

## Research Article

## Fabrication of Polystyrene Composite Reinforced with Silicon Carbide Nanoparticles

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### Abstract

The outer part of a tire is called tread. It can be manufactured by using styrene butadiene rubber. Here polystyrene is used for tire manufacturing due to its attractive properties when compared with styrene butadiene rubber. Silicon carbide synthesis is done by sol gel processing by using two different carbon precursors, called chitosan and graphin. Tetra ethyl ortho silicate is used as silicon precursor. Sol gel process needs 24hr aging of sol gel in the furnace at a temperature of 700<sup>o</sup> C. The characterization of silicon carbide nanoparticles is done by UV-visible spectrometer and Nanoparticle analyzer. The graph were obtained for two different samples using UV-visible spectrometer. The software used here is called WinASPECT PLUS. Particle size of the sample is analyzed by Nanoparticle Analyzer. The particle size of the silicon carbide is found that 14.7nm. After analyzing the samples, the samples were dried for the purpose of polystyrene thin film casting. Polystyrene film was formed by thin film casting method. Three samples were prepared for the testing, one is without adding silicon carbide and remaining two samples prepared by adding silicon carbide. The reagents used for polystyrene film are crystal polystyrene and benzene. Benzene has the ability to evaporate and thin film is formed.

**Keywords:** sol-gel process, polystyrene, Nanoparticle, precursor

### 1. Introduction

A polymer is a large molecule composed of many repeated subunits, known as monomers. Because of their broad range of properties, both synthetic and natural polymers play an essential role in everyday life. Polymerization is the process of combining many small molecules known as monomers into a covalently bonded chain or network. During the polymerization process, some chemical groups may be lost from each monomer.

Polystyrene(PS) is a synthetic aromatic polymer made from the monomer styrene, a liquid petrochemical. Polystyrene can be rigid or foamed. General purpose polystyrene is clear, hard and brittle. It is a very inexpensive resin per unit weight. It is a rather poor barrier to oxygen and water vapor and has a relatively low melting point. Polystyrene is one of the most widely used plastics, the scale of its production being several billion kilograms per year. Polystyrene can be naturally transparent, but can be colored with colorants (Yi Xu, *et al*, 2012)

The Chemical Formula of Silicon Carbide is SiC, which is also known carborundum. It is produced by the carbothermal reduction of silica to form an ultra-hard covalently bonded material. Silicon carbide is one of the most important carbide materials because of its unique properties. Silicon carbide is known as an important non-oxide ceramic with high melting point (2827 °C), high

hardness, high wear resistance, low thermal expansion coefficient, good chemical resistance and good thermal conduction in ceramic industry.

Sol Gel method has been established as a novel process for nano particles synthesis with several outstanding features, such as high purity, high chemical activity, improvement of powder sinterability, possibility for particles mixing at molecular scale and etc. A sol gel process using metal alkoxides has been widely applied for the synthesis of ideal powders; homogeneous, size and shape controlled. The sol-gel process entails a phase transition from one colloidal phase to another. A colloidal system is a mixture where the dispersed phase has a large surface to volume ratio. These systems would thermodynamically prefer to aggregate, but do not because surface chemistry slows down this process. (A. Najafi, *et al*, 2011)

### 2. Experimental setup

The experiment is starts with the Silicon Carbide synthesis. It is the important material in this experiment. In this, two samples of Silicon Carbide are synthesized by the same method.

#### 2.1 Silicon Carbide preparation

The silicon source used in this research was tetraethyl orthosilicate (TEOS Merck) and the carbon source was

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chitosan. Also ethanol (99.99% Merck) was used as solvent and hydrochloric acid (HCl 3.5% wt.Merck) as catalyst. The sol was prepared by mixing 3gr chitosan, 5 ml water and 3ml ethanol and then 7 ml TEOS was added to solution. pH was controlled during mixing by gradually addition of 0.05 mole HCl as catalyst. Then the alcohol removed from sol by heating at 40 °C. During temperature increasing and aging due to the condensation phenomena the particles were joined together and formed polymeric gel containing siloxane bonds with carbonaceous phase in its structure



**Figure 1:** Sol gel formation in magnetic stirrer

The derived gel was aged in oven for 24 hr at ambient temperature and was dried at 110 °C to form xerogel. The gel was pyrolyzed at 700 °C for 1 hr and then was heat treated at 1400 and 1500 °C in an electric furnace with Air flow.

