EVALUATING INTERFACIAL PERFORMANCE OF CARBON-EPOXY COMPOSITES BY FIBER BUNDLE TESTS: THE IMPACT OF NANOFILLER DIMENSION AND SURFACE CHEMISTRY

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1 General Introduction

Fiber-reinforced polymers (FRPs) generally possess different phases, including the matrix, the fibers, and the fiber/matrix interface [1]. The fiber-matrix interface is the transition phase uniting the matrix with the fiber [2]. It is well known that the fiber-matrix interface strongly affects the mechanical performance of fiber-reinforced polymer composites since it governs the load transfer [3]. Studies have revealed that introducing nanofillers into the polymer matrix can result in exceptional mechanical performance enhancements in the fiber-matrix interface. Depending on their one- or two-dimensional morphology, the introduced nanofillers can be responsible for various toughening mechanisms such as crack deflection, crack front pinning, and crack bridging [4]. Besides, nanofillers' chemical modification with the sizing or coating agents considerably enhances fiber and matrix adhesion [5]. Recently, the transverse fiber bundle tensile (TFBT) test has been successfully implemented to estimate the impact of interface modification on interfacial bonding performance [1]. Herein, we were inspired by the idea that nanofillers with different morphologies, including halloysite nanotubes (1D) and graphene nanoplatelets (2D), could lead to a stronger fiber/matrix interphase. The effects of morphology and type of nanofillers upon interfacial strength between matrix and reinforcement have been investigated. Transverse tensile and shear tests of nanoparticle modified epoxy-carbon fiber led to predict the interfacial strength in micro-scale via a facile and robust experimental methodology.

2 Materials and Methods

2.1 Materials

The KCF6K (Kordsa, Turkey) carbon fiber bundles were used in this study. commercially-available bisphenol A based epoxy resin (MGS® L160) with aliphatic curing agent (MGS® H160) was supplied by Momentive Hexion Inc. Commercially available a few layered GNPs (NG01GNP0101, purity > 99.9 %, average thickness 5 nm, average surface area:150 m^2g^{-1}, averaged diameter: 6 µm) were purchased from Nanografi Co. Ltd., (Turkey). HNTs (Al2Si2O5(OH)4) used as nano-reinforcements were supplied by Esan Eczacıbaşı. The diameter and the length of the nanotubes were in the range 20–60 and 100–600 nm, respectively. The silane coupling agent, (3-Aminopropyl)triethoxysilane (APTES), was purchased from Alfa Aesar® and used as received without any purification.

2.2 Sample Preparation

Desired amounts of nanofillers were first homogeneously dispersed in ethanol by tip sonicating (sonic frequency 20 kHz) for 15 min. APTES was introduced into the dispersion and the dispersion further mixed for 4 h at 40 °C. Following, the mixture was poured into the epoxy and tip sonicated for further 30 min. After that, the mixture was degassed in a vacuum oven to remove ethanol at 70 °C for 24 h. Upon removal of ethanol, hardener was added into the mixture, and it was mechanically stirred for 5 min. At this stage, TFBT and shear test samples were prepared by pouring the_mixture into the silicon molds as shown in Fig. 1. The fiber bundle specimens should be polished to reduce the surface roughness before mechanical tests.

2.3 Characterizations

The tensile and shear tests were conducted on a universal machine (Shimadzu AGX) at ambient temperature. The crosshead speed was 1 mm/min. The apparent tensile strength was obtained through dividing the maximum load by the area of the specimen cross section. After tests, the fracture surfaces of the failed specimens were observed using SEM (JEOL 6010).

3 Results and Discussions

3.1 Mechanical Performance

Fiber bundle tests are utilized to investigate the effectiveness of nanofillers with different morphologies and surface chemistry. According to the transverse fiber bundle tensile test results, the interfacial normal strength of HNTs modified epoxy-carbon bundles is measured as 16.91 MPa. On the other hand, with the silanization of HNTs, the interfacial normal tensile strength reaches to 34.76 MPa, which is 105% higher than the neat HNTs modified samples. Similar results are obtained from the shear tests. The interfacial shear strength of HNTs modified epoxy-carbon bundles is measured as 20.3 MPa. On the other hand, with the silanization of HNTs, the interfacial shear strength reaches to 37.06 MPa, which is 85% higher than the neat HNTs modified samples. The APTES modification of HNTs has magnificently improved the mechanical performance of the interfacial strength with the aid of various micro and nano size toughening mechanisms.

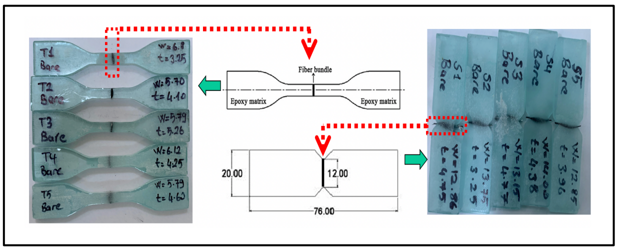

Fig.1. The prepared TFBT and shear samples for mechanical tests.

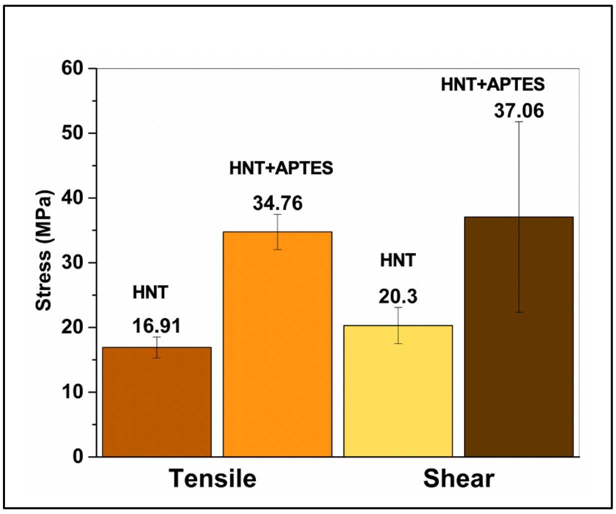

Fig.2. Summary of tensile and shear bundle tests

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