DESIGN, PREPARATION, PERFORMANCE, INDUSTRIALIZATION AND APPLICATION OF ADVANCED CLAY/RUBBER NANOCOMPOSITES

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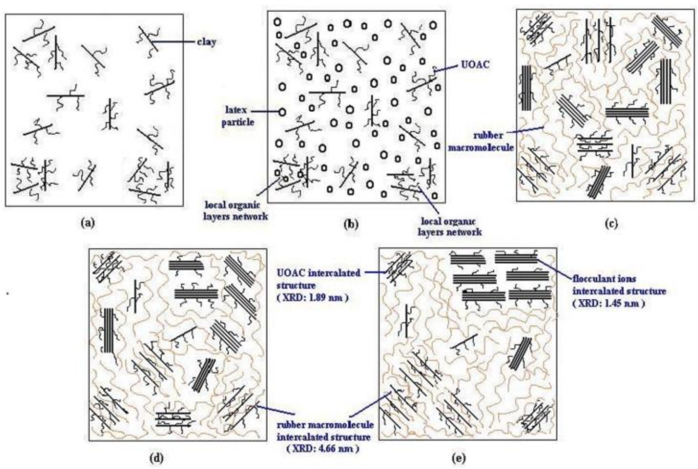
Introduction

Polymer-clay nanocomposites are of great interest for both scientific challenges and industrial applications. Based on our research for over 15 years, design, preparation, performance, industrialization and application of advanced clay/rubber nanocomposites were reviewed and summarized. Based on the advantages, clay/rubber nancomposites can be applied in rubber tire tread composites, inner layer composites and transportation composites. The corresponding products prepared from these new clay/rubber composites exhibit higher performance and low-cost. The first clay/rubber nanocomposites masterbatch production line in the world was established in China and was expected to push these composites moving forward. This paper also reported the progress of fibril silicate/rubber nanocomposites and nano-tube/rubber nanocomposites, and a comparison among them was made.

Results and Discussion

Fig. 1: Scheme of preparation process of clay/rubber nanocomposites by latex compounding method [1-3]



Na^+-MMT was modified organically in situ in its aqueous suspension by controlling the amount of modifier, an UOAC, to prevent clay aggregation. SBR latex and the modified MMT aqueous suspension were mixed to prepare organically modified MMT-SBR nanocomposites by the LCM method. The dispersion structure of nanocomposites by this new strategy can be defined as a"separated structure" with part rubber-intercalated structure.

Fig. 2. Morphology of clay/rubber nanocomposites: 2a nanocomposite with low loading clay (4vol%) by LCM; 2b SBRCN-60wt%(150phr OMC) nanocomposite with high loading clay (150 phr) by melting blending; 2c exfoliated structural nanocomposite by LCM.[4-6]

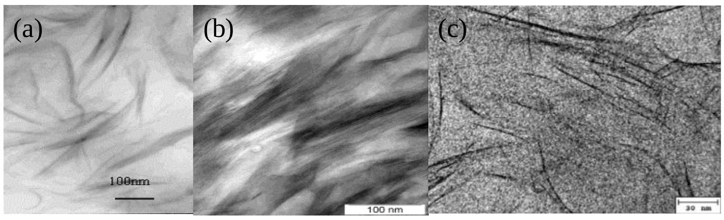
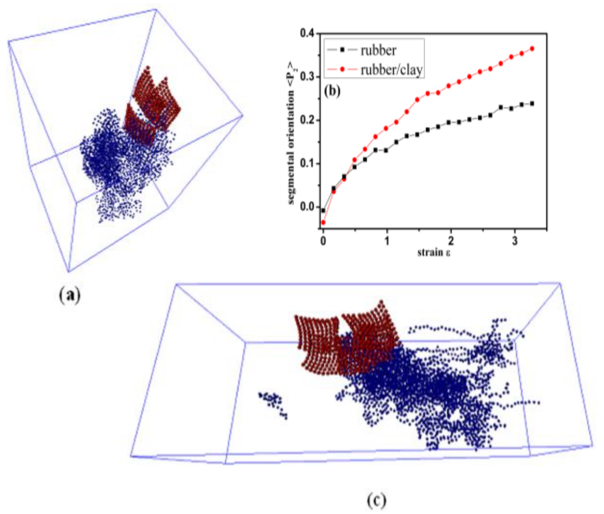


Fig. 3. The performance of clay/rubber nanocomposites: 3a stress-strain curve; 3b gas barrier property; 3c Effects of the clay amount on the flex fatigue life of the composites.[7-8]



These advanced nanocomposites exhibit excellent mechanical and gas barrier properties. The flex fatigue life of carbon black filled styrene-butadiene rubber (SBR) was dramatically improved by incorporation of 4-5 phr nanodispersed clay, which was attributed to the orientation of clay layers and macromolecules chains during fatigue process. Figure 4 is the results of orientation of clay layers and molecular chains illustrated by Molecular Simulation Method. Figure 5 presents a basic process of industrialization of clay/Natural Rubber nanocomposites.

Fig. 4. Orientation of clay layers and molecules during stretching demonstrated by molecule simulation (a) Snapshot of polymer chains filled with clay sheets. Note that for clarify only partial polymer chains and clay sheets are shown. (b) the chain segmental orientation characterized by $<P_2>=(3<\cos^2\theta>-1)/2$ as a function of the strain for rubber and rubber/clay systems.(c) Snapshot of the tensile state of polymer chains filled with clay sheets, note that for clarify only partial polymer chains and clay sheets are shown.

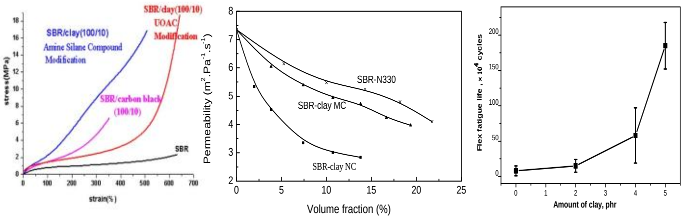


Fig. 5. The industrialization of rubber/clay nanocomposites based on Latex Compounding Method

Conclusion

Among many preparation methods, latex compounding and melt blending methods are of low-cost, easy-controllable and better dispersion and very suitable for rubber based nanocomposites. A series of clay/rubber nanocomposites with varied clay loading from very low to very high level and different interfacial interaction and clay dispersion state were designed and prepared by the two methods. Comprehensive mechanical performance of gum rubber was dramatically improved and could be adjusted by preparation method, clay loading and interfacial interaction. Percolation theory was developed to explain the high nano-reinforcement effect combined with stress transfer theory. Gas barrier property of rubber was also greatly enhanced as expected. Additionally, it was found that incorporation of small amounts of clay layers could greatly improved fatigue-resistance and chipping-cutting resistance of rubber materials, which was attributed to that clay layers could prevent cracks from propagating and induce molecules orientation during stretching process. Molecule dynamic simulation was employed to clarify this assumption with the assistance of TEM observation. However, the distinct and serious flocculation of clay layers driven by temperature and pressure during processing due to the fast motion of elastomer macromolecules should be considered and prohibited. Based on above advantages of clay/rubber nancomposites, rubber tire tread composites, inner layer composites and transportation composites were designed and made. The corresponding products prepared from these new clay/rubber composites exhibit higher performance and low-cost.

Acknowledgments

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