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RESEARCH ARTICLE

HIGH PERFORMANCE NANO CLAY COMPOSITES FOR ELECTRONIC APPLICATIONS

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Abstract:
The primary aim of the study has been to investigate the effect of nano layer distribution in latex matrix, on the mechanical properties, of the latex-nano particle composites. The nano particles selected are organically modified nano clay. It was observed that the key for nano composite technology is the exfoliation of the nano particles into their individual platelets. In this study nano clay is used as filler and is separately incorporated into the latex matrix and the corresponding nano composites are prepared by co-vulcanization method. The mechanical properties are measured and compared with the corresponding macroscopic latex-clay composites. The study reveals that there is a remarkable increase in the properties when nano clay is used as filler in the latex matrix due to the improved latex-nano particle interaction and better homogeneity in the distribution of nano particles in the latex matrix. The effects of nanolayer reinforcement are manifested in terms of reduced swelling by solvents and higher modulus values in the latex-nano particle composites. Tunneling electron microscopic studies (TEM) are conducted to evaluate the extent filler- latex interaction.

Keywords: Better homogeneity, Latex nano particle composites, TEM, Nano layer reinforcement.

Introduction

Polymer materials are usually reinforced with fillers to improve the mechanical properties. Such materials like nano clay can be widely used in the diverse areas including electronics, communication, transportation, construction and consumer products due to its enhanced mechanical properties. Glass fibres, clay, silica and carbon fibres are popular fillers. According to the theories of Cox and Kelly [1, 2], the degree to reinforcement depends on the rigidity and aspect ratio of the filler and the adhesive strength between the filler and the polymer matrix.

The major advantages of adding filler to rubber compound are the reduction in cost of the products and the reinforcement of rubber. Many studies have been published explaining the reinforcing property of carbon black in rubber. But the use of fillers, both reinforcing filler like carbon, silica, etc and non reinforcing fillers like clay, calcium carbonate in latex products is limited since they affect the mechanical properties adversely [3]. The reduction in vulcanizate properties may be due to the lack of proper distribution of filler in the latex, time gap between the deposition of the filler and rubber particles and the presence of protective surface coating both on the rubber particles and the filler [4]. In order to improve rubber- filler interaction, nano fillers are used in the place of conventional fillers especially non reinforcing fillers in dry rubber compounding [5, 6]. But in latex compounding, such nano fillers are not common as it will affect the stability of the latex. However it may be possible to incorporate nano fillers to improve the rubber-filler interactions and hence develop filled latex products.

Earlier workers have studied the reinforcement of clay filler in NR latex. In this case phase mixing typically occurs on a macroscopic length scale. But the study of reinforcement of nano clay filler in NR latex has not been reported earlier. In this case latex-nano clay composite is formed when phase mixing occurs on a nano meter length scale. The overall properties of a composite material are determined not only by the parent components but also by the composite phase morphology and interfacial properties. Nanocomposites usually exhibit improved performance properties compared with conventional composites owing to their unique phase morphology and improved interfacial properties. For these reasons, nano- structured organic- inorganic composites have attracted considerable attention from both a fundamental research and an applications point of view [7, 8]. This study has been undertaken to determine the mechanical properties of latex- nano clay composites and latex- clay conventional composites.

2. Experimental

Centrifuged latex containing 60% DRC was used for the study. All water insoluble compounding ingredients except nonox styrenated phenol (SP) were prepared as 50% dispersions using a ball mill. The nonox SP was prepared as 30% emulsion. The stabilizers used potassium hydroxide and potassium oleate was prepared as 10% solutions is water. 40% china clay filler dispersion was also prepared.

2.1 Preparation of 20% nano clay dispersion

5 gm of organically modified nano clay is accurately weighted and taken in a clean 250 c.c beaker. 20gms of distilled water is added followed by 0.05 gm. of dispersol F and 0.05 gm of dispersion stabilising liquid. The ingredients in the beaker were stirred gently and steadily on a magnetic stirrer at 500 rpm for 96 hrs continuously so as to form a uniform dispersion. Then the beaker with the dispersion was kept open for 24 hrs to expel all the bubbles and faces of air entrapped in the dispersion. The formulations of different latex compounds are given in table l and table 2 respectively. The centrifuged latex was taken in a glass vessel and de ammoniated to 0.2 percent ammonia content. Then it was stabilised by adding potassium hydroxide and potassium oleate solutions. The vulcanising agent sulphur, nonox styrenated phenol, ZDC and ZnO were added as dispersions. The contents were stirred gently and get homogenised. Then the base latex compound was formed.

