

# RADIATION VULCANIZATION OF NATURAL RUBBER LATEX SENSITIZED WITH COMMERCIAL GASES

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## ABSTRACT

The industrial activities using natural rubber latex are fully compatible with rural areas in Amazon and other places in Brazil, as well as in other tropical countries. However the classical sulfur vulcanization presents many occupational problems for the workers in rural areas. Radiation vulcanization of natural rubber latex is a much more friendly process as sulfur compounds are not needed for crosslinking, although chemicals as acrylate monomers, particularly multifunctional acrylates are still used as sensitizers for radiation processes. Two commercial gases, acetylene and butadiene, were selected as sensitizers for the radiation vulcanization of natural rubber latex instead of acrylates. These gases accelerate the crosslinking rates of the cure process and lower the radiation dose required to achieve vulcanization of natural rubber latex and improve the mechanical properties to reduce the tackiness of rubber goods.

Keywords: radiation vulcanization, natural rubber latex, polymer, gases

## I. INTRODUCTION

Sustainable activities are a possible solution for the environmental dilemma, i.e., jungle and species should be preserved and at the same time some economical activities should be developed to fulfill needs of inhabitants. This paper aims to introduce an advanced technology to produce very pure latex products compatible with international standards in rural areas where latex is available. The technique should be simple to be performed by workers without special training, reliable to avoid maintenance and to cope with specifications. The vulcanization process must be energy efficient as energy is a scarce resource in remote areas.

The radiation induced vulcanization of natural rubber latex (RVNRL) has prompted mechanistic comparisons to be made between vulcanization work and other related radiation processes [1] such as radiation grafting, curing and vulcanization. Grafting is the copolymer from a backbone polymer and a monomer. Curing is the rapid polymerization of an oligomer monomer mixture to form a coating, which is essentially bonded by physical forces to the substrate. Vulcanization is essentially crosslinking.

Radiation grafting has been performed for over thirty years [2, 3]. Curing processes were developed twenty years ago. Works in RVNRL have only been in progress for ten years. An important feature common to all three of these radiation induced processes is the use of sensitizers to either speed up the polymerization reaction or to enhance the

degree of crosslinking. Common sensitizers used in all three processes are acrylate monomers.

However the smell of goods made of irradiated latex was bad due to the presence of trace amount of 2-ethylhexyl acrylate (2EHA), which was used as sensitizer for radiation vulcanization of natural rubber (NR) latex together with carbon tetrachloride ( $\text{CCl}_4$ ) that was developed by Devendra and Makuuchi [4]. Other monomers that have high vapor pressure gas other than 2EHA were used as n-butyl acrylate (n-BA) because n-BA has higher vapor pressure and sensitizing efficiency on RVNRL than 2EHA [5]. However n-BA is not suitable as a sensitizer because it tends to destabilize NR latex.

The purpose of this paper is to show the performance of RVNRL process when using butadiene and acetylene commercial gases to decrease the tackiness of rubber goods (orthodontic rubber band) made of irradiated latex. Depending on the product it causes problem during production of dipped goods. Stripping of rubber gloves from the formers becomes difficult due to high tack. So RVNRL should be tack free or with very low tack for the fabrication of latex gloves.

## II. EXPERIMENTAL

**Materials.** Commercially available high ammonia (0,7%) NR latexes were used. The total content of solids is about 60%. Industrial grade acetylene and butadiene gases were

used. Any other chemicals were used without further purification.

**Sample Preparation and Irradiation.** 5kg of concentrated NR latex was weighed and poured into especial reactor vessel of 9 liters capacity. Gas was bubbled into the latex for more than 15 minutes to remove air. Then the reactor was closed keeping the gas bubbling into the latex. Pressure in the reactor was increased to 1,5kgf. Then the pressurized reactor was irradiated with gamma rays from industrial Co-60 sources. The dose rate was 4kGy/hr. The irradiation doses were 10, 20, 30 and 40 kGy. So 500g of irradiated latex were picked up from reactor for each irradiation condition. The Table 1 shows the acetylene and butadiene concentration on several irradiation dose condition.

TABLE 1. Concentration of acetylene and butadiene gases on several irradiation dose condition.

