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ASSESSMENT ON THE COMPRESSIVE STRENGTH BEHAVIOR OF HYBRID FILLED EPOXY NANOCOMPOSITE

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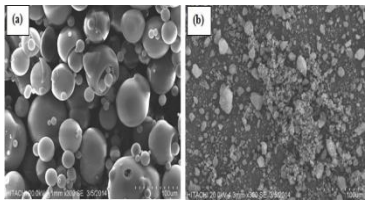
Graphical abstract



Abstract

Compressive strength of the epoxy matrix loaded by combination of hybrid filler is expected to benefit by the hollow nature of microsphere and highly porous silica aerogel and, consequently it also depends on the suitable ratio of microsphere:silica aerogel (Mic:SilAe). In this study, the morphology of the fillers was investigated by Scanning Electron Microscope (SEM) for microstructure analysis. The nanocomposite was then prepared by shear mixing technique. Compressive yield and fracture strength behavior were assessed as a function of Mic:SilAe ratios and its dispersion in epoxy matrix. The compressive yield and fracture strength increased monotonously with inclusion of considerable ratio of Mic:SilAe. The optimum loading of Mic:SilAe in epoxy nanocomposite was attained at filler ratio of 1:1 for compressive yield strength and filler ratio of 5:1 for compressive fracture strength, where the improvement were 28% and 90%, respectively.

***Keywords*:** Compressive, epoxy, nanocomposite, silica aerogel, microsphere

1.0 INTRODUCTION

The mechanical properties of composite reinforced with porous fillers have been studied extensively [1-2]. Dispersion of hollow or porous materials creates porous composite with closed cells. Different amount of hollow or porous fillers can create composite with foam microstructures. In addition, the density of the produced composite will be reduced and allow for the fabrication of light weight materials with high filler content. Better interfacial adhesion between microspeheres and resin resulted in better mechanical properties. High compressive stress of composite reinforced with microsphere corresponds to the energy absorption in the process of crushing of microsphere and loading of microsphere [2]. Besides that, the composite compressive stiffness increased together with filler content too. Moreover, inclusion of microspheres can improve the toughness of polymer matrix by improving the glass transition temperature of the matrix.

Composite microspheres hybrid with inorganic nanoparticles have attracted much interest in the many fields of application [4, 5]. The uniqueness about the hybridization of microsphere and nanoparticles are they can perform as a potential energy absorbing materials in light weight structures. Silica aerogel is nanoparticles that have high porosity above 90% which makes it as super insulation materials. However, silica aerogel have poor mechanical stability due to its nanoporous nature and high porosity. Thus, combination of silica aerogel with various fillers such as fiber, plastic and ceramic fillers has become an efficient method to improve the properties of aerogel composites [6]. It is believed that combinations of new properties can be extended to new applications by

the combination of micro and nanostructures size of fillers into the composite system. The present work aimed to investigate the compressive strength behavior of the epoxy nanocomposite by inclusion of microsphere and silica aerogel.

2.0 MATERIALS AND METHODS

2.1 Materials

The porous silica aerogel (SilAe) were obtained from Maerotech. Phenolic microsphere (Mic) used was BJO-0840 type and supplied by Malayan Adhesives & Chemical Sdn. Bhd. The epoxy used as the polymer matrix was EpoxAmite100 which was purchased from Smooth-On. Inc., Pennsylvania.

2.1 Composite Manufacturing

The Mic:SilAe were incorporated into the epoxy matrix with different weight fraction. The solution mixture was then stir vigorously using mechanical stirrer at room temperature for 3 minutes. Next, hardener is added into the solution and continue stir for 5 minutes. The complete solution was then cast onto a mould and place in a vacuum oven to remove trapped air and left cured in room temperature for 15 hours. Scanning electron microscope (SEM) model S-3400N was used to examine the morphology fillers. Compressive strength of the produced hybrid composite was determined using Instron testing machine (model 5900). The test is performed in reference to ISO 604 standard and the specimen dimension required for this test is 1 cm x 1 cm x 4 cm.

