



DEVELOPMENT OF HIGH PERFORMANCE HYBRID SYNTACTIC FOAMS: STRUCTURE AND MATERIAL PROPERTY CHARACTERIZATION

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ABSTRACT

Syntactic foams are light weight particulate composites that use hollow particles (microballoons) as reinforcement in a polymer resin matrix [1]. High strength microballoons provide closed cell porosity which helps in reducing weight of the material. Due to their wide range of possible applications such as in aerospace and marine structures, it is desirable to modify the physical and mechanical properties of syntactic foams as per the requirements of an application. Various filler materials can be used to modify the foam microstructure to attain these desired properties [1]. The present study deals with increasing the fracture strain and damage tolerance properties of epoxy resin/glass microballoon syntactic foams without a significant decrease in their strength. An approach of modifying the matrix resin with the incorporation of a third phase in the form of filler particles is adopted, resulting in *hybrid syntactic foams*. Two types of hybrid foams are developed using *rubber particle* and *nanoclay particle* fillers respectively.

Such highly damage tolerant hybrid foams will be useful as sandwich core material in automobile, aerospace, and marine structures [1, 3]. This approach effectively increases the fracture strain of syntactic foams without a significant reduction in strength. Another aspect of this study is to focus on using waste industrial materials (rubber particles, Figure 1.) and low cost fillers (nanoclay particles) [5-7] in developing high-performance and cost effective composites.

All foam samples are fabricated using glass microballoons and a resin system made up of D.E.R. 332 epoxy resin, amine based hardener and a diluent. Rubber particles and nanoclay particles respectively are added as a third phase and the mixture is cast in stainless steel molds to obtain rubber hybrid and nanoclay hybrid foams respectively. The hybrid foams are characterized for compressive strength properties. Results obtained are compared with those published by other researchers [2-4]. Enhancement in ductility is achieved in all rubber hybrid

foams without any significant loss in strength as seen in Figure 2.

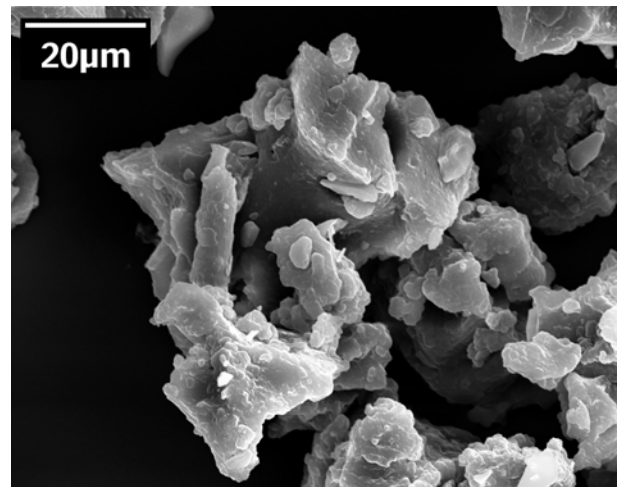


Figure 1 High magnification SEM micrograph of a rubber particle used in the study.

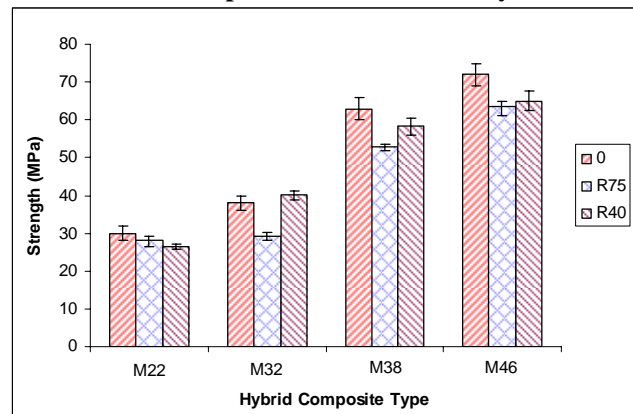


Figure 2. Compressive strength of various hybrid foams containing R75 and R40 rubber particles compared to the corresponding foams without rubber particles.

Compressive modulus (Figure 3) is found to decrease by

about 50%, whereas decrease of about 10% is observed in the compressive strength due to the incorporation of rubber particles. Considerable enhancement in compressive toughness and fracture strain due to incorporation of rubber particles is observed in terms of significantly extended stress plateau region in stress-strain curves of all hybrid foams. Fracture strain of low density foams increased about two times with only about 10% decrease in strength.

