NANO INDENTATION STUDIES ON GRAPHENE NANOPARTICLES REINFORCED EPOXY RESIN AS CONDUCTIVE INK

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ABSTRACT: This paper manages to investigate the effect of different percentage of filler loading and curing temperature of graphene ink containing Graphene Nano platelets filled epoxy resin influences on hardness of printed graphene sample. The procedure was carried out by using simple method starting from formulation of the ink, mixing, printing and curing process in order to produce high conductive ink. Graphene filled epoxy resin have been evaluated using Nano indentation techniques. The study shows that the higher the filler loading, the higher the hardness of the ink.

KEYWORDS: *Graphene; Conductive Ink; Nano Identation*

1.0 INTRODUCTION

Conductive ink is a special type of ink, which allows electric current to flow through it. The ink can be printed directly on a substrate or any flexible surface through a regular printing process. There are several varieties of conductive inks on the market and it is crucial to choose the suitable ink for any electronic application. The ink is usually applied to the substrate and slightly heated to evaporate the solvent and heat up the conductive particles together. Conductive ink is a significant component of any application, with extensively uses in photovoltaic cells, medical devices, membrane switches, as well as RFID chips. It is regarded as the next generation of an electronic device [1]. The application of conductive ink on the flexible substrate is shown in Figure 1.

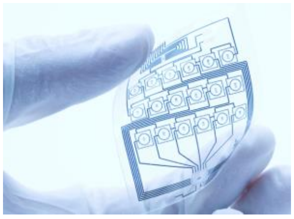

Figure 1 : Application of Conductive Ink on the Flexible Substrate

Conductive inks can replace printed wiring and especially beneficial for small circuit that needs low cost method. Commonly, the crucial component to produce conductive ink is conductive material, polymer binder and a solvent. Atif et al stated that integration of nanofiller has been a very effective strategy to increase the performance of the material itself. In this study, epoxy resin is selected as polymer binder because it offers superlative mechanical properties, thermal stability, solvent resistance as well as ease of processing [2]. In addition, this material can hold other materials together to form a cohesive mechanical adhesion or cohesion. The enhancement of mechanical properties, particularly hardness can be obtained by reinforcing the polymer binder with relatively small amount of nanomaterial.

The nano filler can be either a metallic nanoparticles or carbon nanoparticles [3]. Among these nanoparticles, graphene has become the primary choice in the past decade due to its unique properties with two-dimensional structure. Atif et al also showed that it has large surface area (2630 m2g-1) and possesses excellent mechanical properties such as Young's modulus at 1 TPa and tensile strength of 130 GPa. It makes graphene as one of the strongest material that is available today [2]. This factor has led to the exploration of graphene reinforced epoxy resin in various applications nowadays. In this study, the effectiveness of graphene in enhancing mechanical properties has been investigated by using the nanoindentation technique. This research attempts to evaluate whether the curing temperature and different weight percentage of filler loading influence the morphological and mechanical properties.

2.0 RESEARCH METHODOLOGY

2.1 Samples Preparation

The fabrication of conductive ink involves formulating the ink composition, ink sample preparation, print the ink on the compatible substrate and cure the ink with two different temperatures. The conductive ink was prepared with four different percentages of filler loading: 5 wt. %, 10wt. %, 15wt. % and 20wt. % with the hardener in the ratio of 100:30. The ink was prepared by manual mixing. It involved a stirring process, which took about 10 minutes at room temperature by using glass rod. Stirring plays an important role in ensuring the uniform distribution of epoxy in the mixture and it can break up the agglomerates of graphene and epoxy resin to produce high dispersed graphene/epoxy dispersion. Table 1 illustrates the composition of the conductive ink.

Table 1: The Composition of the Conductive Ink

Sample	Filler		Binder		Hardener	Total
	(%)	(g)	(%)	(g)	(g)	(g)
1	5	0.1	95%	1.9	0.57	2
2	10	0.2	90%	1.8	0.54	2
3	15	0.3	85%	1.7	0.51	2
4	20	0.4	80%	1.6	0.48	2

Once dispersion process was completed, the mixture was cured at two different temperature 160°C and 180°C for an hour. During curing process, it produced high cross linked microstructure that generated high modulus and strength, good resistance to creep and good performance at elevated temperatures. Then, the cured sample was cooled down slowly to room temperature inside the oven [4].

