A study on the Synergistic influence of reduced graphene oxide and MWCNTs on the mechanical properties of epoxy nanocomposite

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ABSTRACT

In this study, the synergistic influence of reduced graphene oxide (RGO) and multi-walled carbon nanotubes (MWCNTs) on the mechanical properties of epoxy nanocomposites investigated. In the first step, the epoxy nanocomposite specimens reinforced with 0.02, 0.04, 0.06, 0.08 and 0.1 MWCNTs weight percentages fabricated using direct homogenization technique. The mechanical properties obtained via a tensile test set up. The results showed the 35.7%, 21.7% and 12.47% increase in the Young's modulus, ultimate stress and yield stress of the 0.04% MWCNTs reinforced specimen. In the second step, the epoxy reinforced with 0.2, 0.4, 0.6, 0.8 and 1 RGO weight percentages fabricated. For the 0.6% RGO reinforced specimen, 37.6%, 18.1% and 13.14% increase in the Young's modulus, ultimate stress and yield stress were seen. Next, the effect of different RGO content on 0.04% MWCNTs reinforced epoxy investigated. The obtained results demonstrated the increase in the mechanical properties of 0.04% MWCNTs-0.4% RGO (Mixing ratio 1: 10). Due to this mixing ratio for 0.06% MWCNTs-0.6% RGO specimen, 42.2%, 25.88% and 18.97% increase in the Young's modulus, ultimate stress and yield stress were seen. The analysis of specimens fracture surface was performed to observe the failure modes and dispersion of nanoparticles in the epoxy matrix. The results revealed that mechanical properties can change significantly by adding two different nanoparticles, simultaneously.

KEYWORDS

Nanocomposite, Synergistic Influence, RGO, MWCNTs, Mechanical properties.

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1. Introduction

Addition of nanoparticles to polymer composites improves their mechanical properties, significantly. Nanotubes and graphene plates are best candidates for this purpose, because of their availability, high strength and flexibility. Many studies have been done on the mechanical properties of nanocomposites [1].

Epoxy resins as a thermoset polymers have different applications in many industries [2]. Thermal, electrical and mechanical characteristics of epoxies can improve by adding nanofillers. Previous studies demonstrate that the simultaneous using of MWCNTs and graphene derivatives leads to uniform distribution of MWCNTs and higher mechanical properties of nanocomposites [1, 3-5].

In the present study, the synergistic influence of MWCNTs and reduced graphene oxide (RGO) on the mechanical properties of epoxy thermoset resins is investigated.

2. Experimental

2.1. Materials

RGO with dimensions between 1 to 10 microns, thick 0.8 to 2 nm and purity of more than 98.8% and MWCNTs with an average length of 10 microns, average outer diameter of 25 nm and purity of more than 98.8% are purchased from United Nanotech Co. CY219 epoxy resin and HY5161 hardener with 2:1 mixing ratio provided from Hanstman company.

2.2. Preparation of nanocomposite specimens

Direct mixing method have been used to prepare nanocomposites [6]. Tensile tests were performed by using a SANTAM universal tensile tester. Scanning electron microscope (SEM) is used to investigate the failure surface of the specimens.

3. Results and discussion

Figure. 1a shows the tensile test results of epoxy/ MWCNTs nanocomposite specimens for weight percentages 0.02, 0.04, 0.06, 0.08 and 0.1 MWCNTs and Figure. 1b is for epoxy/RGO nanocomposite with percentages Weights of 0.2, 0.4, 0.6, 0.8 and 1 of RGO. The maximum increase in Young modulus, ultimate stress and yield stress is related to nanocomposites with 0.04% of MWCNTs and is about 35.7%, 21.7% and 12.47%, respectively. From Figure. 1b, it is found that the maximum increase in Young modulus, ultimate stress and yield stress related to epoxy/0.6%RGO and is about 37.6%, 18.1% and 13.14%, respectively.

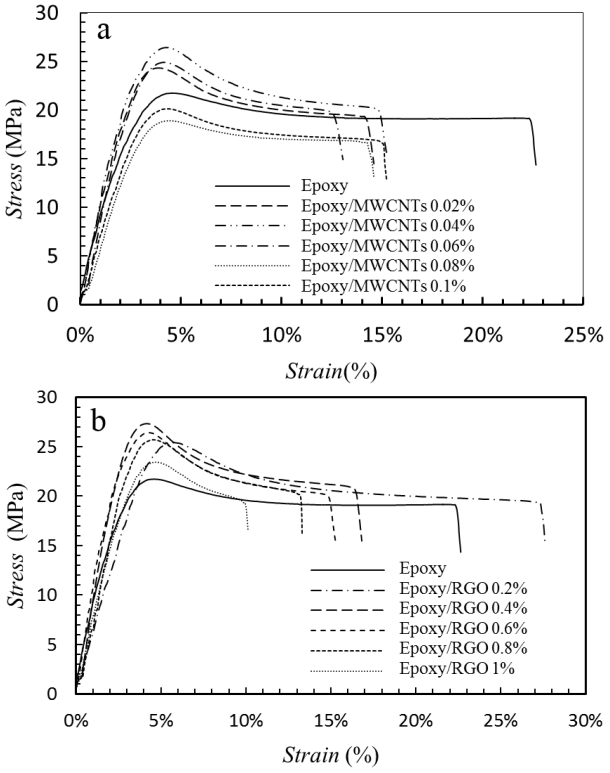

Figure. 1 Strain-stress curve for a) Nanocomposites with different wt% of MWCNTs b) Nanocomposites with different wt% of RGO