The other sample is prepared in the same procedure as explained above, only the change is the carbon source. Graphin is used as the carbon source instead of chitosan. But the quantity is very less, its about 0.5 gm. There was a color change in each SiC sample. It is due to the carbon content presented in the powder. Magnetic stirrer, ultrasonic cleaner, ultra centrifuge, box furnace are the main devices used for silicon carbide synthesis. At temperatures less than 1500 °C, the nucleation of SiC promotes slowly because the SiC formation reaction occurs based on solid-gas mechanism. First all SiO<sub>2</sub> particles convert to the SiO gas phase and react with the solid carbon to produce SiC particles. By temperature raising, the reaction rate of SiO gas increases and consequently results in SiC formation reaction rate improve. So it can be seen that the particle size distribution increases with temperature elevation.

## 2.2 Polystyrene film formation

Next stage is polystyrene thin layer formation. There are two methods available, spin coating method and thin film method. Here we are choosing the easiest method called thin film method. Polystyrene used here is in the crystal form. It is soluble. Here benzene is used as the solvent. Two samples are prepared in different concentration. In first casting 12g polystyrene is mixed with 50 ml benzene. Then it is poured in a tray and allow it to solidify in the fume hood. Solidification takes place after the evaporation of benzene. Next casting is done by mixing 12g polystyrene against 200ml benzene.

## 3. Results and discussion

### 3.1 Comparison between sbr and polystyrene

Comparing the properties of both SBR and Polystyrene helped to choose the best material for tread manufacturing. While comparing the properties, polystyrene have some excellent properties when compared with SBR. Comparison between SBR and polystyrene are given below.

#### 3.1.1 Styrene butadiene rubber (sbr)

Styrene-butadiene rubber (SBR) describes families of synthetic rubbers derived from styrene and butadiene. These materials have good abrasion resistance and good aging stability when protected by additives. In 2012, more than 5.4 million tonnes of SBR were processed worldwide. About 50% of car tires are made from various types of SBR. The styrene/butadiene ratio influences the properties of the polymer: with high styrene content, the rubbers are harder and less rubbery. SBR is not to be confused with a thermoplastic elastomer made from the same monomers, styrene-butadiene block copolymer.

SBR is derived from two monomers, styrene and butadiene. The mixture of these two monomers is polymerised by two basically different processes: from solution (S-SBR) or as an emulsion (E-SBR).

E-SBR produced by emulsion polymerisation is initiated by free radicals. Reaction vessels are typically charged with the two monomers, a free radical generator, and a chain transfer agent such as an alkyl mercaptan. Radical initiators include potassium persulfate and hydroperoxides in combination with ferrous salts. Emulsifying agents include various soaps. By "capping" the growing organic radicals, mercaptans (e.g. dodecylthiol), control the molecular weight, and hence the viscosity, of the product. E-SBR is more widely used. Typically, polymerizations are allowed to proceed only to ca. 70%, a method called "short stopping". In this way, various additives can be removed from the polymer. Solution-SBR is produced by an anionic polymerization process. Polymerisation is initiated by alkyl lithium compounds. Water is strictly excluded.

The process is homogeneous (all components are dissolved), which provides greater control over the process, allowing tailoring of the polymer. The organolithium compound adds to one of the monomers, generating a carbanion that then adds to another monomer, and so on. Relative to ESBR, S-SBR is increasingly favored because it offers improved wet grip and rolling resistance, which translate to greater safety and better fuel economy, respectively.