2.2 Mechanical Properties

The mechanical properties were studied by using Dynamic Ultra Micro Hardness testing (DUH-211S 230VE). Nano indentation measures the value of hardness of the conductive ink. In this study the, the parameter was set for 5kN load and 5 sec holding time. Since the mechanical properties extracted from the Nano indentation are sensitive to the tip geometry, the tip area function has to be calibrated to determine the mechanical property accurately. The indentation was made at a constant strain rate of 0.05/s and a pause time was allowed at the peak load.

3.0 RESULTS AND DISCUSSION

3.1 Mechanical Characterization

Nano indentation analysis was carried out by using the method described by Dong et al [5]. As the indenter was driven into the material, both elastic and plastic deformations caused the formation of hardness impression by conforming to the shape of the indenter to some contact depth. After the indenter was withdrawn, only the elastic portion of the displacement was recovered. This recovery enables one to determine the elastic properties of a material. In nano indentation, hardness can be calculated by dividing the indentation load to the projected contact area of the indentation. For an indenter of known geometry like the Berkovich tip such as in this case, the projected contact area is a function of contact depth, which can be measured by the nano indenter during indentation.

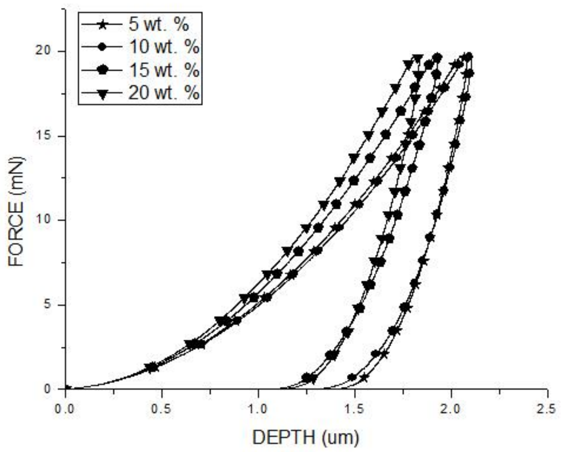

Figure 2: Load-Displacement Curves for 160°C.

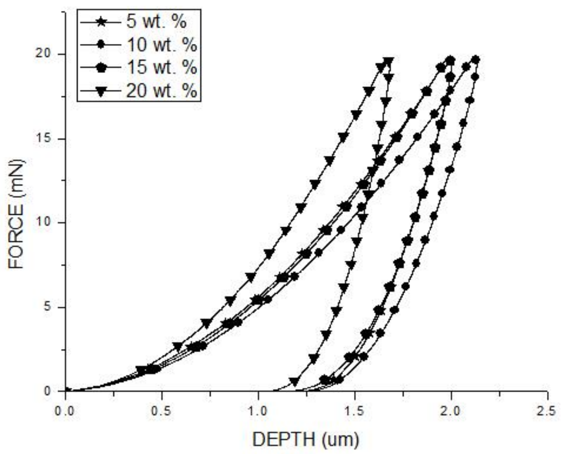

Figure 3: Load-Displacement Curves for 180°C.

From the Figures 1 and 2, the graph indicate that when the percentages of filler loading increase, the penetrations of the indenter decrease, respectively The graph present the typical load indentation depth curve obtained by Nano indentation for screen printed graphene ink that was cured at 160 °C and 180 °C for an hour. The observed curves are consistent and there is no significant difference between all the filler loadings. As can be seen from the graphs, the patternis similar for all filler loadings. The Nano indentation results show an improvement in hardness for the sample at temperature of 180°C. As expected, the higher temperature leads to higher hardness of material. Nano indentation results confirm that the toughness of the ink increases when the curing temperature increases.

4.0 CONCLUSIONS

In conclusions, a simple fabrication process had been used in order the disperse graphene through the epoxy resin in order to produce the conductive ink. This sudy consisted of the characterization of graphene/epoxy resin composite. The main objective was to investigate the mechanical properties when adding low volume of graphene filler loading into the thermosetting resin. The result showed that the mixture of the ink was not well dispersed during mixing method and dispersion strongly influenced the structure of the graphene. From nano indentation study, the hardness increased steadily with the incorporation of 20 wt. % of filler loading. It was expected that an increment of graphene filler loading content could not be verified due to increased difficulties to obtain homogeneous dispersion that contains high percentage of filler loading. A network of well-dispersed graphene may provide a conductive path that leads to high conductivity of ink.

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