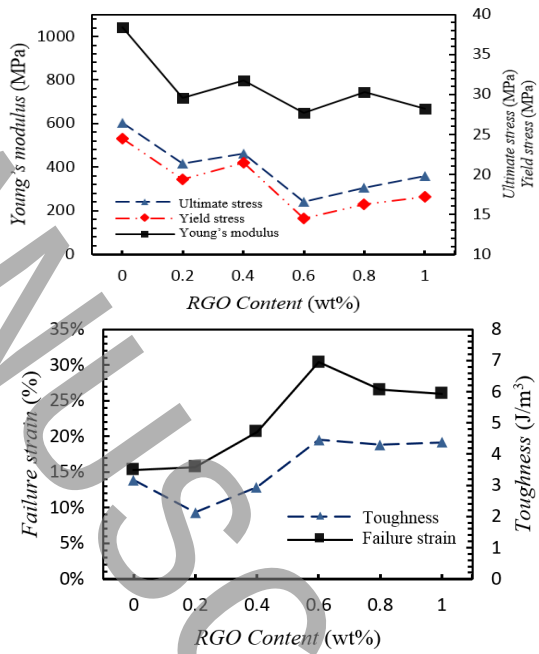

Figure. 2 Mechanical properties of nanocomposite with different wt% of RGO and 0.04% of MWCNTs.

Figure. 2 shows the synergistic effect of 0.04% MWCNTs and 0.2, 0.4, 0.6, 0.8 and 1 weight percentages of RGO. Young modulus, ultimate stress and yield stress nanocomposite epoxy/0.04%MWCNTs

/0.4%RGO (mixing ratio 1:10) improved 4.04%, 4.02% and 10.1%, respectively.

Figure. 3 shows the results of the synergistic effect MWCNTs and RGO with mixing ratio 1:10 and different wt% MWCNTs. The optimal mixture with mixing ratio of 1:10 is epoxy/0.06%MWCNTs /0.6%RGO with 42.2%, 25.88% and 18.97% increase in Young's modulus, ultimate stress and yield stress, respectively.

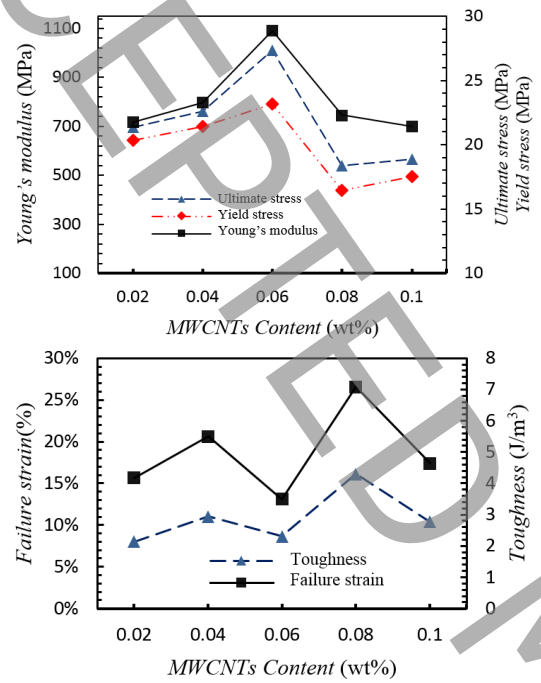

Figure. 3 Mechanical properties of epoxy/MWCNTs/RGO with mixing ratio 1:10 and different wt% MWCNTs

Table 1 has compared results for neat epoxy, epoxy /0.04%MWCNTs, epoxy/0.6%RGO and epoxy/0.06% MWCNTs/0.6% RGO.

Table 1. Comparison between mechanical properties of different nanocomposite with neat epoxy

Mixture/Properties	Young's modulus (GPa)	Ultimate stress (MPa)	Yield stress (MPa)	Toughness (J/m^3)	Failure strain (%)
Neat Epoxy	0.77	21.73	19.45	4.22	22.6
Epoxy/MWCNTs-0.04	1.04 (+35.66%)	26.43 (+21.68%)	24.43 (+12.47%)	3.17 (-24.78%)	15.26 (-32.54%)
Epoxy/RGO-0.6	1.05 (+37.55%)	25.65 (+18.07%)	22.1 (+13.14%)	2.99 (-28.94%)	14.81 (-34.54%)
Epoxy/MWCNTs 0.06-RGO 0.6	1.09 (+42.2%)	27.35 (+25.88%)	23.14 (+18.97%)	2.31 (-45.2%)	10.93 (-51.72%)

4. Conclusions

The results of this study can be summarized as follows:

1. For epoxy/MWCNTs nanocomposite, the maximum improvement is related to 0.04 wt% of MWCNTs. Young modulus, ultimate stress and yield stress increase about 35.7%, 21.7% and 12.47%, respectively, Compared to neat epoxy.

2. For epoxy/RGO nanocomposite, the maximum improvement is related to 0.6 wt% of RGO. Young modulus, ultimate stress and yield stress increase about 37.6%, 18.1% and 13.14%, respectively, Compared to neat epoxy.

3. Addition of 0.04 wt% of MWCNTs to the epoxy/RGO reduces the Young's modulus, ultimate stress and yield stress, and increases fracture toughness and failure strain.

4. The optimum mixture of two nanoparticles that gives the most synergistic effect is 1:10 (1 part of MWCNTs and 10 parts of RGO). Also, the best mixing ratio for increasing toughness and failure strain is 1:15.

5. The maximum improvement of Young modulus, ultimate stress and yield stress for the synergistic effect is related to epoxy/0.06%MWCNTs/0.6%RGO with 42.2%, 25.88% and 18.97%, respectively.

6. The addition of RGO to the epoxy/MWCNTs nanocomposite increases the fracture path and thus prevents the growth of cracks and increases the mechanical strength of the nanocomposite.

5. References

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