

Philosophy and Methodology of Developing Nanocomposite

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Abstract: In this paper, one of the grand challenges to sustain the modern society is to secure adequate water resources of desirable quality for various designated uses. To address this challenge, membrane water treatment is expected to play an increasingly important role in areas such as drinking water treatment, brackish and seawater desalination, and wastewater treatment and reuse. Nanocomposite solvent resistant (NCSR) membranes were developed and utilized for separation of organic biodiesel rich phase. The modified membranes were fabricated via non solvent induced phase separation by addition of different concentrations of functionalized multiwall carbon nanotubes (MWCNTs) in the polyimide (PI) casting solution.

Keywords: Philosophy, Nanocomposite, Developing, Methodology.

I. INTRODUCTION

Low patency rate of currently available vascular bypass grafts, researchers are working towards the development of alternative bypass grafts, ranging from synthetic prostheses to wholly biologic living grafts. The philosophy of measurement required by regulatory agencies such as the United States Food and Drug Administration (FDA) as well as to gain the Conformité Européene (CE) mark is to test above and beyond the limits that would be expected physiologically. The critical parameter of burst pressure is needed for Conformité Européene (CE) mark or United States Food and Drug Administration (FDA) approval before clinical trials can proceed. An accurate measurement of burst pressure in potential porous vascular bypass grafts is, therefore, of utmost importance to ensure adequate strength on implantation in animals and subsequent clinical use. A wide range of methods to measure burst pressure have been used. We tested the burst pressure of a new polyurethane-based nanocomposite vascular prosthesis by using different methods to assess whether the method used affected the results [1].

As defined by Park & Lakes (2007), a biomaterial is a material that replaces either a tissue within the body or a function of the body. The development of novel biomaterials is an iterative process that involves the creation of increasingly safer, more reliable, more inexpensive and more physiologically appropriate replacements for damaged or diseased human tissues. In their article entitled 'Third-generation biomedical materials', Hench & Polak (2002) described three generations of biomaterials that had been developed to that point. In the first generation of biomaterial development, individuals used materials in their local environments for replacing tissues that were lost to damage or disease. Several early civilizations used synthetic materials for treatment of skeletal defects; for example, Black et al. (1982) described the use of metallic implants by ancient Egyptian and Etruscan civilizations for fixation of fractures, as well as for treatment of other skeletal injuries. Rodriguez et al. (2007) noted that a skull was found in

Perú dating to 2000 BC, in which a bony defect had been treated using a thin gold plate. According to Park & Bronzino (2003), rapid developments in the use of biomaterials took place shortly after Lister (1867) described the aseptic surgical technique in his thesis 'On the antiseptic principle in the practice of surgery'. Prior to that time, the absence of effective mechanisms to prevent infection at the surgical site severely limited the use of medical implants. In the late nineteenth century, several surgeons experimented with the use of metallic and natural biomaterials for the treatment of skeletal defects [2].

Nanotechnology is a fast-growing area, involving the fabrication and use of nano-sized materials and devices. Various nanocomposite materials play a number of important roles in modern science and technology. Magnetic and fluorescent inorganic nanoparticles are of particular importance due to their broad range of potential applications. It is expected that the combination of magnetic and fluorescent properties in one nanocomposite would enable the engineering of unique multifunctional nanoscale devices, which could be manipulated using external magnetic fields. The aim of this review is to present an overview of bimodal "two-in-one" magnetic-fluorescent nanocomposite materials which combine both magnetic and fluorescent properties in one entity, in particular those with potential applications in biotechnology and nanomedicine. There is a great necessity for the development of these multifunctional nanocomposites, but there are some difficulties and challenges to overcome in their fabrication such as quenching of the fluorescent entity by the magnetic core. Fluorescent-magnetic nanocomposites include a variety of materials including silica-based, dye-functionalised magnetic nanoparticles and quantum dots-magnetic nanoparticle composites.

II. CONVENTIONAL NANOCOMPOSITE

In the conventional nanocomposite membranes, nanofillers fall into one of the four categories inorganic material; organic material; biomaterial, and hybrid

material with two or more material types. Fabrication of nanocomposite membranes is mostly based on phase inversion (PI) method in which nanofillers are dispersed in polymer solution prior to the PI process, and can be prepared in either flat sheet or hollow fiber configurations. This type of membrane is mainly used in microfiltration (MF) or ultra filtration (UF) processes due to its typical porous structure figure 1.