The precipitated silica dispersion of 2.5 phr, 5 phr, 7.5 phr and 10 phr of 40% conventional clay dispersion was added separately to the respective base latex compounds. Similarly 0.2 phr, 0.4 phr, 0.6 phr, 0.8 phr, 1.0 phr of 20% nanosilica dispersion was incorporated separately into the respective base latex compounds and homogenised. Maturation was given and the latex films of the base latex compound, clay and nano clay filled latex compounds were cast on the glass dishes in each case by Flint and Naunton [9].

2.2 Optimums cure time of the latex compounds

The base latex films were dried at room temperature for 24 hrs. They were vulcanised at 110°C, varying the time from 25 to 40 minutes in an air oven. Dumbbell shaped tensile pieces were punched out of these and cast sheets and tensile properties were measured, using a Zwick universal testing machine. The cure time of the sample for which maximum tensile strength was obtained was taken as the optimum cure time.

After drying for 24 hrs, the base latex film, the clay, and nano clay latex films were vulcanised at 110°C for optimum cure time. The moulded samples were then cooled and dumbbell specimens were cut out of the sheets for tensile testing. The tensile strength, the elongation at break, and the modulus of the vulcanizates were measured using a Zwick universal testing machine model 1445 at an extension rate of 500 mm/min as per ASTM standards. Angular test specimens were punched out of the moulded sheets and the tear strength of the selected vulcanizates was measured on the Zwick UTM.
The swelling index of the samples of base latex compound, clay and nano clay filled latex compounds was determined by equilibrium swelling in toluene according o the following equation

$$\text{Swelling index} = \frac{\text{swollen weight - de swollen weight}}{\text{Initial weight}}$$

Tunnelling electron microscopic photographs of latex-clay and latex- nano clay composites were taken by a TEM 2500J model instrument.

3. Results and Discussion

3.1 Evaluation of tensile properties

Figure1 shows the variation of tensile strength of the base latex vulcanizate with different cure times at a temperature of 110°C. At this temperature the tensile strength of the Vulcanizate increases with cure time. The maximum tensile strength is found out for a vulcanizate gate having the cure time of 28 minutes which is regarded as the optimum cure time at 110°C. So in this study optimum cure time of 28 minutes is fixed to give the other Vulcanizates at 110°C. At the time of 30 minutes the tensile strength of the Vulcanizate is found to be decreased. The table 3 shows the variation of tensile properties of the Vulcanizates at the temperature 110°C with different cure times.

Figures2 and 3 shows the variation of tensile strength of the clay filled and nano clay filled NR latex vulcanizates with the amount of the filler respectively. In the case of

clay filled NR latex vulcanizates it is found that the tensile strength decreases continuously with the amount of the filler. It may be due to the poor latex-filler interaction and also due to the non uniformity in the filler distribution. But in the case of nano clay filled NR latex vulcanizates, the tensile strength increases gradually and reaches a maximum and then slightly decreases. It is noted that maximum tensile strength is observed at a lower level of nano clay filler loading of 0.6 phr. of 20% dispersion, compared to the clay filler loading of 2-10phr of 40% dispersion of clay, used in the study. The net improvement in tensile strength is found to be 30%. This remarkable increase in tensile strength of nano clay filled NR latex vulcanizates compared to the continuous, decrease in tensile strength of the ordinary clay filled NR latex vulcanizates may be due to the more homogeneous distribution of the nano clay in the latex compounds and also may be due to the improved latex-nano clay interaction. Moreover the unique phase morphology and improved interfacial properties are also responsible for the better performance properties of the latex-clay nano composites compared to the conventional composites [10- 14].

Figure 4 and Figure 5 describes the variation of elongation at break of the clay filled and nano clay filled NR vulcanizates with the amount of filler respectively. The elongation at break is found to decrease continuously with the amount of the clay filler in the case of NR latex-clay. This also may be due to the poor latex-clay composites interaction and also may be due to the non uniformity in the filler clay distribution. But in the case of NR latex-nano clay composites the elongation at break gradually increases and reaches a maximum value and then decreases. The maximum value of elongation at break is noticed at a lower level of nano clay filler loading 0.6phr of 20% dispersion of the filler compared to the clay filler loading of 2-10phr of 40% dispersion of the clay, used in the study.

