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Synthesis and Characterization of Polymer Matrix Nanocomposite for Implants

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Abstract: Titanium-di-Oxide nanoparticles (TiO_2) and Hydoxyapaptite nanoparticles (HAp) were synthesized in bulk by adopting simple wet chemical methods and the same were utilized as filler materials in developing polyurethane based nanocomposite. The nanoparticles were dispersed in a polyurethane resin prepared using commercially available polyols, isocyanate and other additives to obtain a polymer matrix nanocomposite. The nanoparticles were dispersed in the polyurethane resin prepared to obtain a nanocomposite which was further analyzed by FTIR and Tensometer characterizations. The characterizations indicated that the nanocomposite prepared had good structural and tensile properties.
Key words: Titanium-di-Oxide, Hydroxyapatite, polyurethane, polymer matrix nanocomposite.

1. Introduction and Experimental

Polymer matrix nanocomposites in the domain of Biomedical Engineering and Implant Science & Engineering demands exceptional physical and chemical properties along with their biocompatibility property. There have been a lot of suggestions from research scholars and groups around the world about preferring ceramic, alumina and other oxides of nanoparticles[1] but their hardness, stiffness and their ability to induce a suitable surface for both blood contact and tissue contact applications are still at bay. The other remarkable work in the field of material designing for biomedical/mechanical purpose is the introduction of biocompatible foam or sponge structures [2]. It has been proved that the structure with pores can be a good material for various applications such as drug delivery, fluid filtrations, cell adhesions etc. This paper is about the research work carried out by a team to explore and reengineer polyurethane based nanocomposite coatings and materials. In this work two fundamental concepts namely inducing pores and inducing stiffness by adding nanoparticles is focused. The nanoparticles preferred for this research were titanium di oxide and hydroxyapatite while the matrix material preferred is polyurethane. All the three materials possess excellent biocompatible property but they lack a little precision in certain challenging applications [4]. Hence the key aim was to bring all the above mentioned nanoparticles and the polymer together and find a perfect combination that could be used as coatings as well as solid blocks. From the earlier trials it was found that the composite with 45% titanium di oxide nanoparticles, 25% hydroxyapatite and 30% polyurethane by mass proved to be the best candidate with good mechanical properties as a film and as a block.

Polyurethane resin synthesis

To obtain polyurethane resin the generalized and simple method [3] of; allowing a polyol to react with a diisocyanate in presence of a chain extender was followed. The polyol used was polytetramethyleneether glycol

(PTMEG) while the diisocyanate used was toluene diisocyanate. 1,4-butanediol and DABCO 1,4-diazabicyclo [2.2.2]octane was used as chain extender and hardener respectively. The reactions were carried out at laboratory temperature.All the chemicals and reagents used in the synthesis procedures were obtained from MERCK unless otherwise mentioned.

Nanocomposite preparation

The nanocomposites were prepared over a polystyrene substrate. Initially the TiO_2 nanoparticles synthesized by a two-step processwere introduced to the polyol PTMEG and mixed well at slightly elevated lab temperature but not more than 40^0C to obtain Mixture A. While the HAp nanoparticles synthesized by a solgel method were added to the diisocyante and mixed well at normal temperature to obtain Mixture B. The addition of TiO_2 will give a good white color to the polyol while HAp adds a mild dirt white color to the diisocyanate. The nanoparticles are mixed with their respective reagents only prior 15 to 25 minutes to the beginning of the entire synthesis. This entire reaction is carried out on a rectangular substrate which is well placed above a dry ice platform. Mixture A is added to Mixture Bslowly assisted by a gentle stirring. Once the addition process is over the dry ice platform is removed and very little DABCO is added. This hardener hardens the entire mixture in the substrate within 3 hours to yield us a solid polyurethane foam block with nanoparticles embedded within its structures.

2. Results and Discussions

2.1 FTIR analysis

FTIR analyses revealed that there exists an overall activation of the bonds (stretching and bending) throughout the surface. From Figure.1, the distribution of Ca, P – Hydroxyapatite and TiO_2 nanoparticles had taken place and these nanoparticles have bonded with the O-H and C-O effectively. Considering the overall result it can be concluded that the composite has an excellent surface activation which is important for the biocompatible polymers. Apart from this the nanocomposite should also possess shape memory and excellent tensile property.

2.2Tensometer Analysis

To measure the tensile strength of the nanocomposite, a specimen was prepared as described in ASTM D3039 and subjected to test and the testing methods as mentioned in ASTM standard was followed. The graph, Figure.2,showed the way the specimen underwent tortures periodically till 17.6N. During the entire procedure the specimen expanded as much as nearly more than twice the original length. From the tensometer analysis it was evident that the material had the desirable tensile strength of 3.5 N/mm Sq.

