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GREEN COMPOSITES FROM FABRIC REINFORCED NATURAL RUBBER FOR HIGH PERFORMANCE ENGINEERING APPLICATIONS

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ABSTRACT

Natural Rubber based composites have been prepared by reinforcing silk fabric. The matrix material for the composite is Glutaraldehyde cured natural rubber. It shows excellent mechanical strength and other physical properties. In the proposed investigation, silk is proposed as reinforcement into the same matrix material. Silk is ecofriendly and biodegradable material with excellent tensile strength. When such kind of fabrics is introduced into the vulcanized rubber as the matrix, it is expected to enhance the physical properties considerably. A considerable enhancement in the stability of natural rubber in terms of tensile properties is noticed on reinforcing fabric into rubber.

KEYWORDS

Silk, Natural Rubber, Glutaraldehyde, Tensile Properties, Solvent Transport.

1. INTRODUCTION

Polymeric materials are applied in almost all areas of our daily life and their stimulated functions are made use of the development of future technologies. When compared with metallic and ceramic materials, polymers are relatively cheap, easily accessible and processed, as they need less energy for production and shaping [1]. Polymeric materials have a variety of fields of application in textiles, electromagnetic shielding, coatings, automotive parts, electronic and household appliances. Elastomers are amorphous polymers existing elasticity above their glass transition temperatures, so that considerable segmental motion is possible [2]. At ambient temperatures, rubbers are relatively soft and

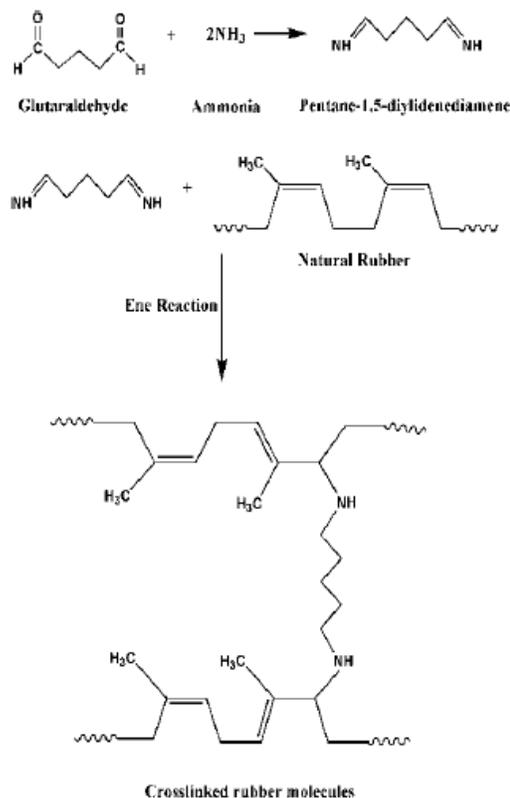
deformable. Their primary uses are for seals, adhesives and molded flexible parts. Application areas for different types of rubber are manifold and cover segments as diverse as tires, shoe soles as well as dampening and insulating elements [3-5]. Natural rubber has excellent mechanical and thermal resistance but poor solvent resistance. Uncured rubber is sticky, can easily deform when warm, and is brittle when cold. In this state, it cannot be used to make articles with a good level of elasticity. Thus, chemical modification of natural rubber has been carried out to improve its physical properties. The chemical modification can be carried out in latex, in solution, or in the dry phase. Some modified natural rubber, which are still commercially available are chlorinated

rubber, hydrochlorinated rubber, cyclized rubber and oxidized rubber [6-10]. Vulcanization is the process in which mainly an elastomer is converted from soft elastomeric state to a thermoplastic state or hard elastomeric state. The process is brought about by linking of macromolecules at their reactive sites, thus forming a three-dimensional network. Vulcanization can improve properties such as mechanical properties, resistance to heat, and resistance to attack by the fluid [11-12]. It is obvious that the cross-link density of the elastomeric phase plays an important role in achieving higher strength. In general, there are three main types of rubber vulcanization, namely, sulfur, peroxide, and radiation vulcanization [13-17]. Sulfur vulcanization is the most popular system for general purpose rubbers. It has now been found that natural rubber can be vulcanized using glutaraldehyde without any specific activator, which is highly favorable to the environment [18-20]. Compared to solid rubber, liquid rubber is advantageous to produce various products from the viewpoint that it can be easily processed and requires less energy.

Glutaraldehyde vulcanization is found to be a better method compared to other vulcanization techniques. Natural rubber has been blended with polystyrene, polyacrylamide, poly vinyl alcohol, poly carbonate, chitosan etc [21].

