Low-k organic dielectric engineering for graphene field effect transistors (GFETs)

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Abstract

Graphene, an atomic thick of sp^2 bonded hexagonal carbon network, has been investigated extensively as the most promising material for future nanoelectronics because of its exceptional physical and electrical properties, such as high mobility, high thermal conductivity, excellent mechanical strength and chemical stability[1]. However, a number of issues need to overcome prior to the practical realizing the excellent electrical performance of graphene based logic devices, in particular, the uniform deposition of scalable layer of dielectric films owing to the inert nature of graphene basal plane. Furthermore, the good scalability of dielectrics film on graphene is considered of particularly critical for such novel applications as graphene tunnel FET (GFET) and graphene bilayer pseudo-spin FET (BiSFET) electronics in which an extremely thin dielectric layer on graphene is required as tunneling barrier and to reduce the screen effect[2]. In addition to the efforts on downscaling uniform inorganic oxide dielectrics on graphene, engineering ultrathin layer of organic low-k dielectrics also become attractive with regard to its low cost, good scalability and flexibility not only as gate dielectrics for flexible electronics but also as seeding and passivation layers[3].

In this work, the physical and electrical characteristics of thin film of organic low-k dielectrics deposited using CVD on graphene have been investigated using Raman, XPS, STM and Graphene FETs, respectively. Our CVD deposition of parylene-C, a cross-linkable polymer with hydrophobic nature, on graphene showed good film thickness scalability down to ~7 nm without revelation of process induced defects[4]. Electrical results of the GFET using this thin organic as top gate dielectric demonstrated good dielectric properties with minimal doping, low leakage current ($\sim 10^{-6}$A/cm^2 at ±2V) and low dielectric constant of ~2.1 as well as low hysteresis less than 30 mV during top gate operation (-2.5V to 2.5V), an indication of low trapped charges introduced by parylene. In addition to parlyene, self-assembled a few layer of PTCDA on graphene were also investigated to further scale the dielectric thickness down to sub-nanometer, which forms very ordered and uniform single crystal hexagonal molecular networks with a band gap of ~1.9 eV and ~2.4 eV derived for monolayer and trilayer PTCDA film, respectively. PTCDA film of 3 and 5 nm with a extracted dielectric constant of around 2.02 show much lower leakage current comparing to 4 layer of h-BN, this, in addition to the tunneling conduction mechanism revealed within its uniform molecular networks, suggests PTCDA as an excellent candidate for organic low-k dielectrics for graphene based tunneling devices. Our experimental results have also demonstrated the feasibility of using parlylene and PTCDA as organic low-k dielectrics for graphene based electronics.

References

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Figure: Dielectric constant graph of low dielectric candidates