Characterization of Graphene Obtained by Chemical Vapor Deposition

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Abstract:

Following the increasing demand for graphene, chemical vapor deposition (CVD) has emerged as a viable method to obtain large-area graphene. CVD graphene shares many of the remarkable properties observed in exfoliated graphene. It still remains of paramount importance to fully characterize CVD graphene, as many of its properties can be altered by a smaller grain size. We studied the mechanical response of CVD graphene membranes, finding a decreased breaking strength. In addition, we fabricated devices to study the individual effect of grain boundaries on electronic transport.

Summary of Research:

We fabricated arrays of membranes by growing graphene by chemical vapor deposition (CVD) on copper foil [1]. Graphene was then transferred from the copper foil onto holey silicon nitride membranes by protecting graphene with a poly(methyl methacrylate) (PMMA) layer and then etching copper away in a ferric chloride solution. These holey silicon nitride membranes were fabricated by growing low pressure chemical vapor deposition (LPCVD) low stress silicon nitride on standard silicon wafers, and patterning them with standard photolithography and reactive ion etching. The PMMA layer was then removed by thermal decomposition in air, leaving graphene freely suspended across holes in the silicon nitride membrane, as shown in Figure 1.

We studied the resulting graphene membranes with atomic force microscopy (AFM). As can be seen in Figure 2, the CVD graphene membranes are wrinkled. By correlating observed features in phase AFM images with those obtained by transmission electron microscopy and scanning transmission electron microscopy, we have determined that grain boundaries are discernable in the AFM images lines [2,3]. This is the case because grain boundaries, which are more reactive than pristine graphene, are decorated with nanoparticles formed during the copper etching process, as well as amorphous carbon residues.

By performing indentation measurements, we have determined that wrinkles and grain boundaries have a measurable effect on graphene’s mechanical properties. First, wrinkles in graphene decrease its effective...
elastic modulus, in comparison to exfoliated graphene, as determined by membrane indentation. We calculate an effective 2D elastic modulus of ~ 55 N/m, which is approximately a factor of 6 less than what had been reported in exfoliated graphene samples [4].

Second, graphene’s polycrystallinity weakens the membranes, as graphene is observed to unzip along grain boundaries (Figure 3).

By determining the location of grain boundaries with a dark field transmission electron microscopy (DF-TEM) method recently reported by our team, it will be possible to study the electrical properties within and in between different graphene grains, by individually contacting these domains (Figure 4).

References:


