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Enhanced Field Emission from Plasma Treated Graphene and 2D Layered Hybrids

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Abstract : Graphene emerges out as a promising material for various applications ranging from complementary integrated circuits to optically transparent electrode for displays and sensors. The excellent conductivity and atomic sharp edges of unique two-dimensional structure makes graphene a propitious field emitter. Graphene analogues of other 2D layered materials have emerged in material science and nanotechnology due to the enriched physics and novel enhanced properties they present. There are several advantages of using 2D nanomaterials in field emission based devices, including a thickness of only a few atomic layers, high aspect ratio (the ratio of lateral size to sheet thickness), excellent electrical properties, extraordinary mechanical strength and ease of synthesis. Furthermore, the presence of edges can enhance the tunneling probability for the electrons in layered nanomaterials similar to that seen in nanotubes. Here we report electron emission properties of multilayer graphene and effect of plasma (CO2, O2, Ar and N2) treatment. The plasma treated multilayer graphene shows an enhanced field emission behavior with a low turn on field of 0.18 V/μm and high emission current density of 1.89 mA/cm2 at an applied field of 0.35 V/μm. Further, we report the field emission studies of layered WS2/RGO and SnS2/RGO composites. The turn on field required to draw a field emission current density of 1μA/cm2 is found to be 3.5, 2.3 and 2 V/μm for WS2, RGO and the WS2/RGO composite respectively. The enhanced field emission behavior observed for the WS2/RGO nanocomposite is attributed to a high field enhancement factor of 2978, which is associated with the surface protrusions of the single-to-few layer thick sheets of the nanocomposite. The highest current density of ~800 μA/cm2 is drawn at an applied field of 4.1 V/μm from a few layers of the WS2/RGO nanocomposite. Furthermore, first-principles density functional calculations suggest that the enhanced field emission may also be due to an overlap of the electronic structures of WS2 and RGO, where graphene-like states are dumped in the region of the WS2 fundamental gap. Similarly, the turn on field required to draw an emission current density of 1μA/cm2 is significantly low (almost half the value) for the SnS2/RGO nanocomposite (2.65 V/μm) compared to pristine SnS2 (4.8 V/μm) nanosheets. The field enhancement factor β (~3200 for SnS2 and ~3700 for SnS2/RGO composite) was calculated from Fowler-Nordheim (FN) plots and indicates emission from the nanometric geometry of the emitter. The field emission current versus time plot shows overall good emission stability for the SnS2/RGO emitter. The DFT calculations reveal that the enhanced field emission properties of SnS2/RGO composites are because of a substantial lowering of work function of SnS2 when supported by graphene, which is in response to p-type doping of the graphene substrate. Graphene and 2D analogue materials emerge as a potential candidate for future field emission applications.

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