3.0 RESULTS AND DISCUSSION

3.1 Morphology Analysis

Figure 1 shows typical SEM micrograph on the phenolic microsphere and silica aerogel. In Figure 1a, the phenolic microsphere was in a sphere-like shape with a clean surface. The microsphere mean diameter size is about 70 µm. Some deformed microsphere can be observed. This indicates that phenolic microsphere possess certain degree of plasticity.

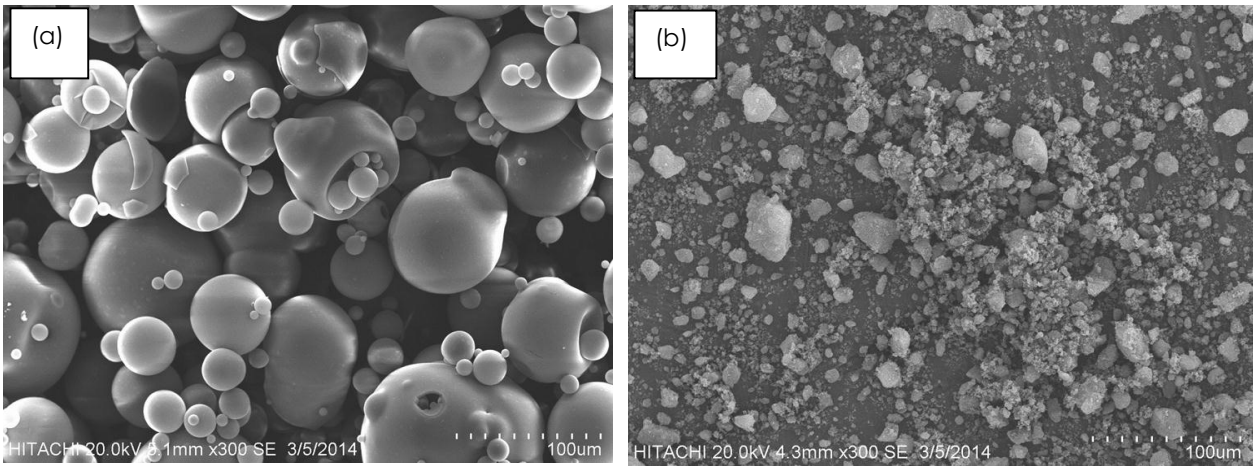


Figure 1 SEM micrograph of (a) phenolic microsphere and (b) silica aerogel

Meanwhile, in Figure 1b shows that the silica aerogel dimension was inconsistent and it have high tendency to clump together due to their high surface energy.

3.2 Compressive Strength

The compressive test provides information on the compressive yield strength and compressive fracture strength as shown in Figure 2. For each individual curve of the composite compressive strength, there are three different regions. Region 1 shows the linear linear elastic behavior of the epoxy nanocomposite. The region ends when the nanocomposite starts to yield and reaches its compressive yield strength. Region 2 shows the flatwise compression curve which correspond to the implosion of the phenolic microsphere under the increasing compression load. While further increase in the load result in the compaction of crushed microsphere and silica aerogel in epoxy nanocomposite.