In the present investigation, silk fabric is reinforced into crosslinked rubber and

studied the tensile properties, surface hardness and solvent transport behavior.



Scheme 1. Proposed vulcanization mechanism of natural rubber via Ene reaction

2. EXPERIMENTAL WORK

Preparation of vulcanized natural rubber

A 10% Glutaraldehyde solution was prepared by diluting 25 % glutaraldehyde solution in distilled water. Separate specimens of silk fabric are made by stretching them to a circular ring casing and the setup is placed in a petri dish. Composite specimens were prepared by optimizing the composition and conditions of curing. Optimization has been done by varying the amount of glutaraldehyde as the crosslinking agent for rubber along with temperature. The composites of silk fabric reinforced with respect to 0%, 2%, 4%, 6%,

8%, 10%, 12%, 14% of glutaraldehyde in to vulcanized natural rubber has been prepared separately.



Figure 1. Composite prepared with glutaraldehyde with Silk fabrics in natural rubber

This setup was placed under electric bulb for 24 hours for curing. These casted samples were then peeled out from the casing.

3. TESTING PROCESS

The prepared composite materials were tested under standard conditions.

1. Swelling studies in benzene.
2. Hardness test was conducted using Shore A durometer.
3. Tensile properties were measured from the results of Universal Testing Machine.

Silk fabric reinforced vulcanized natural rubber with glutaraldehyde were used to study the solvent transport properties in benzene. Solvent transport studies provide the information about the solvent resistance of the material. 1cm x 1cm size specimens were immersed in benzene and measured the weight for different intervals of time. Fig 5 shows the testing process of specimens with benzene.



Figure 2. Glutaraldehyde with silk fabric in natural rubber specimens for benzene solubility test

The prepared tensile composite materials were sent for the following characterizations to the Department of Materials Science, Prince of Songkla University, Thailand.

Hardness test was conducted using Shore A durometer. The hardness data was collected from 3 different parts of the specimen and the average was reported.

4. RESULTS AND DISCUSSION

Vulcanization mechanism of natural rubber in the presence of glutaraldehyde is as shown in scheme 1. Ammonia present in the latex initially reacts with the glutaraldehyde and further the reaction product Pentane-1, 5-diylidenediamine reacts with natural rubber molecules. It forms linkages between the rubber molecules and the reaction can be termed as ene reaction. Figure 3. shows the FTIR spectra of pure and vulcanized rubbers. It exhibits all the characteristic peaks present in cis-polyisoprene. Peak corresponds to 1662

cm⁻¹ is due to the presence of C=C bond. Upon the formation of crosslinking between the rubber molecules, the peak at corresponds to 1662 cm⁻¹ vanished or overlapped by the new peak at 1652 cm⁻¹ from the secondary amines during ene reaction. It clearly confirms the vulcanization of rubber with glutaraldehyde.

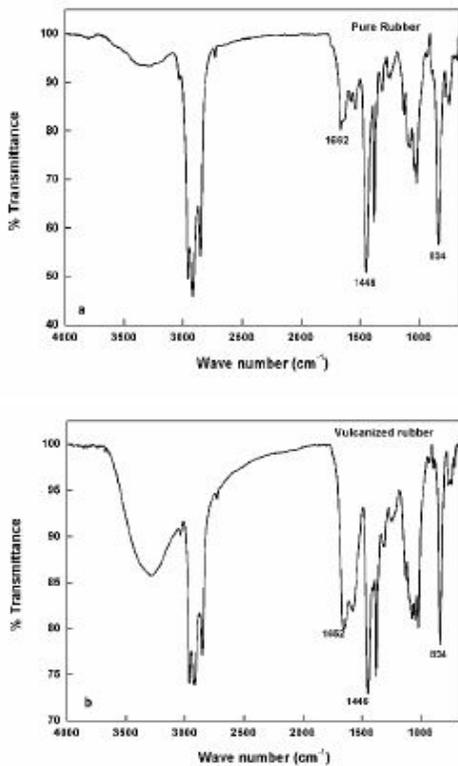


Figure 3. FTIR spectrum of pure and vulcanized natural rubber

Tensile properties of any material can be determined by using universal testing machine. UTM provides ultimate tensile strength and elongation at break of the material. The values of ultimate tensile strength and elongation at break of the composites are depicted in Table 1. Figure 4 shows the variation in ultimate tensile strength of silk reinforced composite for

various composites with different amount of crosslinking agent. An increase in tensile strength is observed in the figure on the addition of Glutaraldehyde into rubber/silk composite. Crosslinking between the rubber molecules enhances the strength of rubber as well as the composite. It clearly indicates the increase in mechanical stability of elastomer by the addition of crosslinking agent along with reinforcing silk fabric. Elongation at break decreases on increasing tensile strength of the composites. The toughness of rubber increase on the addition of crosslinking agent and the rubber molecules can not easily stretch under applied force. Therefore, elongation at break reduces on increasing the amount of glutaraldehyde

