15th International Conference on Fracture (ICF15)
June 11-16, 2023 Atlanta, GA USA

# Thermal behavior during fracture of hybrid epoxy/CNT/GNP composites

Julkarnyne M Habibur Rahman* and Suhasini Gururaja

*Department of Aerospace Engineering, Auburn University, AL, USA*
** Presenting Author email: jzr0114@auburn.edu*

## Abstract

This work reports the distinct thermal signatures during failure of epoxy-based nanocomposites comprised of multi-walled carbon nanotubes (MW-CNTs) and graphene nanoplatelets (GNPs). These fillers individually alter the material properties, but their synergy dramatically improves mechanical performance and other multifunctionality. CNT/epoxy, GNP/epoxy nanocomposites are fabricated and compared with the mixed GNP/CNT/epoxy hybrid nanocomposites containing the same weight percentage. Temperature profiles during tension tests have been observed using an infrared thermography (IR) camera yielding distinctive temperature profiles.

## 1. Introduction

In polymer matrix composites (PMC), polymers are often weak links with damage mechanisms such as matrix cracks often originating in the matrix. Fillers – nanoparticles with large surface area to volume ratios – are often added to the matrix phase to enhance their mechanical properties. Carbonaceous nanofillers such as CNT and GNP are promising candidates due to their exceptional properties. Particle size plays a significant role in improving the mechanical performance of the matrix due to particle/matrix surface interactions, particle motion, and particle dispersion being size-dependent. In particular, uniform dispersion of these nanofillers in the polymer matrix is highly desirable for property enhancement. In the current work, epoxy (Epon 862) with hardener (Epikure 3234) and amine-functionalized MW-CNT (diameter 10~20nm and length 10-30μm) and GNP (5 μm particle size, surface area 120-150 $m^2/g$ ) as a filler are used. The fillers are mixed with epoxy at different stoichiometry to check whether it changes the properties of epoxy.

## 2. Results

Based on earlier work by the authors, epoxy/CNT/GNP composites have been prepared using the procedure shown in Figure 1. First, nanofillers are heated to remove any moisture and mixed with acetone, and sonicated for 1 hour before mixing with the epoxy. After mixing and sonication, vacuum degassing is done to ensure acetone removal. Then, the mixer is stirred with magnetic stirring to ensure dispersion. Hardener is then added to the mixer and degassed. After mixing, the solution is poured into a 3D-printed mold per ASTM-638 Type-IV geometry. Pure epoxy, epoxy/CNT, epoxy/GNP, and epoxy/GNP/CNT at different weight percentages have been prepared using this process. Tensile testing was conducted on a 100 kN MTS (Landmark) system under a displacement-controlled rate of 1 mm/min. Extensometer has been used to measure strains during tensile testing. A SPARK TELOPS (MS M3K) IR camera was used during the tensile testing (frame rate 150Hz) to measure the change in temperature throughout testing.

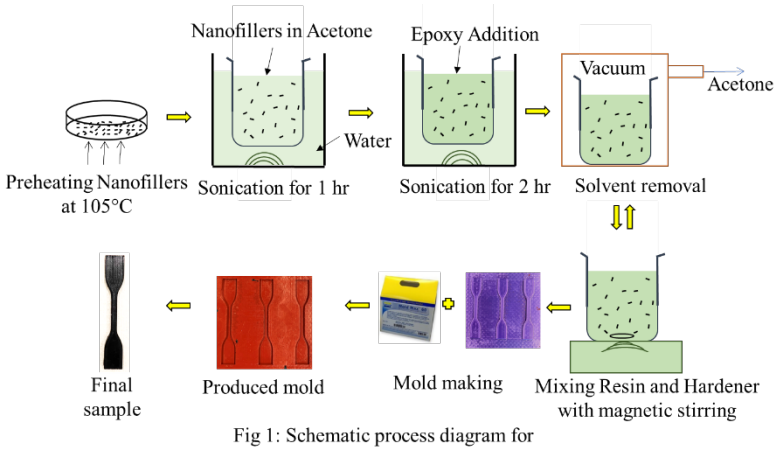


Fig 1: Schematic process diagram for making nanocomposites sample

Figure 2 compares the tensile behavior of pure epoxy and 0.1wt% CNT/epoxy composites depicting an improvement in stiffness (6%) and strength (23%) with the addition of nanofillers.

