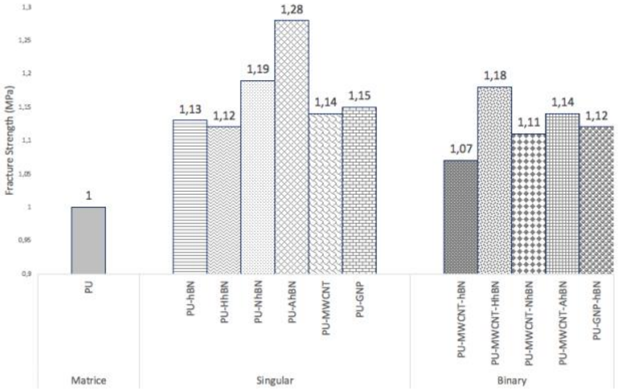

Figure 2. Tensile strength of the nanocomposites.

4. Conclusion

Effect of adding of hexagonal boron nitride to polyurethane in both singular and binary with MWCNT and GNP were investigated. In order to examine the effectivity of different surface modification methods of hBN, three methods were tested and the results were compared with unmodified hBN. The annealed hBN had the best result with 28% improvement amoung the singular hBN fillers. Althogh its modification method had the least yield ratio than the others. NaOH modified hBN was the following with 19% improvement. The result of the H_2O_2 modified hBN was similar to the unmodified hBN showing the less effectivity of modification. Pure hBN results was similar to the MWCNT and GNP fillers showing 12-15% improvement. The binary systems showed that there is no synergic effect between the fillers as the result was not higher than singular ones. A slight increase in MWCNT and H_2O_2 modified hBN could be relevent to same modification method of the fillers.

References

[1] Yan D, Xu L, Chen C, Tang J, Ji X, Li Z. Enhanced mechanical and thermal properties of rigid polyurethane foam composites containing graphene nanosheets and carbon nanotubes. Polym Int 2012;61(7):1107–14.

[2] Navidfar A, Sancak A, Yildirim KB, Trabzon L. A study on polyurethane hybrid nanocomposite foams reinforced with multiwalled carbon nanotubes and silica nanoparticles. Polym Plast Technol Eng 2018;57(14):1463–73.

[3] Yıldırım B, Sancak A, Navidfar A, Trabzon L, Orfali W. Acoustic properties of polyurethane compositions enhanced with multi-walled carbon nanotubes and silica nanoparticles. Mater Werkst 2018;49(8):978–85.

[4] Ghavidel, A. K., Azdast, T., Shabgard, M., Navidfar, A., & Sadighikia, S. (2015). Improving electrical conductivity of poly methyl methacrylate by utilization of carbon nanotube and CO2 laser. Journal of applied polymer science, 132(42).

[5] Ghavidel AK, Azdast T, Shabgard MR, Navidfar A, Shishavan SM. Effect of carbon nanotubes on laser cutting of multi-walled carbon nanotubes/poly methyl methacrylate nanocomposites. Opt Laser Technol 2015;67:119–24.

[6] Karimzad Ghavidel, A., Navidfar, A., Shabgard, M., & Azdast, T. (2016). Role of CO2 laser cutting conditions on anisotropic properties of nanocomposite contain carbon nanotubes. Journal of Laser Applications, 28(3), 032006.

[7] Fang, H., Bai, S. L., & Wong, C. P. (2016). "White graphene"–hexagonal boron nitride based polymeric composites and their application in thermal management. Composites Communications, 2, 19-24.

[8] Pakdel, A., Bando, Y., & Golberg, D. (2014). Nano boron nitride flatland. Chemical Society Reviews, 43(3), 934-959.

[9] Zhang, K., Feng, Y., Wang, F., Yang, Z., & Wang, J. (2017). Two dimensional hexagonal boron nitride (2D-hBN): synthesis, properties and applications. Journal of Materials Chemistry C, 5(46), 11992-12022.

[10] Navidfar, A., & Trabzon, L. (2021). Analytical modeling and experimentally optimizing synergistic effect on thermal conductivity enhancement of polyurethane nanocomposites with hybrid carbon nanofillers. Polymer Composites, 42(2), 944-954.

[11] Navidfar, A., & Trabzon, L. (2019). Graphene type dependence of carbon nanotubes/graphene nanoplatelets polyurethane hybrid nanocomposites: Micromechanical modeling and mechanical properties. Composites Part B: Engineering, 176, 107337.

[12] Zhang, Y., Gao, W., Li, Y., Zhao, D., & Yin, H. (2019). Hybrid fillers of hexagonal and cubic boron nitride in epoxy composites for thermal management applications. RSC Advances, 9(13), 7388-7399.