Improved Stability of the Printed Graphene Electrodes for OLED on the Foldable Paper Substrate

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Abstract

Soft conductive materials, such as graphene and carbon nanotubes, are ideal for the electronic components of circuits and electrodes on the flexible, foldable, and even stretchable devices. Recently, stability against significantly smaller curvature and larger mechanical stress for repeated operation became a key factor to obtain a successful manufacturing of the commercial application of foldable electronic devices.

Here, we have demonstrated the printed circuits on the foldable substrate with graphene ink and graphene/silver nanowire composites. Few layer graphene powder nano-platelet, *Angstron materials graphene N002-PDR*, was dispersed in solvents with appropriate binders to formulate a screen-printable paste [1]. The paste was also modified for an electro-hydrodynamic (EHD) jet printing toward a fabrication of fine line patterns on the foldable paper substrates and flexible polyimide films. Fig.1 shows the line pattern with different scale of width by conventional screen printing (a) and EHD jet-printing under electric field of 1.5kV/mm. Unlike the smooth polyimide film, the wetting of ink/paste of graphene and its composite (AgNW) with relatively rough paper substrates was not homogeneous. Therefore, surface modifycation of paper substrates were essential; *e.g.* poly(4-vinylphenol) coating on the commercial paper substrate successfully planarized the paper surface.

Compared with patterned electrodes formed by neat graphene, graphene/ AgNW (30wt% loading of graphene) circuit showed superior performance as well as folding stability [2]; decrease of relative conductance for -90° and -180° folding (toward inside direction) was only 5% and 12%. Moreover, the conductance was maintained about 70% of initial value after 1000 cycle of continuous folding. About 1.5 Ω/sq (graphene with 30wt% silver NW) was obtained in foldable circuit on the coated paper. In order to further improve the stability against continuous folding /unfolding deformation, paper and plastic substrates were coated with primer containing the flexible additive, poly (ethyleneglycol) diacrylate (PEGDA). The conductance of graphene circuit, employed as auxiliary electrode of green organic light emitting diode (OLED), was significantly enhanced with the PEGDA contents in the primer layer between paper and surface coating of polyimide.

References

[1] Y, Xu, M. G. Schwab, A. J. Strudwick, I. Hennig, X. Feng, Z. Wu, K. Müllen, Adv. Energy Mater. 3 (2013), 1035

[2] S.M. Jo, D. G. Yoon, R. Bail, B. D. Chin, ECS J. Sol. Sta. Sci. and Tech. 5, (2016) R3185

Figures

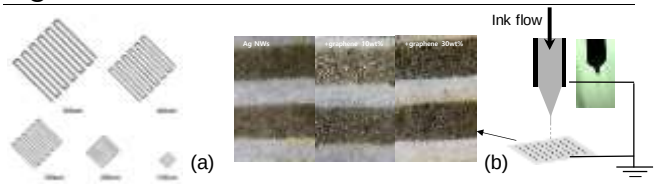

Figure 1: (a) Screen-printed graphene paste circuit lines on colorless polyimide (100 to 500μm) (b) Line patterns of graphene and graphene/silver nanowire composites on paper by EHD jet-printing

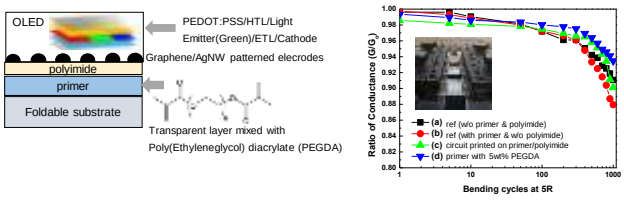

Figure 2: Layered structure of OLED with graphene/AgNW electrode and primer interlayer as a stabilizer against folding. Ratio of conductance for graphene-based circuits in OLED with continuous curvature 5R.