Fabrication of Conductive Polyurethane by using Silica Nanoparticles

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***Abstract*—Plastic is a type of organic polymer material that can be shaped or molded as per the required applications. They are characterized by resistance to corrosion, electrical conductivity, malleability, colors, transparency, durability, and cost. One of the important parameter is electrical conductivity of plastic to weight ratio. By adding additives to plastics the electrical properties are manipulated as per application. This work reports the development of conducting polyurethane for electronic applications It includes synthesis of silica nanoparticles using sol-gel process and its characterization using microscopic, spectroscopic results and conductivity results.**

Keywords— Solvo-thermal method, conductivity, polyurethane, Silica Nanoparticles.

I. INTRODUCTION

Plastics are synthetic polymeric material, which are made of organic macromolecules by joining many monomers. Multi-dimensional structures are made out plastic. This includes single dimensional fibers, two dimensional surfaces of different thicknesses as sheets, three dimensional solid and hollow structures [1]. These polymeric materials are cost effective with excellent electrical insulation property, chemical property, good processability, toughness and flexibility [2]. Plastics are classified into two types i).Thermoplastics, ii).Thermosets. Thermoplastics can be easily recycled and reused when heated; it will become liquid without change in internal structure. Whereas the thermoset plastics will not be reformed due to changes in polymeric crosslink [3]. Polyethylene (PE) is a widely used thermoplastic material, because of high strength and large molecular weight, durability and elasticity. The main limitations in these polymeric materials are decomposing time, and other environmental issues. Adding semiconductor and insulator material as additive is added advantage which may not tune the electrical property of plastics. Therefore, the development of conductive polymers, use of nanoparticles synthesized by various methods to have improved mechanical, physical, chemical and optical properties are need of the day [4]. Recently nanomaterials like Carbon nanoparticles nanosilver, ZnO, are used as additives in PE for various applications [5].

In 1956, preparation of silica particles has been synthesized by reacting tetraethyl silicate in alcoholic solution with water [6]. Tetraethyl orthosilicate (TEOS) and sodium silicate solution were used as major precursor for preparation of silica nanoparticles [7]. Silica nanoparticles are one of the widely used additive materials for rubbers, plastics and paints [8-12]. Other applications of silica nanoparticles are reduction of cement consumption in concrete [13], disperse in lubricant oil for superior dispersibility [14], battery separators and catalyst [15]. Silica nanoparticles, shape and size can be maintained by controlling the reactant parameters such as pressure temperature, time, solvent concentration, pH and many other factors [16].

Wet and vapor-phase process are the two major methods for the preparation of Silica nanoparticles. Wet phase method involves hydrolysis, condensation, sol-gel, chemical precipitation, micro emulsion processing, hydrothermal techniques and pressured carbonation [17]. Silicon tetrachloride is hydrolyzed in a hydrogen-oxygen flame to synthesis fumed silica is called vapor-phase method. This method produces a product with high purity, more uniform particle size distribution, large surface area and a smooth nanopores surface [8].

This experimental work focuses on preparation of silica nanoparticles using hydrothermal process. The main objectives are to achieve high yield in short duration of time using simple method to reduce the cost. Synthesized material has been used as a plastic additives and its electrical property has been analyzed.

II. EXPERIMENTAL SECTION

A. Materials

A precursor solution was prepared from tetraethyl orthosilicate (TEOS: $C_8H_{20}O_4Si$) with a purity of 96.0 % was purchased from Tokyo Chemical Industry Co. Ltd [18]. Ethanol (99.9 %) was purchased from Changshu Hongsheng Fine Chemical Co. Ltd [19]. Ammonia solution (NH_4OH) with purity of 30 % was purchased from LOBA Chemie Pvt. Ltd, Mumbai [20]. All the chemicals were used without further purification. Autoclave instrument is used to achieve required pressure, temperature and ultrasonic bath used to reduce the agglomeration between nanoparticles.

B. Synthesis of SiO_2 nanomaterials:

The SiO_2 nanoparticles are prepared by the following procedure. A mixture of TEOS (5 ml) dissolved in ethanol (25 ml). NH_4OH (6 ml) solution dropped slowly in prepared solution and stirred for 10 minutes intensively at room temperature. The milky white mixture solution was transferred to autoclave for 1 hour. The total synthesized product was found as white powder. The schematic diagram of synthesis process is shown in Fig. 1. In an hour of time, 0.5 gm of SiO_2 nanoparticles was synthesised using simple cum cost effective method.

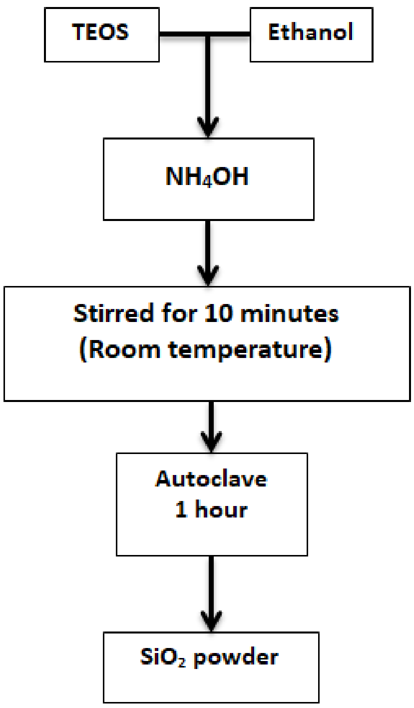

Fig .1 Schematic diagram of preparation of SiO_2 nanomaterial

III. Result and Discussion

A. Reaction mechansim:

Silica nanoparticles can be synthesized by silicon alkoxide precursors (tetramethyl orthosilicate (TMOS), tetraethyl orthosilicate (TEOS), and sodium silicate (Na2SiO3)) [21]. In this work one of the above alkoxide TEOS is used as a precursor and ethanol used as a solvent. pH of the solution before reaction is 7. In this hydrolysis NH4OH was added as a catalyst in the prepared solution till the pH reaches 9. Change in pH initiated the formation of silica nanoparticles which was visible as milky white solution [22]. At low pH levels, linear chains with low crosslink density silica particles are formed. When pH increases (basic), crosslinking between polymers became more and branched [23]. The complete synthesis process reaction is shown in equation 1.

