EFFECT OF PULVERIZED SILICA AND RADIATION DOSE ON THE MECHANICAL PROPERTIES OF RADIATION (GAMMA-RADIATION) VULCANIZED NATURAL RUBBER LATEX FILM

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Abstract: *A study of the effect of pulverized silica on the properties of radiation vulcanized natural rubber latex (RVNRL) film has been done. Radiation vulcanization of natural rubber latex was done by using Co-60 gamma radiator at room temperature using n-butyl acrylate (n-BA) as sensitizer. The additives (pulverized silica and n-BA) were blended with NR latex just before irradiation. It was found that both silica concentrations and radiation doses were important for the improvement of the tensile and swelling properties of natural rubber latex film. The tensile strength, tear strength and gel content were found increasing and the elongation at break, permanent set and swelling ratio of rubber film were found decreasing with increasing concentration of silica and also increase in absorbed doses. The optimum radiation dose and silica concentration were found at 12 kGy and 1.0 phr respectively which showed the tensile strength 12.77 MPa and tear strength 52.97 N/mm.*

Keywords: *Natural rubber latex, Radiation vulcanization, Tensile strength, Tear strength, Elongation at break.*

1. Introduction

Natural rubber is of little use as it possesses elasticity only over a limited range of temperature, it become soft and sticky on heating and brittle on cooling, it has low tensile strength and poor resistance to abrasion. By vulcanization and use of proper proportion of additives, the elasticity and other mechanical properties of natural rubber can be improved significantly. The conventional sulphur used for vulcanization of natural rubber causes a very harmful effect directly both on environment and the human body. The dipped rubber goods are directly related to our health. In this study we have focus on the radiation vulcanization [1, 2] and use of pulverized silica as an additive to improve the physical and mechanical properties of natural rubber. The aerated natural rubber latex reacted readily with pulverized silica in the presence of a sensitizer and found that molecular weight of the vulcanized side chain was large and percentage of silica present as free polymer was small [3]. The effect of silane coupling agent for the sulphur curing natural rubber matrix and showed that the reinforcement effect of natural rubber vulcanizate was improved significantly [4]. Kyong-Hwan Chung investigated the effect of silica reinforcement for natural rubber (NR) and butadiene rubber (BR) vulcanizate by a sol-gel reaction with tetraethoxysilane at different temperatures [5] and found the hardness of the vulcanized rubber increased with silica filling in the rubber matrix.

It is suggested in this work that pulverized silica can be used as a good reinforcing agent for the radiation vulcanized natural rubber latex film.

2. Experimental

2.1 Natural Rubber Latex (NRL)

The natural rubber field latex was collected from the Atomic Energy Research

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Establishment (AERE) rubber garden, Savar. Immediately after collection of NRL from rubber tree, it was preserved with ammonia solution obtained from BDH, England. NRL was concentrated to 60% total solids content (TSC) using a laboratory scale centrifuge machine model SPL-100, Saito Separator Ltd., Japan.

2.2 Preparation of NRL for Irradiation

The concentrated NRL was diluted to 50% TSC by adding 1.5% dilute ammonia solution. A 5 parts per hundred rubber (phr) *n*-butyl acrylate (n-BA) obtained from Kanto Chemical Co. Inc., Japan as radiation vulcanization accelerator (RVA) and different concentration of pulverized silica from GPR, BDH, England were added to diluted NRL as reinforcing agent and stirred with a magnetic stirrer for 1 hour. The RVA and silica mixed NRL was irradiated [6] by Co-60 gamma source.

2.3 Preparation of Rubber Films

Irradiated rubber latex, MMA grafted rubber latex and blend rubber latex were cast on raised rimmed glass plates to make rubber films. They were leached with distilled water for 24 hours at room temperature and then air dried until transparent [7]. Then the films were dried in an oven at 70ºC for one hour.

2.4 Measurement of Properties of Rubber

Dumbbell-shaped test piece of rubber film was used to measure the tensile strength and elongation at break of rubber film and trouser shaped test piece of rubber film was used to measure the tear strength, using a universal testing machine (Instron, model 1101, England) interfacing with a computer.

3. Results and Discussions

The physical properties of NRL film and 1 phr silica blend irradiated (12 kGy) NRL film are shown in the Table 1.

The tensile strength, tear strength and gel content of NRL film are lower than that of silica blend irradiated NRL film. Elongation at break, permanent set and swelling ratio of NRL films are higher than those of silica blend irradiated NRL film. The cause of higher tensile strength, tear strength and gel content and lower elongation at break, permanent set and swelling ratio of silica blend irradiated natural rubber latex film may be due to the presence of cross-linked rubber.

