TENSILE AND FRACTURE TOUGHNESS ENHANCEMENT OF EPOXY RESIN REINFORCED WITH GRAPHENE NANOPLATELETS

N.D. Alexopoulos[1], Z. Paragkamian[1], S.K. Kourkoulis[2] and P. Poulin[3]

[1] University of the Aegean, Department of Financial and Management Engineering,
821 32 Chios, Greece

[2] National Technical University of Athens, Department of Mechanics,
Laboratory of Testing and Materials, Theocaris Building, Zografou Campus,
15773 Athens, Greece

[3]Université de Bordeaux, Centre de Recherche Paul Pascal - CNRS, Avenue Schweitzer,
33600 Pessac, France

1. Introduction

Graphene, a single layer of graphite has captured the attention of scientific community due to its exceptional properties. It is considered to be a unique lightweight, two-dimensional material with improved mechanical and electrical properties (Young´s modulus ~1 TPa, tensile strength 130 GPa, maximum electrical conductivity over 6000 S/cm, thermal conductivity 5000 W/mK) which make it extremely innovative [1, 2]. Graphene nanoplatelets (GNPs) is a newly developed material with low cost (available at about \$ 5 / lb) which often increases the modulus of elasticity of various matrices [3].

Investigation on the graphene-reinforced resins remains still limited and is mainly restricted to the study of the electrical conductivity of the newly-developed materials. In the present work, the effect of graphene nanoplatelets addition on the mechanical properties of the resulting polymer nanocomposites will be investigated.

2. Experimental procedure

For the preparation of the materials, the system of epoxy resin SR 8100 and hardener SD 8824, supplied from SICOMIN, FRANCE was used. Concerning nano-reinforcement, two types of graphene nanoplatelets (GNPs) were used: Grade C-750 and Grade M-15 with thicknesses 2 and 6 nm, respectively, supplied by XG Sciences, USA. Initially, GNPs were dispersed within the epoxy resin using a high speed shear mixer followed by a cure cycle recommended for the specific epoxy resin. According to this procedure, epoxy nanocomposite tensile and fracture toughness specimens were prepared at different GNPs concentrations, namely 0.10, 0.25, 0.50, 1.0, 2.0, 3.0 and 5.0 wt% as reinforcement.

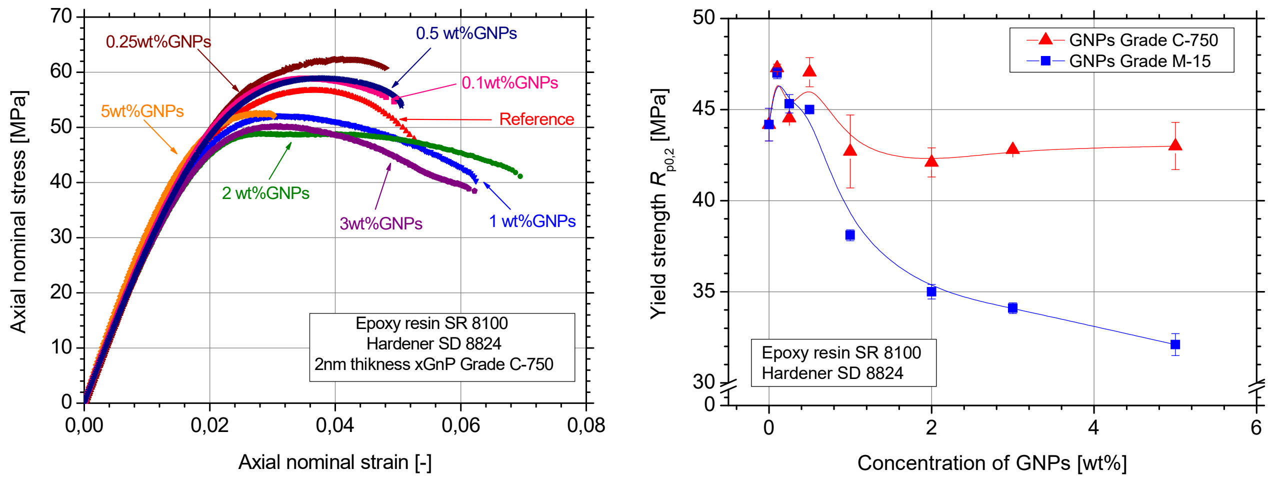
An MTS Insight 10 kN testing machine was used for the mechanical tests. The tensile tests were carried out according to the ASTM D638 specification. The fracture toughness tests were performed according to the ASTM D5045 at room temperature. The rate of displacement of the frame grips was kept constant and equal to 0.001 mm/min for the fracture toughness tests. Proper extensometers were attached on the tensile specimens to determine the axial strain along their gauge length. Concerning the fracture toughness specimens a suitable clip-gauge extensometer was used to measure the displacement of the edges of the crack (Crack Mouth Opening Displacement, CMOD). A data logger was used to store the data concerning load, axial strain and CMOD in a digital file.

In order to obtain representative average values of the tensile properties, at least three tests have been carried out for each test series. The mechanical properties of epoxy/GNPs nano-composites, such as yield stress, tensile strength, elongation at fracture and fracture toughness were calculated from the respective mechanical tests.

3. Results

The results of the experimental protocol indicate that both the GNPs type and concentration play an important role on the mechanical performance of the nanocomposites. Typical axial nominal stress - axial strain curves for the 2 nm NGPs can be seen in Figure 1a. For the case of Grade C GNPs, the tensile strength was increased and ductility was decreased for low concentrations (< 1.0 wt% GNPs). On the contrary, for higher GNP concentrations, e.g. 1.0, 2.0, 3.0 wt%, all strength properties were decreased and ductility was increased, when compared to the respective properties of the neat resin specimens (Figure 1b). For even higher concentrations (> 5.0 wt% GNPs) a decrease of all mechanical properties was observed. Regarding the type Grade M GNPs having larger thickness and diameter, the higher the GNPs concentration, the lower the mechanical properties were noticed.

In addition, it was observed that the critical stress intensity factor K_{cr} decreased with increasing large (> 1.0 wt%) GNPs concentration for both types investigated. On the other hand, available literature results showed that a small K_{cr} increase should be expected for very small (< 1.0 wt%) GNPs concentrations.



(a) (b)

Figure 1. (a) Typical tensile flow curves of nano-reinforced resins and (b) evaluated yield stress $R_{p0.2\%}$ of the specimens for different reinforcing concentrations.

4. References

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