$$C_2H_5O - \underset{OC_2H_5}{\overset{OC_2H_5}{Si}} - OC_2H_5 + 4C_2H_5OH \rightarrow Si(OH)_4 + 4O(C_2H_5)_2$$

$$\downarrow NH_4OH$$

$$SiO_2 + NH_3\uparrow + 3H_2\uparrow + 4C_2H_5OC_2H_5\uparrow \quad ...(1)$$

B. Microscopic results:

The synthesized SiO_2 powder was characterised using LABOMED optical microscope. The surface morphology of the particles is analysed. It shows amorphous white colour solid powder. The magnified microscopic image of SiO_2 powder is shown in Fig. 2.

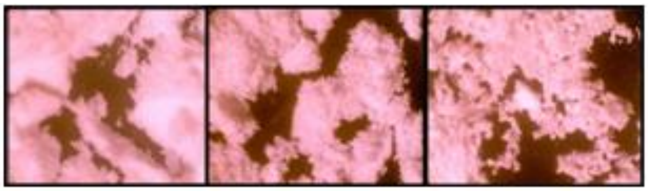

Fig. 2. Optical microscopic image of sio2 nanomaterials.

C. UV-Vis Spectroscopic result:

UV Visible spectroscopic analysis of synthesized SiO_2 nanoparticles was shown in Fig.3. The similar detail experimental work was carried out by Mohd Qasim et al., with different concentration of precursor, solvent and reducing agent results changes in morphology of nanoparticles and change in uv-visbile spectroscopy absorbance in the range of λ_{max} at 221 to 228nm [24]. However, In the current work The maximum absorbance peak was at λ_{max} at 327 nm. The change in absorbance can be due to particle size distribution and agglomeration. The particle agglomeration and size distribution shows that various other smaller peaks in graph. The optical band gap was calculated by Max Planck equation (2), Planck constant (h) is 6.626×10^-34 Joules sec and velocity of light (c) is 2.99×10^8 meter/sec and band gap calculated is 3.79 eV. So the band gap of synthesized SiO_2 nanomaterial exhibit semiconductor property.

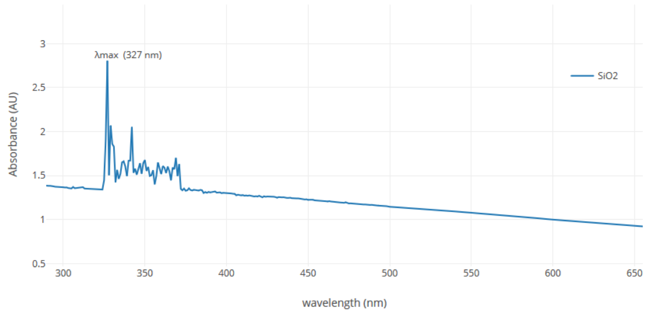

Fig.3. UV-Visible Spectroscopic graph of synthesized SiO_2 nanomaterials

$$E = (h * c)/\lambda \qquad ...... (2)$$

D. Analysis of electrical resistivity of slica nanoparticles:

The resistivity test for the synthesized silica powder is measured by using multimeter. 10 ml of double distilled water is used as solvent and it's resistivity is ~726 Ω. 0.05 g of synthesized silica powder is add into the solvent and dispersed, its shows the change in resistivity 1011 Ω, 1054 Ω, 1108 Ω, 1192 Ω, 1286 Ω and 1404 Ω. Increasing the concentration of SiO_2 into 0.06 g, 0.07 g, 0.08 g, 0.09 g and

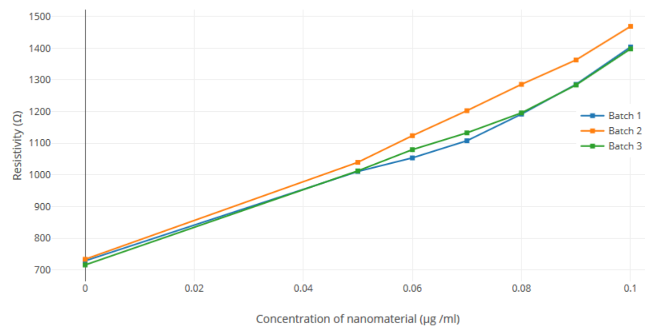

Fig. 4 Change in resistivity graph of Sio2 nanomaterials with respect to change in concentrations

0.1 g. In Fig. 4. The linear growth of resistivity with respect to increase in concentration shows the material has higher resistivity.

IV. CONCLUSION

In this work SiO_2 nanoparticles were synthesized in cost effective single step hydrothermal process. The characterized result of optical microscope, UV-Visible spectroscopy and electrical conductivity of the nanomaterial was analyzed. The band gap the SiO_2 nanoparticles in this work was 3.79 eV. Due to this semiconducting property, it can be suitable material to improve the mechanical strength with negligible tuning the electrical property of plastic materials.

FUTURE WORK

Future work of this project is optimizing and adding SiO_2 nanomaterials as additives in plastics, to enhance the mechanical strength.

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