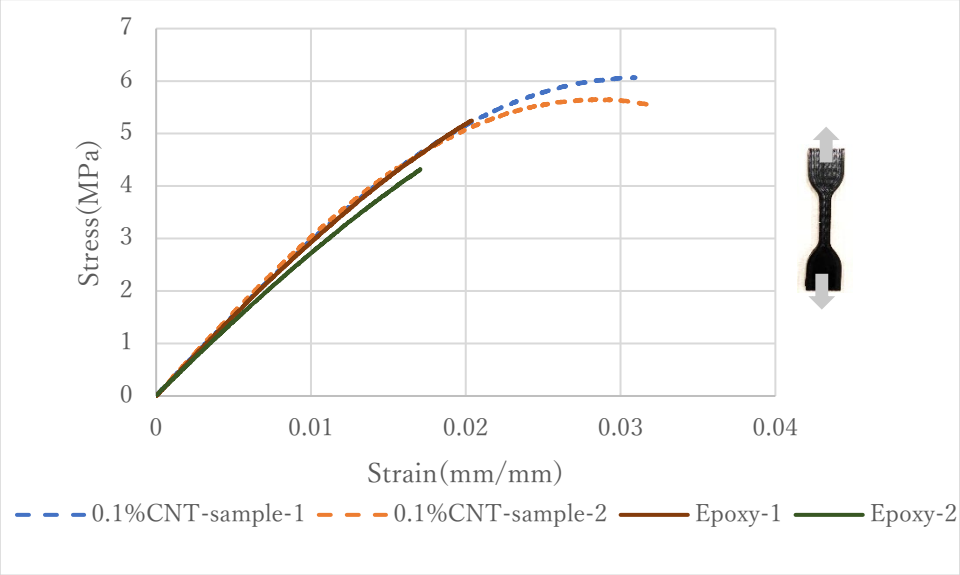


Fig 2: Stress-strain diagram of epoxy and 0.1wt% CNT/epoxy sample

In addition to strain measurement, full-field temperature evolution during the tensile testing was monitored using IR thermography (see Figure 3). 0.1wt%CNT/epoxy specimens consistently showed around a 10°C increase in temperature at failure, while pure epoxy specimens showed around 2ºC change. Additional tests are ongoing to determine the correlation between nanofiller length, volume fractions, dispersion, alignment, and stoichiometry with fracture behavior and associated temperature change. Atomic force microscopy (AFM) will be used to get an idea of the dispersion characteristics of the fillers in the epoxy matrix. Specifically, a correlation between sonication, nanofillers' length, and nanocomposites' mechanical performance are being investigated. The use of these novel composites for strain/damage sensing applications is being investigated.

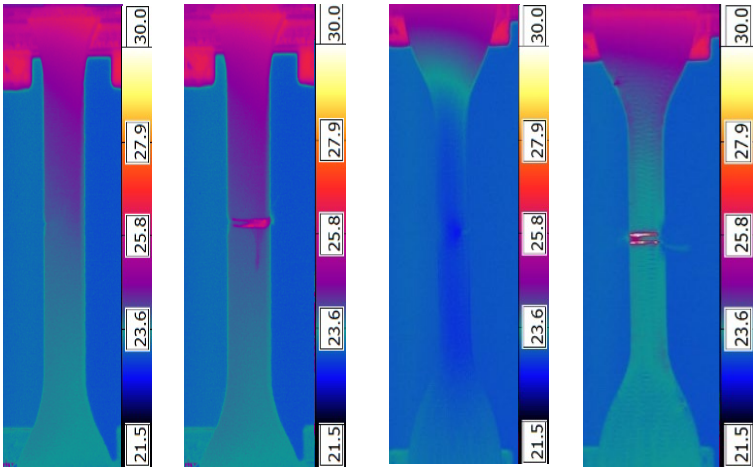


Fig 3: (From left to right) Epoxy sample before failure, Epoxy sample after failure, 0.1% CNT sample before failure, 0.1% CNT sample after failure

**3. Conclusions**

The effect of nanofillers on the local microstructure of epoxy has been examined with the help of infrared thermography during in situ tensile tests. In the future, impedance tests are also planned to measure the resistance change with respect to the change in material properties.