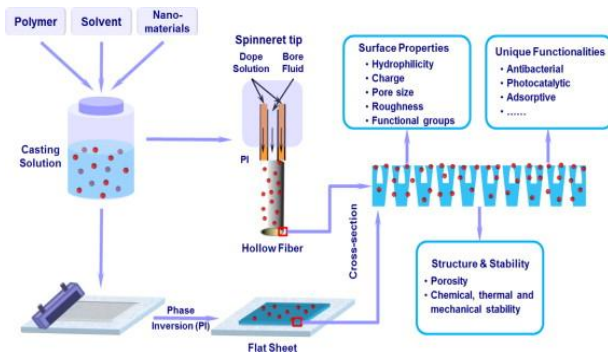


Figure 1: Fabrication of conventional nanocomposite

Piezoresistivity in conductive polymer nanocomposites occurs because of the disturbance of particle networks in the polymer matrix. The piezoresistance effect becomes more prominent if the matrix material is compliant making these materials attractive for applications that require flexible force and displacement sensors such as e-textiles and biomechanical measurement devices. However, the exact mechanisms of piezoresistivity including the relationship between the matrix polymer, conductive particle, internal structure and the composite's piezoresistance need to be better understood before it can be applied for such applications. The objective of this thesis is to report on the development of conductive polymer nanocomposites for use as flexible sensors and electrodes. Electrically conductive and piezoresistive nanocomposites were fabricated by a scalable melt compounding process. Particular attention was given to elucidating the role of matrix and filler materials, plastic deformation and porosity on the electrical conduction and piezoresistance. These effects were parametrically investigated through characterizing the morphology, electrical properties, rheological properties, and piezoresistivity of the polymer nanocomposites. The electrical and rheological behavior of the nanocomposites was modeled by the percolation-power law. Furthermore, a model was developed to describe the piezoresistance behavior during plastic deformation in relation to the stress and filler concentration [3].

III. NANOCOMPOSITE SYNTHESIS

Transesterification is the most commonly used method to produce biodiesel which is achieved by reaction of a triglyceride molecule with alcohol in the presence of a catalyst. Among different kinds of catalyst, bases as the homogenous catalysts are commercially used most frequently to produce biodiesel which results in a relatively short reaction time. The reversible nature of the transesterification shows that the reaction needs excess

methanol to drive the equilibrium towards the products side. In this study, biodiesel was synthesized via transesterification of canola oil and 100% extra methanol in the presence of sodium hydroxide which was added with amount of 1 wt% of oil in the 1 L double neck flask equipped with thermometer, reflux condenser, and a magnetic stirrer. The transesterification was performed at the agitation speed of 1000 rpm and temperature of 60–65 °C for 2 h based on the optimum results of literatures. At atmospheric pressure, the methanol vapor was condensed by cooling water. At the end of reaction, the transesterification product was moved to a vacuum oven under 600 mmHg vacuum at around 65 °C for 30 min for removal of residual alcohol. After the evaporation of the alcohol, the mixture was placed in a separating funnel and left for 12 h for phase separation. The upper phase containing methyl esters was separated from glycerin rich phase. In order to reduce the alkalinity of the biodiesel rich phase, phosphoric acid was added to get pH 7. After the neutralization, the formed salt, potassium phosphate (Na₃PO₄), was removed from biodiesel rich phase with filter paper [4].

An Agilent Technologies 7890A gas chromatography (GC) system with a column from J&W Scientific and a model of 19091J-413 HP-5 with specification of 30 m×0.32 mm×0.25 μm film thickness was used to investigate the glycerol rejection in the permeate FAME samples from the nanofiltration process. Calibration curves for the GC were generated using two internal standards (butanetriol and tricaprin) and silylating agent (N-methyl-N-(trimethylsilyl)trifluoroacetamide (MSTFA)) according to the ASTM D6584-00 method.

IV. SYNTHESIS OF SILICA NANOPARTICLES

Due to its wide-range applications and excellent chemical performance, silica has attracted considerable interest in biomedical materials and surface modification science. Here, we developed a study on the preparation of silica nanoparticles with a size of 300 nm according to a modified Stöber method. Briefly, a mixture of solution A (4.0 mL of TEOS and 46 mL of ethanol) and solution B (9.0 mL of NH₄OH, 16 mL of ethanol, and 25 mL of distilled water) were used for the synthesis of silica nanoparticles. These two solutions were mixed by pouring the TEOS solution into the NH₄OH quickly with constant stirring (450 r/min) (of particularly note is to keep the TEOS away from the bottle wall). The onset of turbidity indicated the formation of nanoparticles. In recent years, there have been tremendous efforts in the synthesis of nanomaterials for their unique properties and applications different from their bulk counterparts. To incorporate multiple functionalities into one individual nanostructure is a challenging and interesting field in nanomaterial synthesis. Though various chemical routes have been developed to prepare core-shell nanocomposites, it is still believed that explorations of novel synthetic methodology and further engineering on shell structures will contribute new properties and applications to this field. This work focuses on the study of core-shell nanocomposites, aiming for producing complex nanostructures with process facility