Table 1. Shows the Tensile test data collected for Silk fabric reinforced natural rubber with Glutaraldehyde

Amount of GA (mL)	Ultimate Tensile Strength [MPa]	Elongation at Break (%)
0	4.00	59.21
2	4.36	57.96
4	5.06	54.88
6	6.30	43.27
8	6.37	23.33
10	8.21	21.23
12	8.42	21.66
14	10.37	17.11

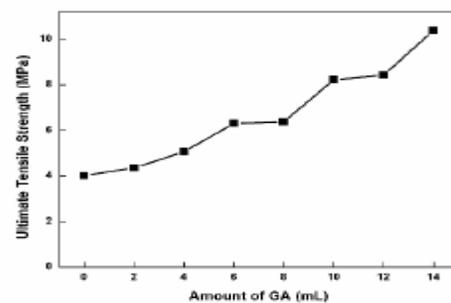


Figure 4. Variation on tensile strength for various amounts of GA

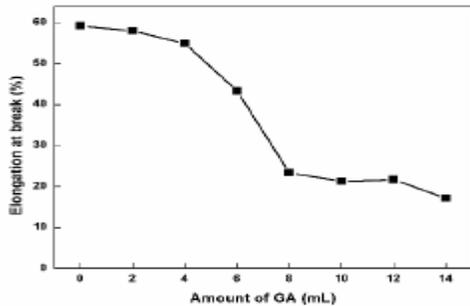


Figure 5. Variation on elongation at break for various amounts of GA

Shore-A hardness is commonly used to measure hardness of elastomeric materials. Table 2. shows the surface hardness values of the prepared composites. An increasing trend in hardness is noticed upon the addition of glutaraldehyde as seen in Figure 6. Crosslinking of rubber phase with glutaraldehyde enhances the toughness of the rubber composite by increasing hardness. 14 mL glutaraldehyde cured composite shows the superior hardness among the series of samples studied.

Table 2. Shows the Tensile test data collected for Silk fabric reinforced natural rubber with Glutaraldehyde

Amount of GA (mL)	Surface Hardness (Shore-A)
0	48
2	55
4	65
6	68
8	75
10	76
12	78
14	80

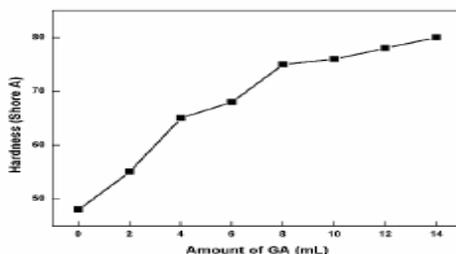


Figure 6. Variation on surface hardness for various amounts of GA

Swelling experiments are appropriate to understand the solvent transport behavior of an elastomer. Natural rubber and its composites are flexible, which can be used in case of manufacturing fuel lanes and boiler pipes. Benzene has been used to study the solvent transport properties of the resulting composites. Figure 8 shows the variation of solvent uptake for

various composites with different amounts of glutaraldehyde. Addition of glutaraldehyde decreases the diffusivity of rubber composites. Formation of three-dimensional network during crosslinking reduces the flexibility of polymer chains under solvent stress.

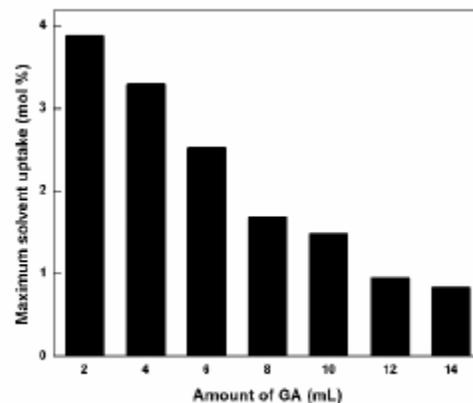


Figure 7. Variation on maximum solvent uptake for various amounts of GA

5. CONCLUSION

In the present paper, the possibility of reinforcing ecofriendly silk fabric into cured natural rubber using glutaraldehyde as crosslinking agent. The method of preparation of the composite is simple and cost effective compared to other conventional methods. The study reveals

that, addition of glutaraldehyde into rubber/silk composite is found to be worth in view of developing material with excellent stability in the field of materials science. Enhancement in tensile strength, surface hardness and solvent resistance of the resulting composites suggests the material can be used in high performance elastomeric applications.

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