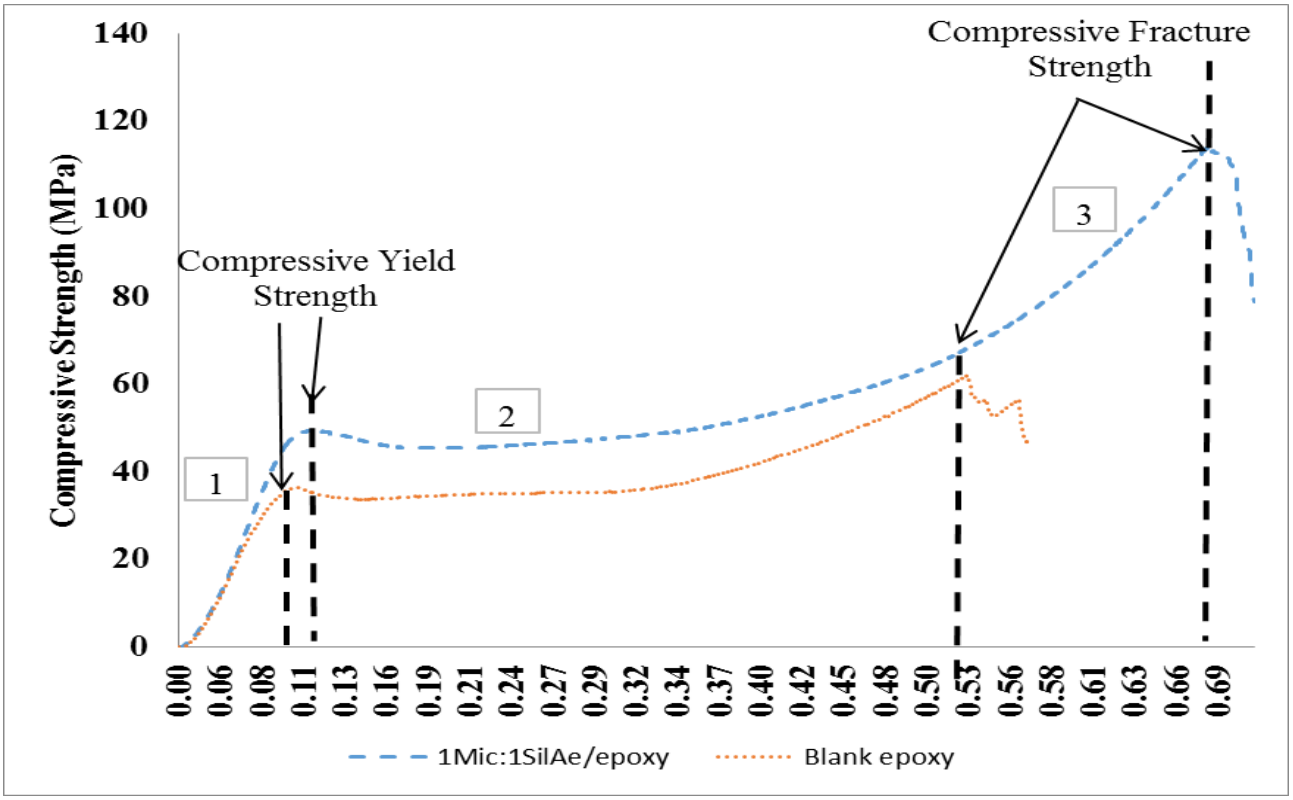


Figure 2 Compressive yield strength and compressive fracture strength trend line for 1Mic:1SilAe/epoxy and blank epoxy nanocomposites

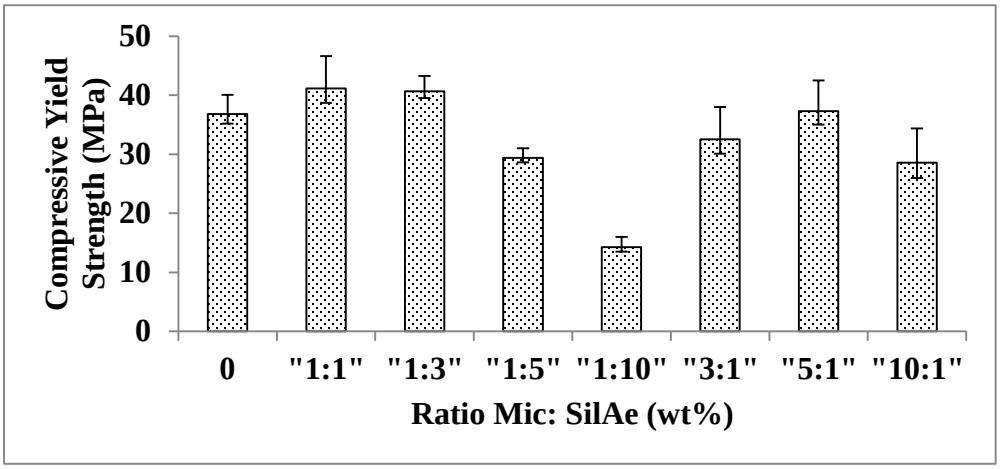


Figure 3 Compressive yield strength and compressive fracture strength trend line for 1Mic:1SilAe/epoxy and blank epoxy nanocomposites

