Anisotropic Electrical Transport in Graphene Field-Effect Transistor Modulated by Sub-micron Gold Gratings

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In this work, we investigate the anisotropic electrical transport in graphene field-effect transistors (GFETs) modulated by periodic sub-micron gold gratings. Due to the work function difference between graphene and gold, electrons transfer from graphene into the metal, resulting in p-type surface charge transfer doping of the graphene channel. The 320nm-linewidth gratings were defined using electron-beam lithography and a highly optimized lift-off process. The characterizations of devices via scanning electron microscopy (SEM) reveals the well-defined pattern with a precise 55:45 duty cycle, as shown in Fig 1. Atomic force microscopy (AFM) reveals extremely low line-edge roughness and steep metal sidewall profiles, as shown in Fig 2. Furthermore, the CVD-grown graphene region remains defect-free and clean, which provides an ideal platform for the comparison of anisotropic current direction.

To directly unveil the electrical potential modulation, Kelvin Probe Force Microscopy (KPFM) was utilized to measure the surface potential of graphene. The potential difference between graphene on gold and graphene on SiO2 is about 150meV, verifying the mechanism of surface charge transfer doping.

To evaluate the impact on carrier transport of these periodic gold gratings, electrical measurements were conducted on the GFETs, as shown in Fig 3. The transfer characteristics (Id-Vg) of the grating devices show a significant positive shift of the Dirac voltage (V_{dirac} ~ 40V) for both transport directions, fitting in the KPFM result of p-type doping. More importantly, an obvious transport anisotropy is observed depending on the channel direction. When the carrier transport direction is parallel to the gold grating lines, the current is significantly enhanced, benefiting from the increased carrier density induced by surface charge transfer doping. On the other hand, when the carrier transport is perpendicular to the gratings, the devices suffer from a reduced channel current. This reduction indicates that while graphene remains p-type doped, the periodic potential barriers introduced by the graphene on gold/graphene on SiO_2 interfaces dominate the perpendicular transport, acting as a block.

In conclusion, we have demonstrated that periodic sub-micron gold gratings can effectively modulate the electrical properties of GFETs, resulting in an obvious transport anisotropy. While both transport directions benefit from the p-type surface doping which increase the carrier concentration, their transport behaviors are significantly different. Ultimately, this work highlights the capability of precise nanofabrication to control the electrical properties of two-dimensional materials, paving the way for advanced nanoelectronic applications.

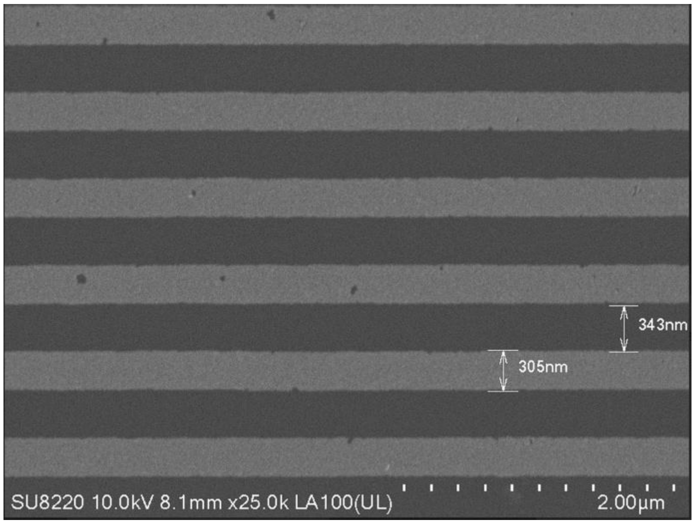

Figure 1: The SEM image of 320nm gold grating

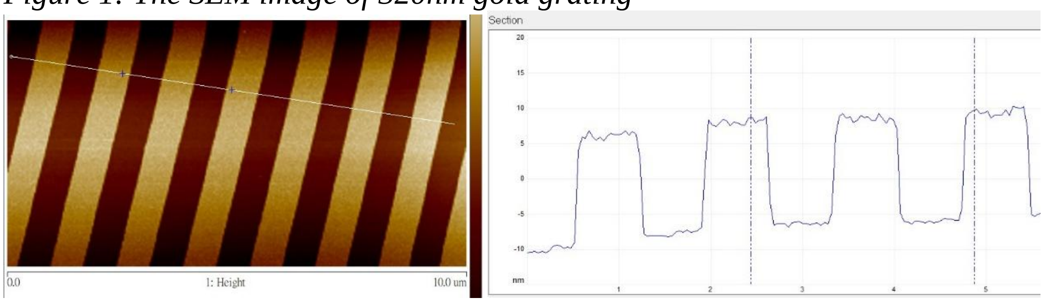

Figure 2: (Left) AFM topography of the 320nm gold gratings. (Right) Corresponding cross-sectional profile extracted along the solid white line.

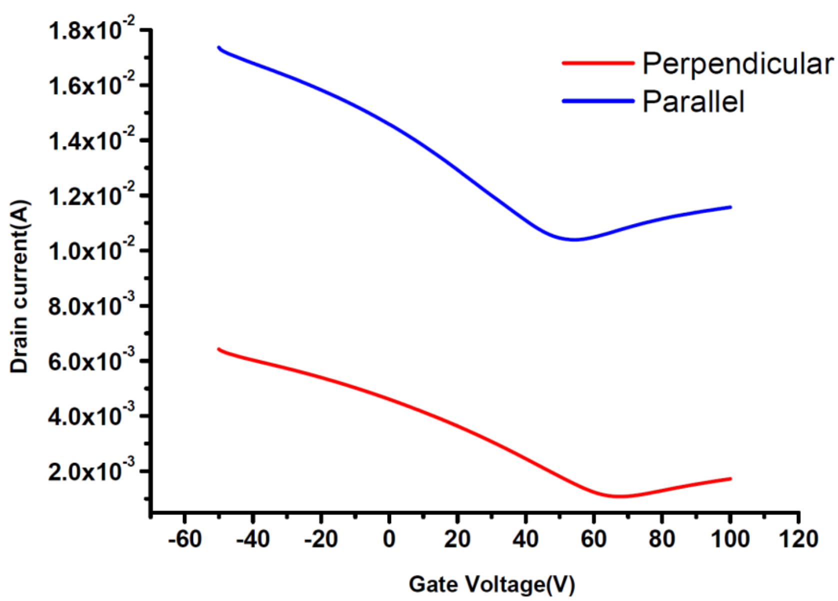

Figure 3: The transfer characteristic of the anisotropic transport. The blue curve represents transport parallel to the gratings, while the red curve denotes in-plane transport perpendicular to the grating lines.