#### 3.1.2 Properties of styrene butadiene rubber

- This type of rubber is usually very weak unless reinforcing fillers are incorporated. With suitable fillers, this becomes a strong rubber
- It has similar chemical and physical properties like natural rubber

- It has better abrasion resistance
  - It has poorer fatigue resistance
  - Heat resistance is better than natural rubber
- Low temperature flexibility and tensile strength are less than that of natural rubber

**Table 1** Properties of SBR

Properties	Value
Tensile strength	10-25 MPa
Young's modulus	2-10 MPa
Elongation	250-700%
Glass transition temperature	-65to-50°C
Hardness	40-95 shore
Density	900 kg/m <sup>3</sup>

3.2 Polystyrene (PS)

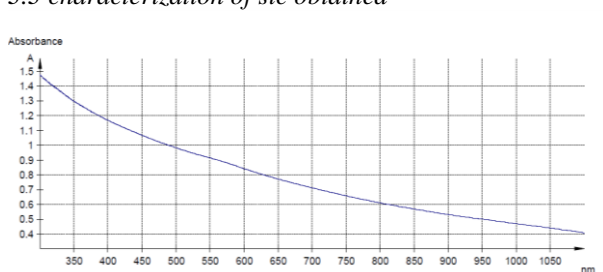
Styrene is an aromatic monomer, commercially manufactured from petroleum. Polystyrene is a vinyl polymer, manufactured from the styrene monomer by free radical vinyl polymerization.

The mechanical properties of a polymer include its strength, elongation, modulus, impact strength, and toughness. Crystal forms of the polymer polystyrene have low impact strength. Polystyrene polymers get degraded on exposure to sunlight, due to photo oxidation, which affects its mechanical properties. The following table shows the value of the mechanical properties

**Table 2:** Properties of polystyrene

Properties	value
Tensile strength	30 to 56 MPa
Young's modulus	3000 to 3600 MPa
Density	16 to 640 kg/m <sup>3</sup>
Elongation at break	3 to 4%
Glass transition temperature	100°C

3.3 characterization of sic obtained



**Figure 2:** Characterization graph

From the graph, it is observed that as the wavelength increases, the absorbance is reducing.

3.4 Particle size determination

201310041538002. nsz  
 Measurement Results  
 Date: Friday, October 04, 2013 3:38:22 PM  
 Measurement Type: Particle Size  
 Sample Name: silicon11  
 Scattering Angle: 173  
 Temperature of the holder: 25.0 °C

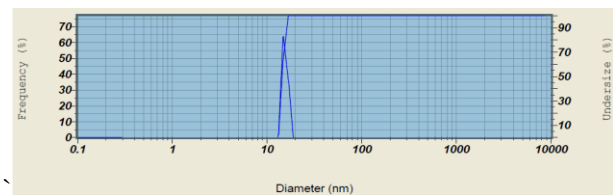
T% before meas.: 9453  
 Viscosity of the dispersion medium: 0.896 MPa·s  
 Form of Distribution: Standard  
 Representation of result: Scattering Light Intensity  
 Count rate: 3093 kCPS

3.3.1 Calculation results

**Table 3:** Particle analysis result

Peak No.	S.P.Area Ratio	Mean	S. D.	Mode
1	1.00	14.7nm	0.9nm	14.5nm
2	---	---	---	---
3	---	---	---	---
Total	1.00	14.7nm	0.9nm	14.5nm

Cumulant Operations  
 Z-Average : 0.5 nm  
 PI : 0.323



**Fig 3:** Particle analysis graph

**Conclusion**

Polystyrene has excellent physico-chemical properties; because of this reason polystyrene can be used for making treads in tires. When adding silicon carbide and polystyrene, a strong bond will be formed between silicon and polystyrene. Due to this bonding, it can withstand high load and heat. Since silicon carbide have a melting point about 2827<sup>0</sup> C, it can carry high heat energy. The earlier reports revealed that sol-gel process is the best method for silicon carbide synthesis. It is economical and highly purified form of silicon carbide can made by this process. Normal polystyrene have some properties, and after the addition of silicon carbide it will improve. From the above study, we concluded that polystyrene can be use instead of SBR in tire tread.

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