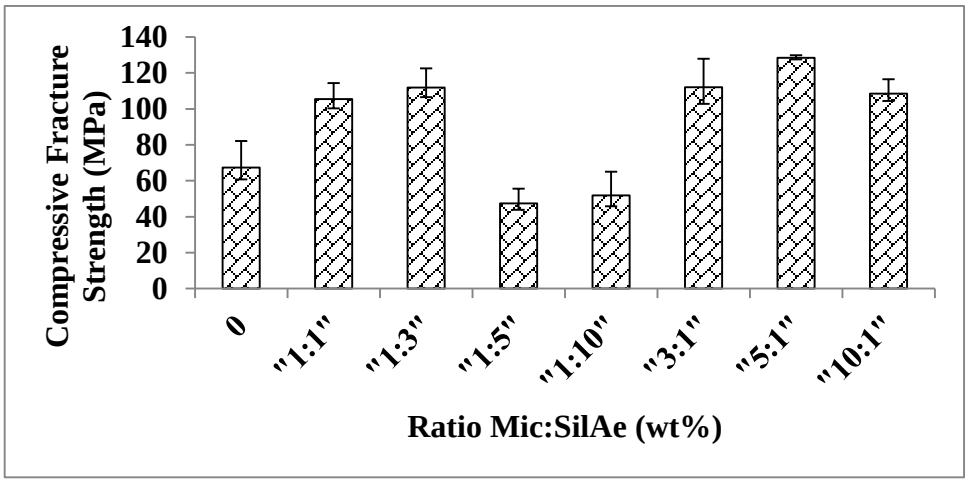


Figure 4 Effects of fillers weight fraction ratio on the compressive fracture strength of blank and hybrid epoxy nanocomposites.

The overall results of the compressive yield strength and compressive fracture strength are given in Figure 3 and Figure 4, respectively. Figure 3 shows that inclusion of 1Mic:1SilAe increase the compressive yield strength of the epoxy nanocomposite to 41.15 MPa. Inclusion of more SilAe up to 10 wt% with constant 1wt% of Mic (1:10), shows reduction in compressive yield strength to 14.29 MPa. Similarly, addition of 10 wt% of Mic and 1wt% of SilAe (10:1), tend to reduce the compressive yield strength of the epoxy nanocomposite. Inconsistent clump size of SilAe promotes lack of adhesion between filler and matrix. In addition, adding more SilAe into the epoxy nanocomposite system increased the tendency of SilAe to re-aggregates and reduced the surface area of SilAe to interact with epoxy. In Figure 4, the compressive fracture strength of the epoxy composite increased monotonously with increasing Mic content up to 5 wt% Mic loading with constant amount of 1wt% SilAe. Indeed, the compressive fracture strength of 5Mic:1SilAe/epoxy composite is markedly higher than blank epoxy and 1Mic:5SilAe/epoxy nanocomposite too. As Mic content increased up to 5wt% with constant 1wt% loading of SilAe, the epoxy volume decreased and both fillers are responsible to take up more load under compression, and as a result the compressive fracture strength increase. Addition of Mic above 5wt%, tends to weaken the structure of the nanocomposite due to the hollow nature of the microsphere act as voids [6].

4.0 SUMMARY

In conclusion, reinforcing of small loading of 1:1 (Mic:SilAe) in epoxy, increased the compressive yield strength of epoxy nanocomposite, while adding of more Mic loading in epoxy, the compressive fracture strength increased monotonously up to 5wt% of Mic content with constant 1wt% of SilAe loading (5:1). Combination of suitable ratio hollow nature microsphere and highly porous structure of silica aerogel with better dispersibility and good interfacial bonding explained the increment in compressive strength properties.

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