# 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. Electron emission properties of multilayer graphene (MLG) prepared by a facile exfoliation technique have been studied. Effect of plasma ($CO_2$, $O_2$, Ar and $N_2$) treatment was studied by Raman spectroscopy and investigated for field emission based application. 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/cm$^2$ at an applied field of 0.35 V/μm. Further the plasma treated MLG exhibits excellent current stability at lower and higher emission current value.[1] 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. [1-3] We report here the field emission studies of a layered $WS_2$-RGO composite at the base pressure of ~1x10$^{-8}$ mbar. The turn on field required to draw a field emission current density of 1μA/cm$^2$ is found to be 3.5, 2.3 and 2 V/μm for $WS_2$, RGO and the $WS_2$-RGO composite respectively. The enhanced field emission behavior observed for the $WS_2$-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/cm$^2$ is drawn at an applied field of 4.1 V/μm from a few layers of the $WS_2$-RGO nanocomposite. Furthermore, first-principles density functional calculations suggest that the enhanced field emission may also be due to an overalp of the electronic structures of $WS_2$ and RGO, where graphene-like states are dumped in the region of the $WS_2$ fundamental gap.[2] Also, We report our experimental investigations on *p*-doped graphene using tin sulfide, $SnS_2$, which shows enhanced field emission properties. The turn on field required to draw an emission current density of 1μA/cm$^2$ is significantly low (almost half the value) for the $SnS_2$/RGO nanocomposite (2.65 V/μm) compared to pristine $SnS_2$ (4.8 V/μm) nanosheets. The field enhancement factor $\beta$ (~3200 for $SnS_2$ and ~3700 for $SnS_2$/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 $SnS_2$/RGO emitter. The magnitude of work function of $SnS_2$ and a $SnS_2$/graphene composite has been calculated from first principles density functional theory (DFT), and is found to be 6.89 eV and 5.42 eV, respectively. The DFT calculations clearly reveals that the enhanced field emission properties of $SnS_2$/RGO composites are because of a substantial lowering of work function of $SnS_2$ when supported by graphene, which is in response to *p*-type doping of the graphene substrate.[2]

## References

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