Flexible, graphene-integrated, 122,880 pixels, electrophoretic display

F.Tomarchio[‡], L.Lombardi[‡], R. Agaiby[§], M.Banach[§], F.Torrisi[‡], A.C. Ferrari[‡]

[‡] Cambridge Graphene Centre, University of Cambridge, Cambridge CB3 OFA, UK
[§] Plastic logic Ltd, Cambridge, UK
ft272@cam.ac.uk

Abstract
Flexible displays are essential components in wearable screens, electronic newspapers, and smart identity cards [1]. Flexibility is usually limited by the weakest interface or by the most brittle layer in the stack, which is often a conducting oxide or metal [1]. Widespread use of flexible displays faces challenges due to processing limitations, such as high temperature (>200°C) [2] and fabrication costs of the active-matrix backplane[3,4,5]. Here, we present an active-matrix, flexible electrophoretic display that includes in its pixel electronics films of solution processed graphene combined with Single Wall Carbon Nanotubes (SWNTs). Graphene is produced by liquid phase exfoliation of graphite [6,7,8]. SWNTs are produced by arc discharge[9]. These are also functionalized with 3% carboxyl groups [9] to enhance dispersibility in water[10]. The SWNTs are individualized and stabilized in solution using tip sonication [11]. The de-bundling is performed employing linear chains surfactants [11], followed by ultracentrifugation to remove residual bundles [11].Coating by Meyer bar is used to deposit first the SWNTs dispersion and subsequently the graphene-ink, directly on the backplane of the display. The SWNTs-graphene ratio is 40:60% in mass, that assures the uniformity of the film on the backplane without aggregates. The SWNTs role is fourfold: 1) decreasing the contact angle of the ink on the backplane from 27.5° to 9.75°, 2) increasing the interfacial adhesion of the graphene ink with the substrate, 3) formation of a conductive network on the backplane for the subsequent graphene coating [12, 13], 4) promoting the charge transfer between graphene flakes, improving the conductivity of the graphene film [14]. The graphene coating improves the adhesion of the graphene/SWNTs film on the backplane during the processing of the display. The display contains 122880 pixels (320x384) (Fig.1a), driven by the same number of Thin Film transistors (TFTs). Graphene and SWNTs conformally cover 3μm deep vias (Fig.1b) and create the contact with the gold electrodes underneath. The graphene/SWNTs layer has strong adhesion on the backplane, with a peel force of 2.68 N. No delamination or cracking occurs up to a radius of curvature of 0.5mm, assuring the full flexibility of the display.

References
[1] PCP Bouten, Wiley (2005)
[2] J.Lewis et al. Mat. Today **4** (2006) 38
[3] S.R.Forrest. et al. Nature **428** (2004) 911
[4] Y. Chen. et al. Nature **423** (2003) 136
[5] M. A. McCarthy et al. Science **6029** (2011) 570
[6] Y.Hernandez et al. Nat. Nanotech. **3** (2008) 563
[7] F. Torrisi et al. ACS Nano **6** (2012) 2992
[8] M.Lotya et al. J. Am. Chem. Soc. **131** (2009) 3611
[9] M. E. Itkis et al. Nano Lett., **3**, (2003), 309
[10] B.White et al. J. Phys. Chem. C, **111**, (2007), 13684
[11] T.Hasan et al. J. Phys. Chem. C **111** (2007) 12594
[12] L. Hu et al. Nano Lett. **4** (2004) 2513
[13] D. Zhang et al. Nano Lett. **6** (2006) 1880
[14] D. S. Hecht et al. Adv. Mater. **23** (2011) 1482

Figures

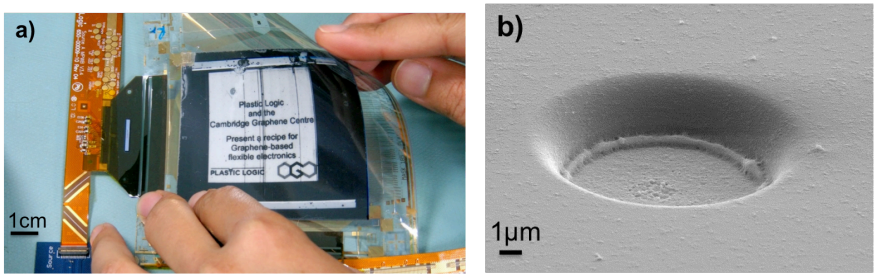

Fig 1. a) picture of the final flexible display, b) SEM image of one of the "via" of the backplane coated with graphene/SWNTs.