The increase is elongation at break of NR latex-nano clay composites may be due to the more uniform homogeneous distribution of nano clay in the latex matrix and also due to the improved latex-nano clay interaction. Besides, the unique phase morphology and improved interfacial properties are also responsible for the improved performance properties of the latex- nano clay composites compared to the conventional latex-clay composites.

Figure.6 shows the effect of different dosage of the filler, clay on the tear strength of the conventional latex-clay composites. Here also the tear strength continuously reduces with the amount of the clay in the latex as in the case of tensile properties. Figure 7 gives the variation of tear strength of the nano clay filled NR latex vulcanizates with the amount of the nano clay. In this case also, even at the very low nano clay filler loading of 0.6 phr, the tear strength is found to be higher due to the unique phase morphology and the improved interfacial properties of the latex-nano clay composites compared to the latex-clay conventional composites. Moreover higher latex-nano clay filler interaction in the latex-clay nano composites and the more uniform nano clay distribution which in turn due to the more uniform surface area of the nano clay filler compared to the conventional latex-clay composites again shows that, nano composites exhibit improved performance properties compared with conventional composites.

Table 4 shows the variation of the modulus and the swelling index values of the latex-clay composites, and table5 shows the variation of the modulus and the swelling index values of the latex-nano clay composites. The modulus values are found to be higher for the latex-nano clay compounds compared to the latex-clay conventional composites. The increased modulus values shown by the latex-nano clay vulcanizates may be due to the higher latex-nano clay interaction and also due to the more uniform nano clay distributions. In the case of swelling index values, the latex-nano clay composites show, lower values due to the reduced swelling by solvents compared to the conventional latex-clay composites. This depicts that the addition of nano clay restricts swelling due to more latex-nano clay attachment compared to the latex-clay attachment in the conventional composites.

Figure 8 and 9 shows the TEM photographs of latex-silica and latex- nanosilica composite respectively. Latex- nano silica photograph shows better homogeneity, better filler interaction and uniform exfoliation throughout the latex matrices. This also supports the enhancement of the mechanical properties of the latex-nano silica composites.

4. Conclusions

The study shows that the clay nano particle distribution in the NR latex matrix affects the mechanical properties. The following conclusions can be drawn from the study.

1. The exfoliation of organically modified nanoclay in the latex greatly improves the mechanical properties of the matrix through the reinforcement provided by the silicate nano layers. So it can be used as an effective resistor in electronic transistor systems for a longer period of time.
2. The effects of nanolayer reinforcement are also manifested in terms of reduced swelling by solvents, and higher modulus values.
3. Lesser amount of nano clay (0.6phr of 20% nano clay dispersion) is only required for the better mechanical properties compared to the amount of clay (up to 10 phr of 40% clay dispersions) in the

Table.1 Formulations of the base latex compound

Ingredients	Unfilled
NR Latex	167
10% KOH	1.0
10% Pot. Oleate	1.0
50% ZnO	1.0
50% ZDC	2.0
50% Sulfur	2.0
30% Nonox SP	3.0

Table.2 Formulations of the latex filled nano composites.

Ingredients	Parts by weight (wet) gm								
	Latex-clay composites				Latex clay nano-composites				
NR Latex	167	167	167	167	167	167	167	167	167
10% KOH	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10% Pot. Oleate	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
50% ZnO	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
50% ZDC	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
50% Sulfur	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
30% Nono SP	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Clay	2.5	5.0	7.5	10	-	-	-	-	-
Nano-clay	-	-	-	-	0.2	0.4	0.6	0.8	1.0

Table 3 Variation of tensile parameters of base latex compound.

Temperature	Time (minutes)	Tensile strength MPa	Elongation at break (%)
110	20	25.16	1525
110	22	26.04	1485
110	24	27.18	1463
110	26	28.42	1440
110	28	29.87	1465
110	30	28.01	1350

Fig.1 Variation of tensile strength of the base latex compound.

