A Graphene-based Hybrid Structure as Flexible, Transparent Field Emitter

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Graphene is a two-dimensional (2-D) carbon material having unique band structure and outstanding thermal, mechanical and electrical properties [1]. Since the ground-breaking research work of Novoselov et al. in 2004 to propose a simple technique to produce graphene [2] and later through their 'progress article' on the development of this novel 2-D material [3], graphene has received lot of attraction as the most important material for future electronic devices. It is well known that graphene has high mechanical strength (Young's modulus ~1.0 TPa) with flexibility, high transmittance (~97.5%) and high electron mobility (~15,000 cm^2/V.cm). Some of the potential applications of graphene are sensors, transistors, super-capacitors, solar cells, flexible displays etc. One of the future exciting applications is in developing transparent, flexible electrodes. A hybrid of carbon nanotubes over graphene can be considered as an ideal structure for application as flexible and transparent field emission displays. These flexible and transparent displays could have wide application ranges - flexible head-up displays, foldable electronics, lightning tiles etc.

We present here our recent research efforts in developing an all-graphene based cathode and anode structures for flexible and transparent field emission device. Graphene film was grown onto thin Cu foil by thermal chemical vapor deposition and later transferred to a transparent, flexible polymer (PET) substrate through hot press lamination [4]. This transparent and flexible electrode was first used as the anode of a field emission device, in which an interface-controlled multiwall carbon nanotube (MWCNT) structure grown on copper substrate [5] was used as the cathode. This device showed the applicability of graphene-based electrode as a part of field emission devices.

In a further development to this work, we aimed to develop a fully flexible and transparent field emission device, based on graphene. Cathode of this field emission device was developed by spin-coating multiwall carbon nanotubes (MWCNT) onto graphene-PET electrode, as mentioned earlier. A green-phosphor coated graphene-PET film was used as the anode. The device was characterized to understand the field emission response of this graphene-based hybrid field emission device and it offered appreciable emission current. Straight line nature of the Fowler-Nordheim plots guarantee that the electron emission is through tunneling of electrons across the energy barrier. The device also showed good transparency and flexibility [6], which was promising for its application in future flexible and transparent electronic gadgets. The device was also tested for stability of its emission characteristics for 10 hours and has shown appreciable performance. Processing techniques followed to manufacture this novel filed emitter can easily be scaled-up and be tailored for any transparent and flexible substrate. Our results offer exciting applications of graphene in foldable electronics.

References

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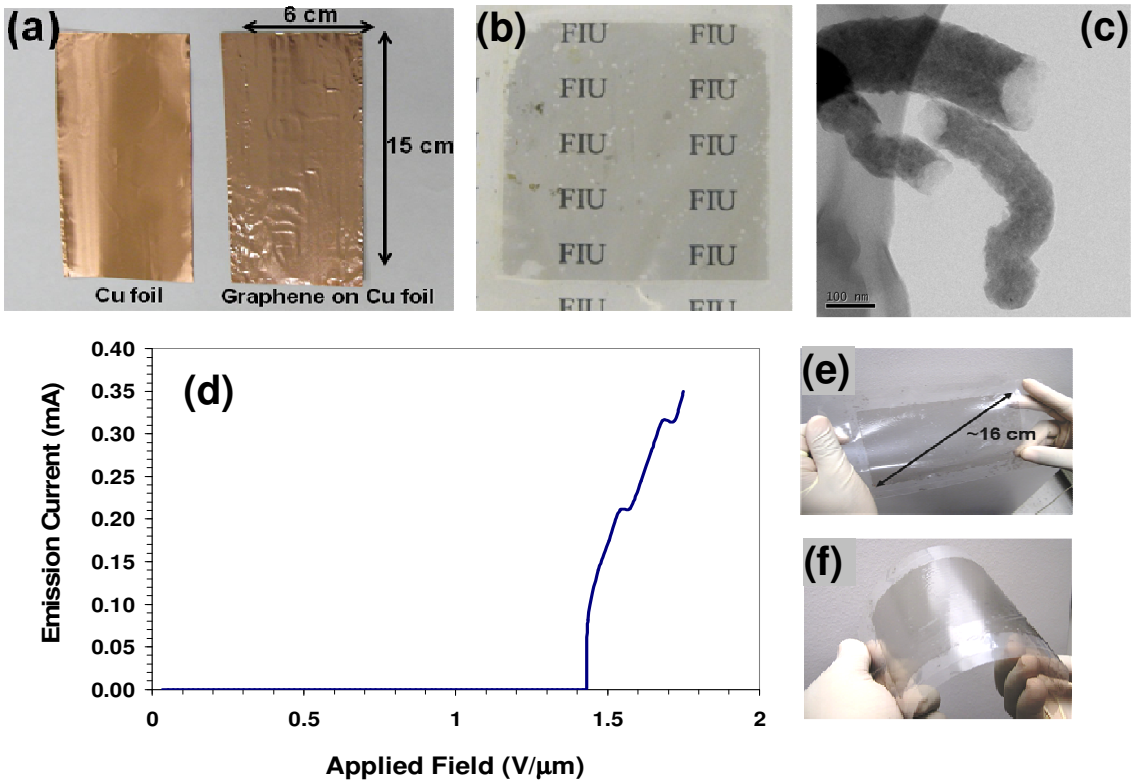
Figures



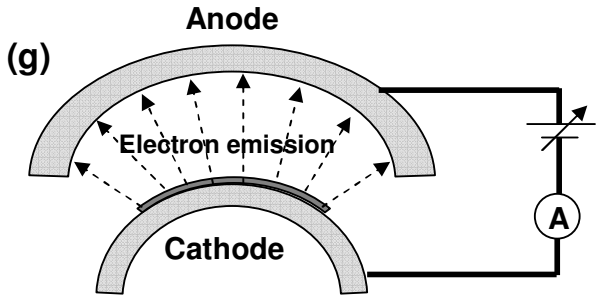


Figure caption
(a) Photos of graphene grown on thin Cu foil, (b) transparency of the graphene film, after transferring onto a PET substrate, (c) TEM image of the MWCNTs embedded on the graphene electrode, (d) field emission response of the graphene-based hybrid field emitter device, (e) graphene transferred to transparent polymer substrate, (f) flexibility of the electrode is demonstrated and (g) schematic of the field emitter device.