Low Temperature Graphene Growth

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Abstract:

Graphene shows great promise for mechanical, chemical, and electronic applications. However, the physical implementation of a graphene layer in CMOS devices is currently limited, due to the high temperature growth, circa 1000°C. We succeed in growing graphene at a lower temperature on copper film and on evaporated copper foil, down to 700°C. We compare between graphene growth on different substrates and temperatures and find similar growth on Cu film and Cu foil, and a temperature dependant graphene grain size.

Summary:

Due to its phenomenal electron mobility (up to 200,000 cm² V⁻¹ s⁻¹) and mechanical (~ 1 TPa) properties, graphene shows great promise for nanoelectronic applications. High quality graphene is required for many applications, most notably transparent, flexible electronic devices. However, the physical implementation of a graphene layer in patterned devices is currently limited, due to the high temperature growth, circa 1000°C. Although graphene can be transferred onto a device, transfer techniques are limited in small scales due to alignment restrictions.

We succeed in growing graphene on copper foils at a lower temperature by using ethylene gas, instead of methane, combined with low flow rates (C₂H₄, 4 sccm) and long growth times (60 min). We inspect the graphene grain size using the dark-field transmission electron microscopy (DF-TEM) technique. This technique allows us to quantize important graphene characteristics such as graphene grain size and grain orientation [1]. We find that graphene grain size is dependent on the growth temperature, starting from 250 nm for 1000°C and decreasing to 50 nm for 800°C. Figure 1 shows a DF-TEM false-color image of a graphene growth at 850°C. The average grain size is 100 nm, and there are two main orientations observed, as well as a rip at the bottom left showing the mechanical weakness of the smaller-grain graphene.

Figure 1: False color dark field TEM of a 850°C graphene growth on Cu foil. Insert (top left): Diffraction pattern, showing two main orientations. The two orientations are marked by a different texture in the image.
We also grew graphene on evaporated copper thin films at lower temperatures, opening a possibility of integrating a graphene layer in pre-patterned devices for academic and industrial applications. Graphene growth on copper foil and on evaporated copper film at 1000°C results in full surface coverage, and in comparable grain size..

We then continue to examine graphene growth on evaporated copper films at lower temperatures, down to 700°C. Micro-raman spectroscopy confirms the existence of single layer graphene (2D/G ratio ~ 2), however the D peak, which indicates the extent of defects and disorder in graphene, increases with lower growth temperature, as can be seen in Figure 2. The decrease in graphene quality with lower temperature growth is probably caused by two factors – the decrease in copper grain size, as well as the decrease in graphene grain size as seen before. In conclusion, we grow succeed in growing graphene at a lower temperature on copper foil, and on evaporated thin copper film, and we examine its crystalline properties.

References:


Figure 2: Raman spectra of graphene growths at various temperatures on evaporated Cu film.