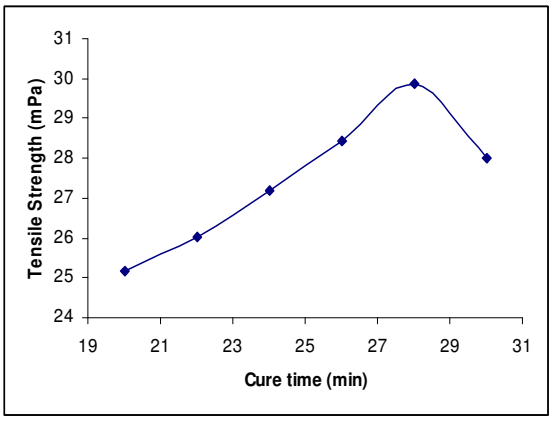


Fig. 2 Variation of tensile strength of latex-clay composites with the amount of clay.

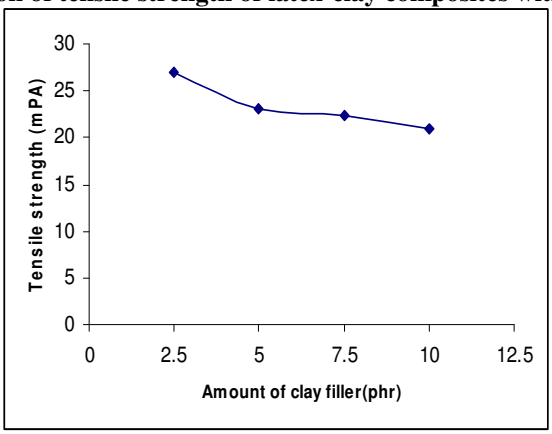


Fig.3 Variation of tensile strength of latex-clay nano composites with the amount of nano clay

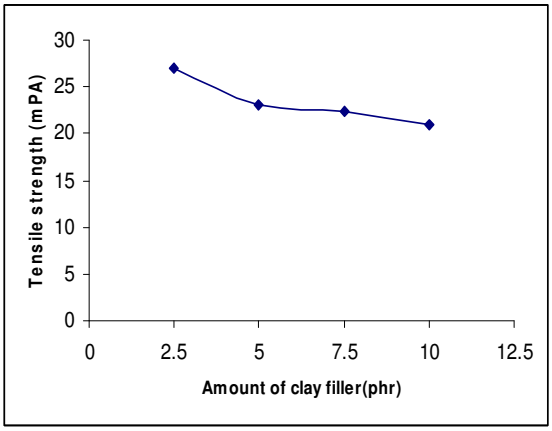


Fig.4 Variation of Elongation at Break of latex-clay composites with the amount of clay.

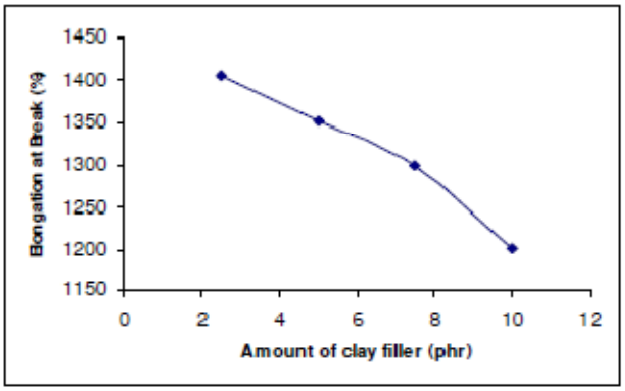


Fig.5 Variation of Elongation at Break of latex-clay nano composites with the amount of nano clay

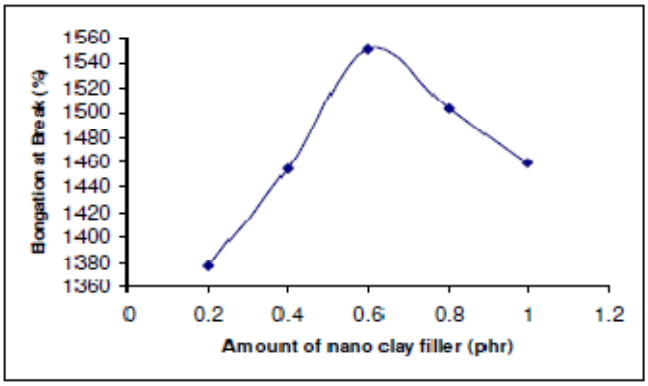


Fig. 6. Variation of tear strength of the latex-clay composites with the amount of clay filler.