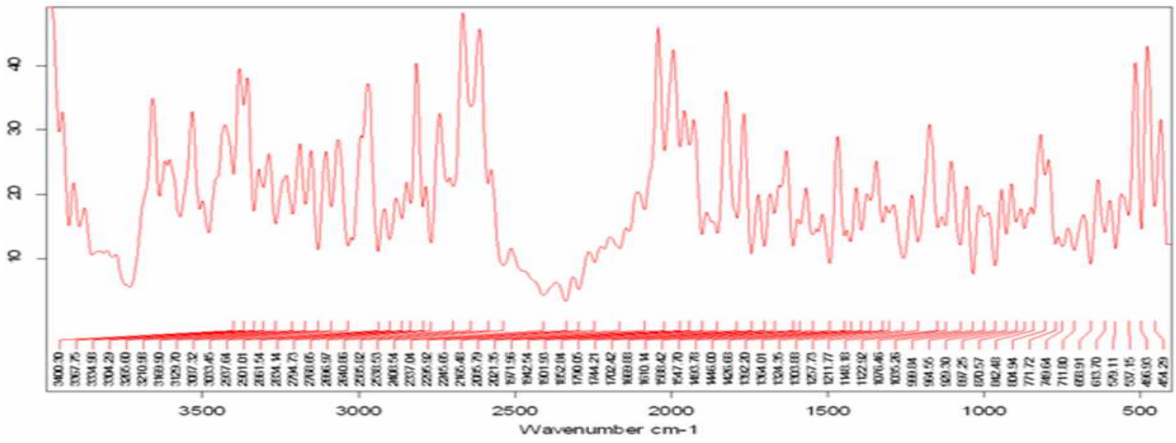

Figure.1: FTIR graph obtained for the nanocomposite film

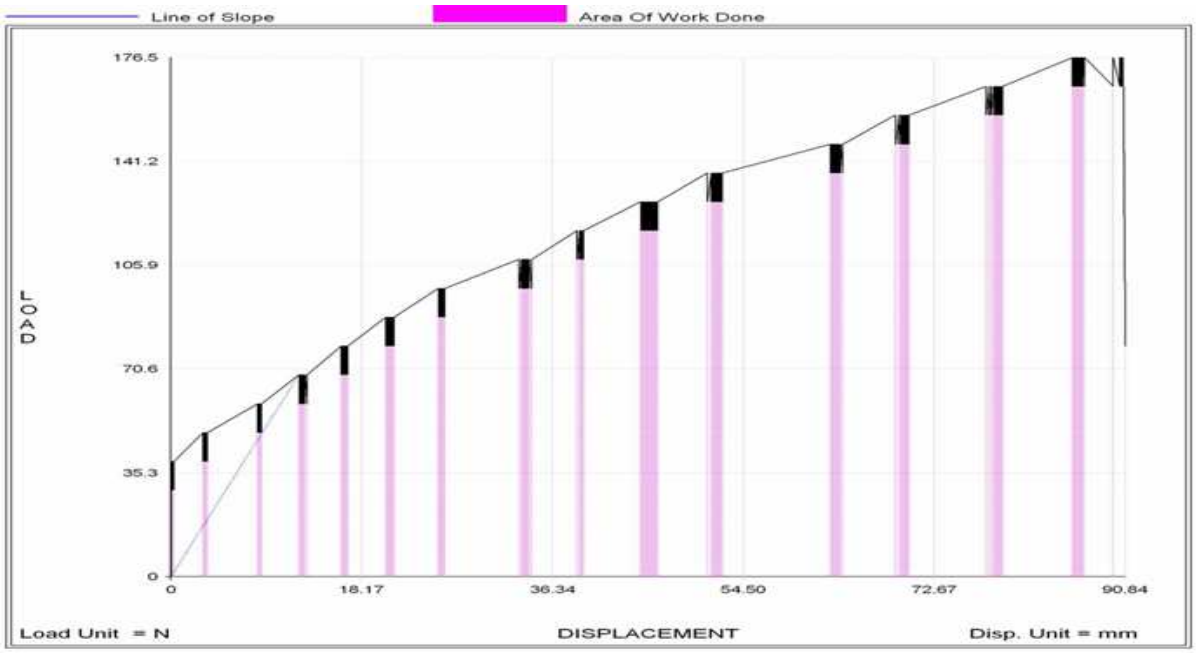

Figure.2: Tensometer graph displaying the tensile property of the nanocomposite material.

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