Table 1: Physical properties of NRL film and silica blend irradiated NRL film.

Sample	Tensile Strength (MPa)	Tear Strength (N/mm)	Elongation at break (%)	Permanent set (%)	Swelling ratio	Gel content (%)
NRL Film	7.02	14.02	1450	112	18.4	88.12
Silica blend Irradiated NRL film	12.77	52.97	752.18	30	5.73	98.99

Irradiated rubber latex films were prepared at the absorbed dose of 4 kGy, 8 kGy, 12 kGy, 15 kGy and 20 kGy and with 0.2 phr, 0.4 phr, 0.6 phr, 0.8 phr and 1.0 phr concentration of pulverized silica. Figure 1 shows that the tensile strength of radiation vulcanized natural rubber latex (RVNRL) film increases with the increasing concentration of pulverized silica. Tensile strength is also increased with increase in absorbed radiation dose and reaches a maximum at an absorbed dose of 12 kGy, after that the tensile strength is almost unchanged. It is known that tensile strength of a polymer depends on the cross-linking [6] and the maximum tensile strength is obtained at optimum cross-linking of a polymer.

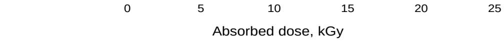

Fig. 1: Effect on tensile strength of rubber film at various radiation doses and various concentrations of silica added.

The maximum value of tensile strength of irradiated natural rubber obtained is about 12.92 MPa at 15 kGy absorbed dose and 1.0 phr silica concentration added which is almost similar (12.77 MPa for 12 kGy and 12.86 MPa for 20 kGy absorbed dose and with 1.0 phr silica concentration added). The effect of silica concentration on the natural rubber and radiation dose on tear strength is also studied. The results are depicted in Fig. 2.

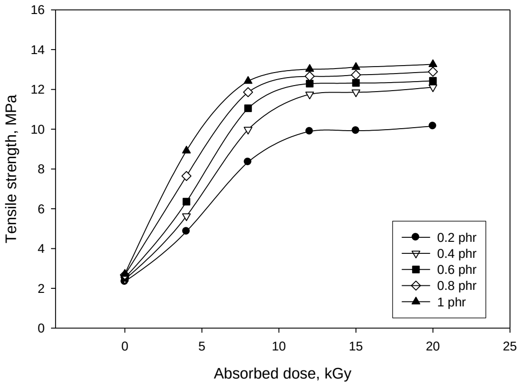

Fig. 2: Effect on tear strength of rubber film at various radiation doses and various concentrations of silica added.

A significant improvement of tear strength of rubber film has been achieved by radiation vulcanization of rubber latex with pulverized silica. It is found that, tear strength increases with increasing silica concentration and radiation dose and reaches 52.97 N/mm at 12

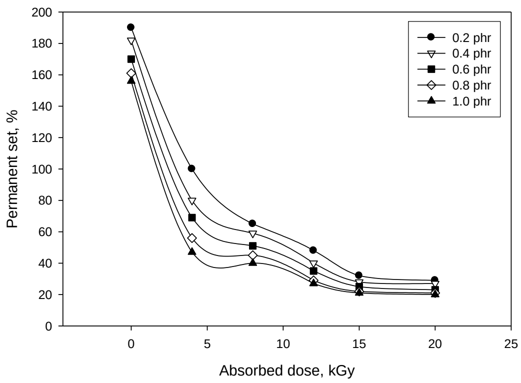

Fig. 3: Effect on elongation at break of rubber film at various radiation doses and various concentrations of silica added.

kGy absorbed dose and 1.0 phr silica concentration, after that radiation dose the change in tear strength is not significant (53.73 N/mm and 53.73 N/mm at 15 kGy and 20 kGy absorbed dose respectively and with 1.0 phr silica concentration).

The change in elongation at break of natural rubber blends with various concentrations of silica and at various absorbed doses is presented in Fig. 3. Results indicate that elongation at break decreases with increasing absorbed dose. The decreasing trend of elongation at break may be caused by the increase of cross-linking of polymer [6] in blends with increasing the absorbed dose. The elongation at break is also decreases with increasing concentration of silica added to the rubber latex.