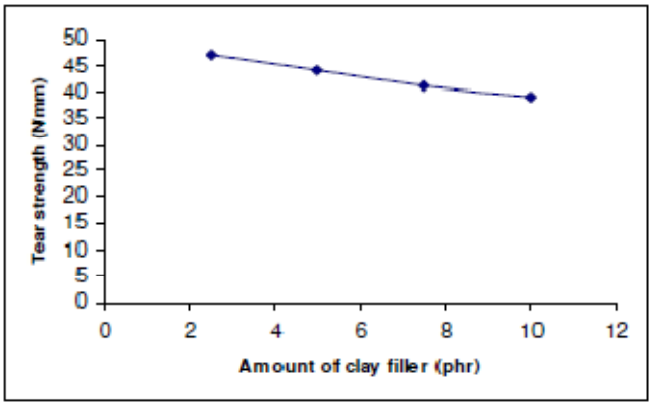
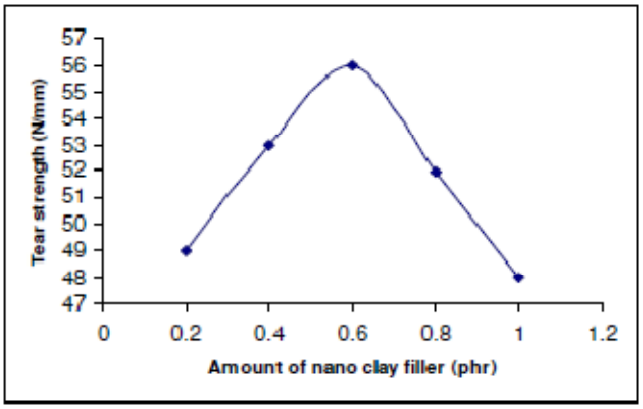


Fig. 7 Variation of tear strength of the latex clay nano composites with the amount of nano clay filler.



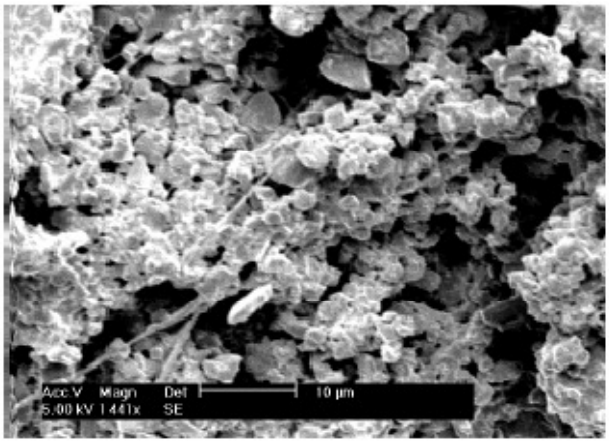


Fig.8. TEM photograph of NR latex- clay composite.

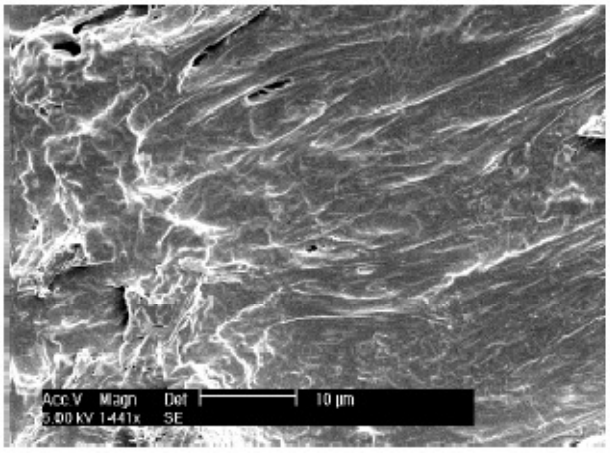


Fig. 9. TEM photograph NR latex- nano clay composite.

Clay Filler Loading (Phr)	Modulus (%)	Swelling Index
2.5	1.37	1.51
5	1.53	1.89
7.5	1.78	1.99
10	1.85	2.33

Table 4.Variation of Modulus and Swelling Index of latex-clay composites with clay filler loading.

Nano Clay Filler Loading (Phr)	Modulus (%)	Swelling Index
0.2	1.98	1.55
0.4	2.25	1.43
0.6	2.62	1.21
0.8	2.50	1.48
1	2.23	1.65

Table 5.Variation of Modulus and Swelling Index of latex-Silica Nano Composites.

conventional latex-clay composites.

4. The mechanical properties of the conventional latex-clay composites continuously decrease with increase in the amount of clay filler.

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