Dose KGy	Acetylene phr	Butadiene phr
10	0.68	1.41
20	0.80	3.23
30	0.96	5.62
40	1.16	---

**Preparation of Cast Films.** Preparation of cast films of latex was done by spreading 97ml latex on several raised rimmed glass plates. The thicknesses of the rubber films were about 1.8mm. They were allowed to air dry till transparent (for about 48h). The films were heated in an oven at 70°C for 3h after leaching. Leaching of the cast films was done with hot water distilled at 70°C for 1h.

**Measurement of Tensile Properties.** Pieces of rubber film for dumbbell shaped test were cut using dumbbell cutter of precise size for natural rubber film (ASTM 412-87). Tensile and related properties were measured by using an Instron testing machine.

**Measurement of Swelling Ratio and Gel Fraction.** A weighed amount of rubber film was immersed into toluene for 48h. The rubber film was taken out from the solvent and the adherent solvent was soaked from the swelled film. The swelling ratio was calculated from the difference in weight of the films before and after swelling. The same films were dried at 50°C for 24h and then dried using a vacuum oven at 50°C for 5h. The gel fraction was calculated from the difference in weight of the films before swelling and after drying.

### III. RESULTS AND DISCUSSION

Figure 1 shows that the optimum dose of gamma rays irradiation of NR latex using commercial gases is

10kGy. The maximum tensile strength of film prepared from gamma rays irradiated NR latex using acetylene is about 16MPa. In order to achieve the same tensile strength value, 16MPa, the NR latex without sensitizer needs a gamma-rays irradiation dose of about 100kGy, in inert atmosphere conditions using nitrogen [5]. However, the maximum tensile strength was not achieved when the latex was irradiated after bubbling with butadiene.

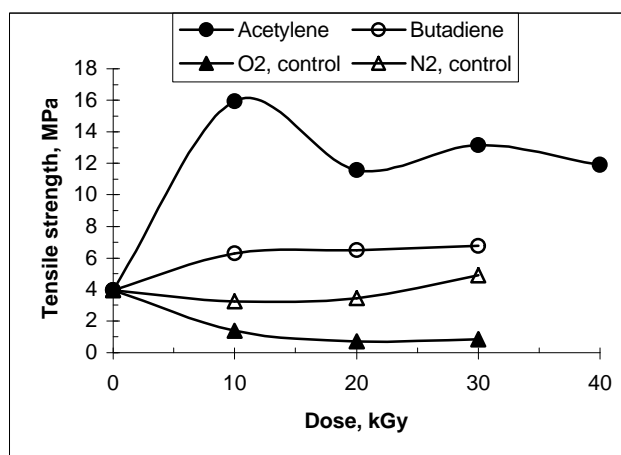


Figure 1. Effect of oxygen, acetylene and butadiene bubbling on the tensile strength. Samples were prepared from the irradiated NR latex.

The effect of the irradiation dose on strain at break (Eb) of film prepared from gamma rays irradiated NR latex bubbling with acetylene and butadiene is shown in Figure 2. It can be seen that the Eb is not hardly changed with the irradiation dose. From the results, it was ascertained that the Eb does not depend on the acetylene and butadiene concentration at the irradiation dose condition.

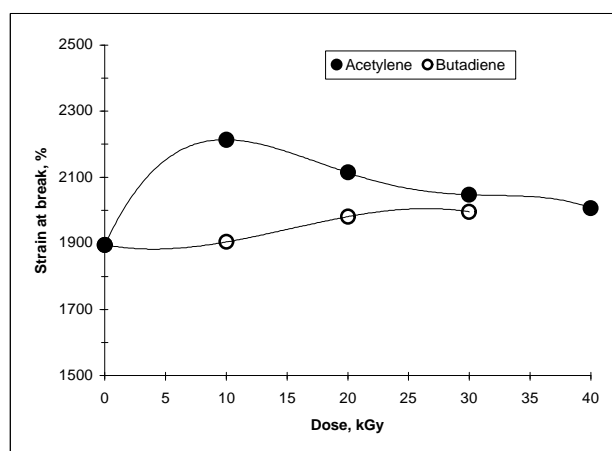


Figure 2. Strain at break of the same sample in Fig 1.

The maximum tensile strength was not achieved with butadiene but this result is in disagreement with the decrease of swelling ratio with increasing irradiation dose (Figure 3) and the high gel fraction value (Figure 4).