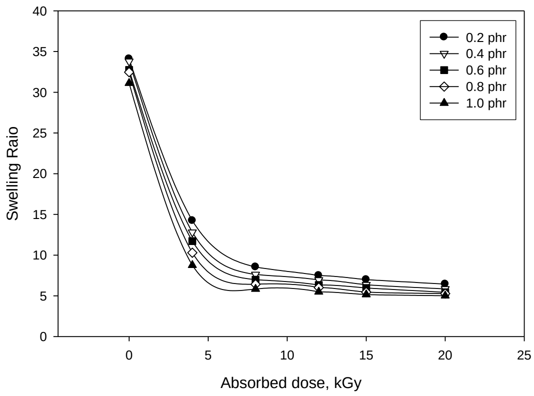

Fig. 4: Effect on permanent set of rubber film at various radiation doses and various concentrations of silica added.

Fig. 4 shows a permanent set of rubber films obtained from blend with different concentration of silica added and at various absorbed doses. Silica added vulcanized rubber film shows a significant decrease in permanent set. This is due to increase in cross-linking which makes the rubber molecules more compact. It also decreases with increased radiation doses. The decreasing trend of the permanent set is fast till 4 kGy radiation dose is reached, and after then it becomes slow. The lowest permanent set 20% is obtained with the rubber latex mixed with 1 phr silica at 15 kGy. For 0.6 and 0.8 phr silica the value of permanent set obtained is 25% and 23% percent respectively.

The swelling ratio decreases with an increased cross-linking density. Fig. 5 shows the results of swelling ratio of silica added vulcanized rubber films. Sharp decrease of swelling ratio with radiation dose is found for all silica added vulcanized rubber films at 4 kGy dose. On further increase of dose the swelling ratio does not show that significant lowering. From 4 to 8 kGy radiation dose the swelling ratio lowered in a short range, but after that all the doses represents almost constant swelling ratio.

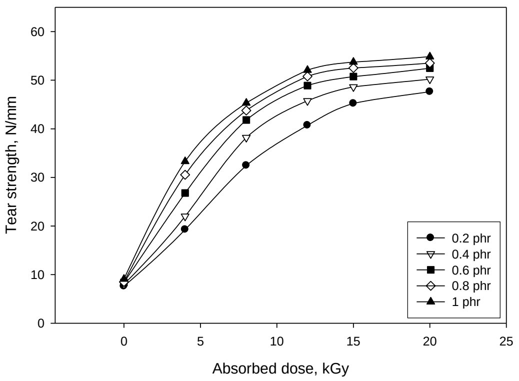

Figure 5. Effect on swelling ratio of rubber film at various radiation doses and various concentrations of silica added.

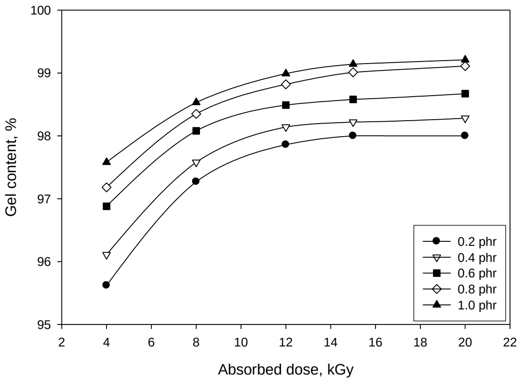

Figure 6. Effect on gel content of rubber film at various radiation doses and various concentrations of silica added.

Gel content of silica added vulcanized rubber is the measure of the amount of the cross-linked rubber in total sample. Gel content of rubber films obtained from blend with different concentration of silica added and at various absorbed doses is shown in the Figure 6. It is found that for 1 phr silica, vulcanized rubber has high gel content in comparison to other silica concentrations. From 4 kGy radiation dose its gel content increases up to 12 kGy and from 12 kGy dose the increment is not so significant.

4. Conclusions

It can be suggested that the absorbed radiation dose and amount of silica added both are responsible for the improvement of the properties of natural rubber latex film. This improvement shows better particle cohesion and improved entanglement of molecular chains. The tensile strength of irradiated natural rubber shows a maximum (12.92 MPa) at 15 kGy absorbed dose and 1.0 phr pulverized silica added which is almost similar to 12.77 MPa at 12 kGy absorbed dose and 1.0 phr pulverized silica added. The maximum value of tear strength is found to be 53.78 N/mm at 20 kGy absorbed dose, which is also similar to 52.97 N/mm at 12 kGy absorbed dose. Elongation at break decreases with increasing concentrations of silica added and absorbed radiation doses. However, the feasibility and optimum dose for the improvement of the mechanical properties of natural rubber latex film is 12 kGy radiation dose and 1.0 phr pulverized silica concentration.

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