

### SUMMARY AND CONCLUSIONS

All rubbers have shortcomings in one or more properties. Thus there are technical reasons for blending two rubbers in order to achieve the right compromise. Processing difficulties may also be overcome by blending. Appreciable difference in price of different rubbers emphasizes economic reasons for blends. In developing a useful blend, there is a need to understand which elastomers can be successfully blended and what underlying factors influence the results.

The data presented in this thesis consist of the results of a systematic study conducted on the morphology, vulcanisation kinetics, melt flow behaviour, miscibility behaviour, effect of fillers and degradation behaviour of NR-EVA blends. The effects of blend ratio and filler on the cell structure and properties of microcellular soles based on NR-EVA blends have also been investigated. Emphasis has been given for studying the effect of different crosslinking systems on the above characteristics of the blends. It is expected that these blends can be advantageously used in many applications such as footwear, tubings, cables, automobile components, etc.

The thesis consists of eight chapters. The first chapter deals with various aspects of elastomer blends and a review of the earlier

work done in the field of elastomer blends. The scope and objectives of the present work are also given in this chapter. Types of commercially available elastomer blends, problems associated with blend formation, necessity for blending elastomers and the major advantages of elastomer blends have been reviewed. The melt flow behaviour, morphology of blends and methods to characterise the polymer blends have also been discussed in this chapter.

The second chapter contains a detailed account of the experimental procedures adopted for the preparation of the blends and the test samples. The description of the testing procedures and the details of the equipment used are included in this chapter. The characteristics of the materials used for the study are also described in this chapter.

The third chapter describes the effect of blend ratio on morphology and the effect of three cure systems on the vulcanisation kinetics and technical properties of NR-EVA blends. The morphology of NR-EVA blends was such that the EVA formed the dispersed phase where its proportion was below 40 per cent and NR formed the dispersed phase when its proportion was 40 per cent or below. In the range of 40:60 and 50:50 EVA:NR both polymers formed continuous phases leading to an interpenetrating network structure. Blending of EVA with NR increased the tear resistance, modulus, hardness and abrasion resistance and adversely affected the compression set

and rebound resilience of NR, at all proportions. Morphology-property relationship has been made. In NR-EVA blends a mixed cure system consisting of DCP and sulphur gave better technological properties than DCP alone, especially at high proportion of NR. The activation energy and cure time were found to be lower in the case of mixed cure blends.

Chapter four discusses miscibility and crystallization behaviour of NR-EVA blends. The thermal behaviour, crystallinity and dynamic mechanical properties of the blends have been investigated with special reference to the effect of blend ratio and crosslinking systems. The DSC and DMTA results showed that the blends are incompatible in crosslinked and in uncrosslinked state. The predominant crosslinking of natural rubber phase as a result of the addition of sulphur or mixed crosslinking agent could be analysed by the shift in the glass transition temperature of the natural rubber phase towards higher temperatures. Addition of NR to EVA decreased the crystallinity of the EVA, as evidenced by the DSC and X-ray analysis.

The effects of blend ratio, crosslinking systems, silica content and temperature on the melt flow behaviour of NR-EVA blends are reported in chapter five. The extrudate morphology of the blends at different shear rates has also been reported in this chapter. All systems showed pseudoplastic behaviour as evident

from the decrease in viscosity with increase in shear stress. The decrease of viscosity of the blends with the increase of temperature was prominent at low shear rates. At lower shear stress ( $< 3 \times 10^5 \text{ N/mm}^2$ ), the viscosity of the blends appeared to be non-additive function of the viscosity of the homopolymers. This behaviour was observed at the lower proportion of the EVA phase ( $< 40\%$ ) where it formed a dispersed phase in the continuous NR matrix. The observed anomaly has been explained due to the structural build up of EVA particles in the NR matrix at lower shear region.

Extrudate morphology of the blends showed that at higher shear forces the NR domains are broken down into smaller particles. The stratification of the extrudates with NR forming the core region and EVA as the sheath was observed. This is associated with the migration of low viscosity EVA phase towards the periphery of the extrudate.

The sixth chapter consists of the results of the studies on the effect of silica on mechanical and dynamic mechanical properties of NR-EVA blends. Precipitated silica improved the tear strength and did not affect the tensile strength when the proportion of NR in the blend was higher. Addition of silica adversely affected the technological properties, except compression set of blends having higher proportions of EVA. Silica was found to impart resistance to degradation by  $\gamma$ -radiation and ozone, for NR-EVA blends.  $\tan \delta$

values of unfilled blends increased as a function of temperature. Addition of silica decreased the  $\tan \delta$  values. Addition of silica increased the storage modulus. The loss modulus of filled and unfilled blends decreased with temperature. In the case of EVA and high EVA blends the storage modulus decreased with temperature and the decrease was more sharp in the rubbery region.

The seventh chapter describes the degradation behaviour of NR-EVA blends. The effect of blend ratio and the type of crosslinking system on thermal ageing,  $\gamma$ -radiation and ozone resistance of the blends have been evaluated. It is observed that blends containing higher proportion of EVA show better thermal ageing and  $\gamma$ -radiation resistance. It is also noted that mixed cure system gives lower retention of tensile strength after thermal ageing and  $\gamma$ -irradiation. But modulus 300% is better for this system. The ozone resistance of peroxide cured vulcanisate was better than that of the other cure systems. The morphological studies discussed in the third chapter help to explain the degradation behaviour of the blends.

The eighth chapter of the thesis describes the effects of blend ratio and fillers on the cell structure and properties of microcellular sheets made from NR-EVA blends. The concentration of blowing agent was adjusted so as to get the same expansion in all the blends. Higher proportions of the EVA in the blend enhanced the abrasion resistance and split tear strength of microcellular sheets based on

NR. As the proportion of EVA is increased compression set and shrinkage are increased. The change in properties with increasing EVA content is basically due to the characteristics of EVA and the accompanying change in cell structure of the microcellular sheet. Among china clay and calcium carbonate fillers, the latter one imparted higher expansion and split tear strength and gave lower set and abrasion resistance.