and feature application performance. Self-assembly templating is the main approach throughout this thesis, though hard-templating method is involved in some part the study. Characterization and development of polymer nanocomposites filament wire for Fused Deposition Modelling (FDM) was investigated. The polycaprolactone (PCL) filled montmorillonite (MMT) and Hydroxyapatite (HA) composites were prepared by melting and compounding using a single screw extruder. The mechanical properties were assessed by tensile, flexural and Charpy impact tests while the thermal properties were studied via differential scanning calorimetry (DSC) and thermogravimetry analyzer (TGA). Simulated body fluid (SBF) test was used to assess the bioactivity properties of the composites. The filament wire with the diameter of 1.75 ± 0.05 mm were fabricated using a single screw extruder with die hole 1.6 mm in diameter. Design of experiment (DOE) software was used to find the optimum setting for the screw speed, roller speed and die temperature in order to achieve the specific diameter of the filament wire. The flexural strength, elastic modulus and flexural modulus of PCL/MMT blends increased with the decrement of tensile strength and impact strength [5]. Apparently, the inclusion of HA upon PCL/ MMT composite shows a slight improvement in elastic modulus, flexural modulus and flexural strength with reduction of impact strength. Addition of MMT and HA enhanced the thermal stability and the decomposition temperature of the composites. Formation of apatite crystals on the PCL/MMT/HA composites surfaces confirmed the occurrence of bioactive properties. Composites with 3 wt.% of MMT and 10 wt.% of HA were chosen as optimum composition in terms of strength and bioactive properties to be fabricated as filament wire for FDM process. Owing to the distinguishingly remarkable properties which Carbon Nanotubes have, there have been major strides towards the development of ever better Carbon Nanotube (CNT)-polymer nanocomposite structures. However, these nanocomposite structures are less completely understood and deliver somewhat inferior to their full reinforcement capabilities. This has been reasoned to be a result of the nano-scale effects such as improper bonding at the CNT- polymer interface which results in low interfacial strength. It has been recognized by many that the CNT-polymer interface characteristics play a major role in stress transfer across the interface. I.A.Guz et al.[1] have provided with reasons for the necessity in establishment of theoretical and computational models for studying the binding force between the nanotube and the polymer, and other interface characteristics.

V. CONCLUSION

Progress in the development of polymer-matrix nanocomposite membranes for water treatment has been tremendous in recent years. Besides tuning the physicochemical properties of membranes (hydrophilicity, porosity, charge density, thermal, and mechanical stability), the incorporation of nanomaterials can provide membranes with some unique properties of nanomaterials and also possibly induce new characteristics and functions based on their synergistic effects. Nanocomposite solvent

resistant PI membranes with a variety of MWCO in the range of ultra to nanofiltration were synthesized by different MWCNTs loadings via phase inversion method. These novel membranes were used for biodiesel purification prepared via transesterification reaction of canola oil by alkaline catalyst. The synthesized NCSR membranes showed excellent glycerol removal up to 100% glycerol rejection for M2 and M3 without significant decline in flux permeation.

REFERENCES

- [1] Croce, F., Appetecchi, G. B., Persi, L., & Scrosati, B. (1998). Nanocomposite polymer electrolytes for lithium batteries. *Nature*, 394(6692), 456-458.
- [2] Decher, G., & Schlenoff, J. B. (Eds.). (2006). *Multilayer thin films: sequential assembly of nanocomposite materials*. John Wiley & Sons.
- [3] Novak, B. M. (1993). Hybrid nanocomposite materials—between inorganic glasses and organic polymers. *Advanced Materials*, 5(6), 422-433.
- [4] Musil, J. (2000). Hard and superhard nanocomposite coatings. *Surface and coatings technology*, 125(1), 322-330.
- [5] Leyland, A., & Matthews, A. (2000). On the significance of the H/E ratio in wear control: a nanocomposite coating approach to optimised tribological behaviour. *Wear*, 246(1), 1-11.