Rapid Graphene Fabrication and Ultrafast Characterization

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Chemical vapour deposition (CVD) of graphene on copper is a widely studied method for manufacturing monolayer graphene on large-area substrates. As for any emerging material, cost-efficiency is one of the key factors on the road to industrial scale fabrication. Minimizing processing time is obviously one the essential parameters. The optimization of the whole fabrication process includes also characterization methods suitable for high throughput.

We demonstrate ultrafast characterization of graphene by simultaneous third-harmonic and photoluminescence microscopy. In addition, we present rapid synthesis of monolayer graphene on copper. Utilizing photo-thermal CVD, uniform high-quality graphene films covering the whole copper surface can be fabricated only in about 30 s (~11 mbar). In addition, the total processing time can be significantly reduced due fast ramp rates enabled by minimized thermal mass. Cold wall chamber minimizes contamination originating from the sidewalls, which is one critical factor in fabricating monolayer material. Cold wall facilitates also real-time temperature control by enabling utilization of pyrometer in temperature detection. Confocal µ-Raman mapping and electrical measurements including various devices were used to confirm the graphene quality. Raman spectroscopy showed clear evidence of high-quality monolayer graphene as we observed an average 2D/G > 3 with very low defect density (D/G ratio) using an area of 25×25 μm^2. Field-effect mobility determined using constant mobility model was 3000 cm^2/Vs [1]. We expect that these results will partly pave the way toward cost-efficient graphene fabrication.

In addition to typical global back gate utilized graphene field-effect transistors (GFET), we have also fabricated highly tunable local top and bottom gate controlled complementary graphene devices [2]. Both top and bottom gate oxides (Al_2O_3) were grown using atomic layer deposition (ALD). In the CMOS-like configuration, two transistors are individually controlled by electrostatic doping. This complementary structure along with the field-effect control over the graphene channel enables switchable operation between inverter (p–n FETs) and voltage controlled resistor (n–p FETs). Moreover, our approach enables variety of different substrates including non-conductive ones.

Finally we introduce alternative methodology for graphene analysis by presenting ultrafast characterization capabilities of simultaneous third-harmonic and fluorescence microscopy [3]. Without optimization of the homemade tool, imaging is for example orders of magnitude faster than in conventional Raman mapping (an area of hundreds of micrometers squared was imaged only in few seconds). The multiphoton microscopy produces images with high contrast in third harmonic generation (THG) between monolayer graphene compared to the substrate. While different monolayer samples produce constant THG signal, bilayer can be clearly distinguished from monolayer. Furthermore, the THG signal increases with the number of graphene layers to a threshold thickness until the signal starts to decrease.

References

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