Because, high gel fraction value is also indicative of high crosslink density and grafting. However, the maximum tensile strength value indicates high crosslink density. This means that it is occurring a grafting process during latex irradiation with.

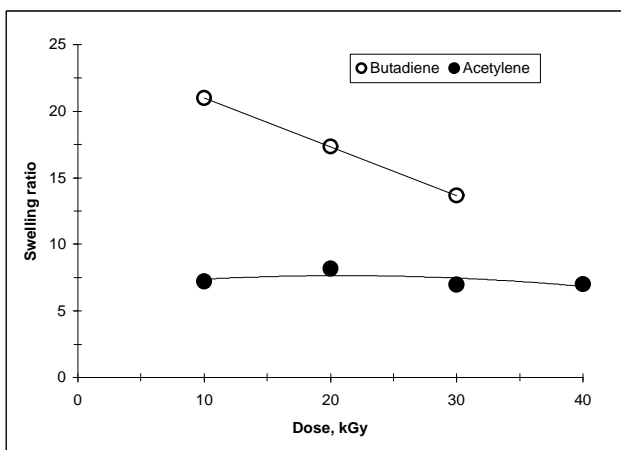


Figure 3. Swelling ratio of the same sample in Fig 1.

The Figure 4 shows the high gel fraction values of the films prepared from irradiated latex containing butadiene and acetylene.

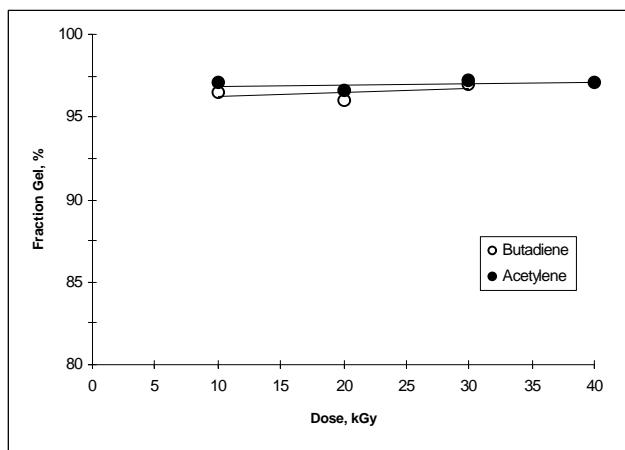


Figure 4. Gel fraction of the same sample in Fig. 1.

The soluble fraction in toluene consists of non rubber material such as ester. Low molecular weight hydrocarbon and uncrosslinked natural rubber. The presence of low molecular weight NR makes it difficult to reach a three dimensional network, and this fraction is easily soluble in toluene. Crosslink density for vulcanized NR was determined from the swelling ration using Flory Renher equation [5]. The effect of irradiation dose on the crosslink density is shown in Table 2.

TABLE 2. Crosslink density  $\times 10^{18}$  number of network moles of chain/ml.

Dose, kGy	Butadiene	Acetylene
10	2.9	17.5
20	4.1	14.2
30	6.0	18.6
40	---	18.4

The maximum crosslink density ( $18.6 \times 10^{18}$  number of network moles of chain/ml) of the film was achieved by bubbling about 0.96phr of acetylene and irradiating the latex at 30kGy. At similar irradiation dose, high crosslink density was also observed for film prepared from latex irradiated bubbling 5.62phr of butadiene. In order to obtain a film with crosslink density of  $17.5 \times 10^{18}$  number of network moles of chain/ml, an irradiation dose of 10kGy was required for latex added with 0.68phr of acetylene. It appeared that this was in agreement with the irradiation dose from maximum tensile strength. It should be noted that a crosslink density of about  $17.5 \times 10^{18}$  number of network moles of chain/ml is the least amount of crosslink needed to obtain a totally three-dimensional network throughout the NR matrix.

#### IV. CONCLUSION

The optimum dose of gamma rays irradiation of NR latex using acetylene gas as sensitizer is 10kGy. The maximum gel fraction value was 97%, which is very high when compared with acrylic monomers sensitizers. Grafting occurs when using butadiene gas as sensitizer while crosslink occurs when acetylene gas is used. Radiation vulcanised natural rubber latex films obtained using acetylene as sensitizer has better mechanical properties compared to that of RVNRL obtained using acrylic monomers as sensitizers. Include the reduction of the tackiness of rubber goods made of irradiated latex.

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