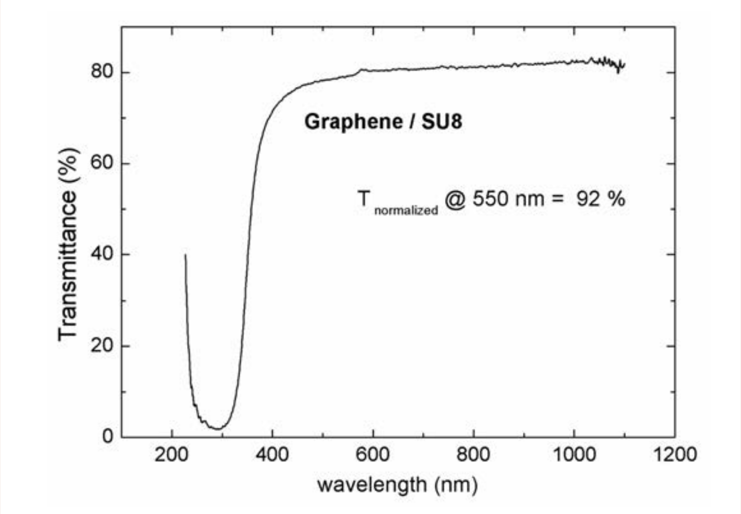
Graphene-Epoxy Flexible Transparent Capacitor Obtained by Graphene-Polymer Transfer and UV-Induced Bonding

By Marco Sangermano

We reported a new approach for the preparation of a graphene-epoxy flexible transparent capacitor obtained by graphene-polymer transfer and UV-induced bonding. SU8 resin was employed for realizing a well-adherent, transparent and flexible supporting layer. The achieved transparent graphene/SU8 membrane presents two distinct surfaces—one homogeneous conductive surface containing a graphene layer and one dielectric surface, typical of the epoxy polymer. Two graphene/SU8 layers were bonded together by using an epoxy photocurable formulation based on epoxy resin. The obtained material showed a stable and clear capacitive behavior.

FIGURE 1

UV-Vis spectra of the G/SU8 membranes, for graphene layers grown by CVD on Cu-foil, with the reported normalized transmittance ($T_{normalized}$) of the simple graphene membrane

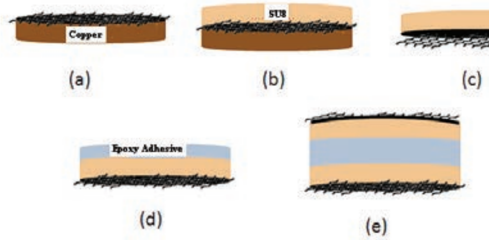


As well known, a parallel plate capacitor consists of two parallel conducting electrodes separated by a dielectric material. Capacitors play an important role in electronic circuits when they are thin, small in volume, lightweight and reliable.[1-2] Graphene is considered one of the most suitable substrate materials for preparing electrodes. In this field, graphene-conducting polymer composites are becoming the most suitable choice to prepare flexible capacitors.[3-5] Commonly adopted strategies for the fabrication of graphene-based devices grown on metals rely on the transfer of the graphene membrane from the catalyst substrate to the device substrate, where the graphene layer is integrated with proper structures.

Quite recently we have followed a new strategy to prepare graphene-

FIGURE 2

Production process



The production process includes (a) deposition of graphene by means of CVD on Cu; (b) spin coating of SU8 on top of the graphene layer; (c) wet etching of Cu substrate; (d) wirewound application of cycloaliphatic epoxy resin on the SU8 layer; and (e) coupling of the epoxy layers and UV curing to form the final device

based polymer electrode.[6] A graphene to SU8 epoxy polymer transfer method was established. This transfer technique consists of coupling the graphene layer to a supporting polymer before a chemical etching of the catalyst is performed, in order to release the supported graphene from the synthesis substrate.

Graphene membranes were synthesized on the Cu foils substrate obtaining a continuous graphene coating consisting of 1-3 layers and a 10 µm thick layer of SU8 resin which was deposited on the few layer graphene (FLG) membranes by means of spin coating. After baking and a subsequent UV-curing process, the G/SU8 membranes were released by chemical etching in acid solutions.

The final G/SU8 membrane presents two distinct surfaces—one homogeneous conductive surface containing a graphene layer and one dielectric surface, typical of the epoxy polymer. Moreover, the G/SU8 membrane is highly transparent, with a transmittance higher than 90% (see Figure 1).

Two G/SU8 layers were bonded together by using 3,4-Epoxycyclohexylmethyl-3,4-epoxycyclohexane carboxylate, epoxy photocurable resin (CE, Sigma-Aldrich®) as an adhesive. First, UV curing was investigated by means of RT-FTIR analysis. When the pristine epoxy resin was UV-irradiated, a final conversion of about 80% was calculated. The formation of a high Tg epoxy network (140°C) induced a vitrification effect with a plateau conversion of 80%.

This epoxy formulation was used as UV-curable adhesive to bond the G/SU8 membranes. A sandwich film was prepared by coating the photocurable formulations on the non-conductive surface of the G/SU8 membrane. To complete the sandwich, a second G/SU8 film was deposited maintaining the conductive surface on the air side. This sample was irradiated with UV light and the final material is flexible, notwithstanding the high Tg of the epoxides taking into account the small thickness. In Figure 2, we schematized the adopted production strategy.

The obtained polymer sandwich was characterized by impedance spectroscopy. For what concerns the electrical properties, we could measure very small leakage currents with the DC analysis, as low as 100 pA at 100 V potential (not shown), corresponding to a bulk resistance of 1 TΩ, which is big enough for practical applications. The AC response was such that a stable and clear capacitive behavior was found, with a slight deviation from ideality, at rather high frequencies above 100 kHz. The devices under test showed typical capacitance values around 20 pF, which also is suitable for practical applications in discrete components. This is an elegant and an easy-to-process strategy to obtain transparent and flexible organic capacitors. Further research is underway with the aim of enhancing the capacitive behavior. ◗

References

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