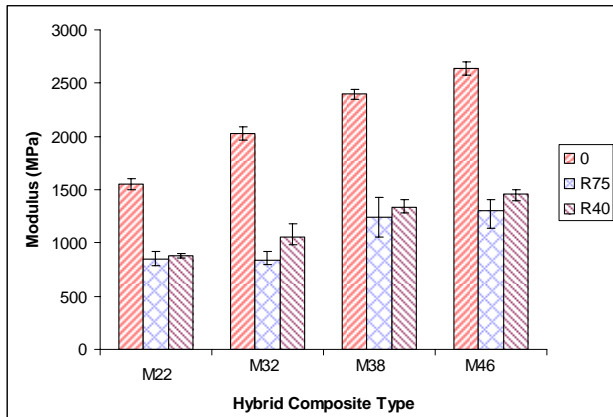


Figure 3. Modulus of various hybrid foams containing R75 and R40 rubber particles compared to the corresponding foams without rubber particles.

Figure 4 shows results from compression test of nanoclay hybrid foams. Nearly 10-20% reduction in compressive strength is observed due to the incorporation of 2% nanoclay by volume, and no significant change in strength is observed due to incorporation of 5% nanoclay by volume.

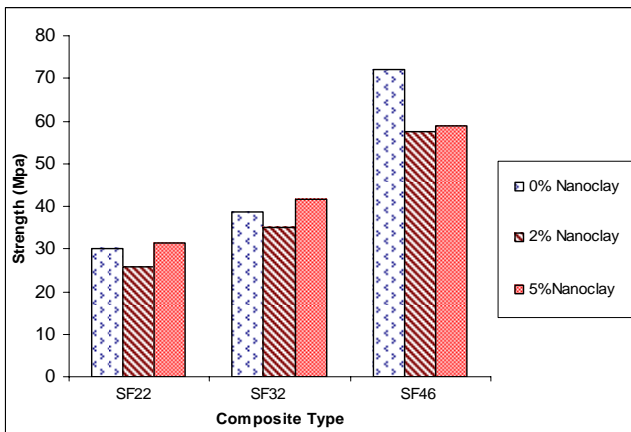


Figure 4 Compressive strength of foams with different microballoons and nanoclay volume fractions.

Increase in fracture strain with little change in strength caused considerable increase in toughness of the material. Toughness, measured as area under the stress strain curves, shows about 80 and 125% increase due to incorporation of 2 and 5% nanoclay in low density syntactic foams. In medium density foams the increase is found to be about 150 and

200% for the same nanoclay contents. In high density foams the toughness has increased by about 125% due to the incorporation of nanoclay. Specimens do not show a definite fracture point even at strains as high as 35%. Partial intercalation of nanoclay particles is obtained in the matrix material, which is observed through TEM (Figure 5).

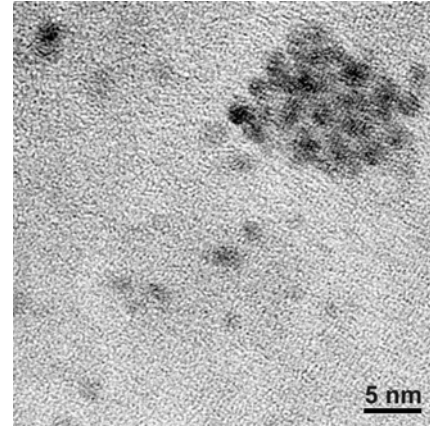


Figure 5 High-resolution TEM image of nanoclay/epoxy composite with a 2% volume fraction of nanoclay.

ACKNOWLEDGMENTS

The author wishes to thank the DOW Chemical Company, 3M Corporation and Rouse Polymeric for providing epoxy resin, glass microballoons, and rubber particles, respectively, and related technical information.

REFERENCES

1. Shutov FA., 1991, Syntactic polymeric foams, In: Klempner D, Frisch KC, editors. Handbook of polymeric Foams and Foam Technology, Hanser Publishers, New York.
2. Gupta, N., Kishore, Woldesenbet, E., and Sankaran S., 2001, "Studies on compressive failure features in syntactic foam material", Journal of Materials Science, **36**, 18, pp. 4485-4491.
3. Gupta N, E. Woldesenbet, and P. Mensah, 2004, "Compression properties of syntactic foams: effect of cenosphere radius ratio and specimen aspect ratio", Composites A: Applied Science and Manufacturing, **35**(1), pp. 103-111.
4. Gupta, N. and Woldesenbet, E., 2004, "Microballoon wall thickness effects on properties of syntactic foams", Journal of Cellular Plastics, **40**, pp. 461-480.
5. Pinnavia, T.J. and Beall, G.W., 2000, Polymer-Clay Nanocomposites, Wiley Series Polymer Sci.
6. Messersmith, P.B. and Stupp, S.I., 1992, "Synthesis of Nanocomposites – Organoceramics", Journal of Materials Research, **7**, pp. 2599-2611.
7. Novak, B.M., 1993, "Hybrid Nanocomposite Materials – Between Inorganic Glasses and Organic Polymers", Adv. Mater. **5**, pp. 422-433.