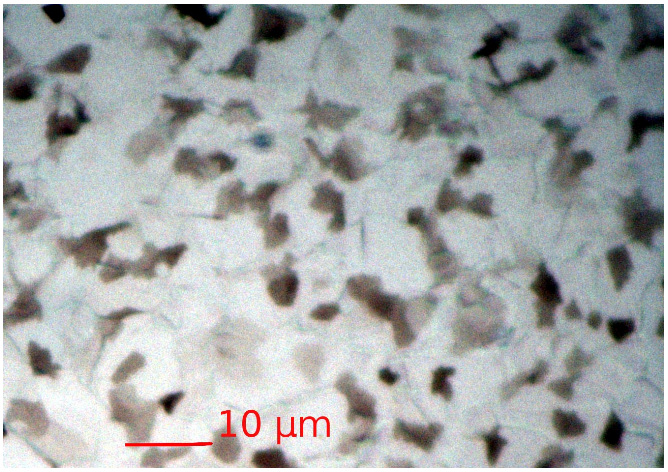
Frequently Asked Questions about Graphene Grown via Chemical Vapor Deposition



Multilayer graphene film grown on nickel coating transferred onto a silicon dioxide wafer

Q. What is the difference between graphene grown on nickel and copper?

A: The graphene grown on nickel film is multilayer and is not uniform. It looks like a patchwork whereas the “patches” have different thicknesses. The thickness of the film varies from 1 to 4 layers. The graphene layers within the same patch are aligned relative to each other (there is a graphitic AB-staking order). The size of the patches is about 3-10 microns. In contrast to the CVD graphene grown on nickel film, the graphene film grown on copper foil is monolayer (One layer thick, uniform). The film is polycrystalline and consists of “grains” or “domains” with slightly different lattice orientation. The grains merge with each other during the CVD process.

Q. Does the graphene cover both sides of the copper foil?

A. Yes. Both sides of the foil are exposed to the gases during the CVD process and the graphene covers both of the sides.

Q. The piece of copper foil with graphene is larger than is needed for our experiment. We want to use a small piece and keep the rest for other experiments. Can we do it?

A. Yes, the copper foil with graphene can easily be cut with household scissors. When cutting the foil, avoid touching the graphene surface, as you may damage the graphene. The wafers with graphene grown on nickel film can be cut with a diamond scribe along the crystallographic orientation of the wafer.

Q. We ordered single layer graphene and receive a piece of copper foil. We studied the foil under microscope and could not find any graphene. Is it there?

A. Yes, it is there. The optical density of single-layer graphene is about 2.5%. It is extremely difficult to see under the microscope. The best you can do is to focus the microscope slightly above the surface of the foil and look for dust particles “levitating” above the surface of the substrate. You may also notice the grain boundaries. Transfer the graphene onto a dielectric surface (preferably a silicon wafer with a 285 nm oxide layer) and do Raman spectroscopy to analyze your samples.

Q. What precautions should be observed when handling the CVD graphene?

A. The graphene is resistant to most chemicals. One should avoid scratching the graphene. We do not recommend cleaning graphene by sonication in solvents, as this procedure can destroy the graphene. It is also known that graphene can be destroyed by plasma. The CVD graphene can withstand heating up to 350°C on air and up to 800°C in vacuum or in the inert gas environment.

Q. What is the shelf life of CVD graphene?

A. To the best of our knowledge, there is no report of degradation of the CVD graphene over time when it is kept in a safe dry place. The copper foil with single-layer graphene can exhibit some coloration due to slow oxidation of the copper foil, which does not affect the quality of the graphene film.

Q. I transferred the graphene to my substrate, now I want to remove the graphene. Is it possible?

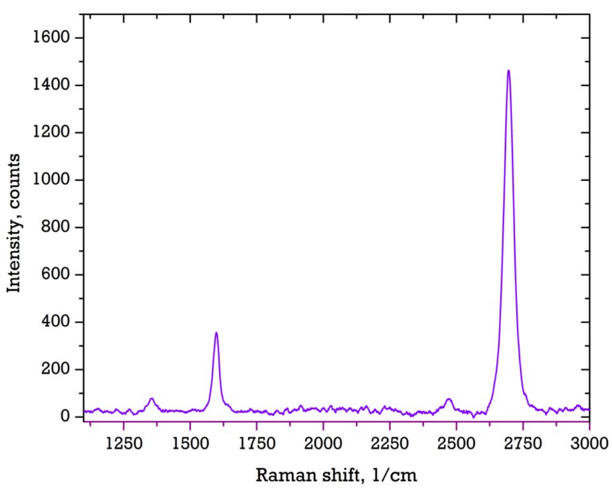
A. Yes. Sonication of the substrate in water removes the graphene coating. Alternatively, the graphene coating can be removed by oxygen plasma.

Q. What can the Raman spectrum tell us about the quality of our graphene?

A. Raman spectroscopy is a simple and efficient method to examine the quality of graphene. To simplify the analysis, the single-layer graphene should be transferred onto a dielectric surface (preferably a silicon wafer with a 285 nm oxide layer). Note that the Raman spectrum of graphene grown on copper foil will be distorted by the strong background signal. It is not necessary to transfer the multilayer graphene from Ni film to do a Raman analysis.

There are many scientific publications that describe Raman analysis of the various types of graphene in detail. We will discuss it here briefly. The most prominent features of the Raman spectrum of graphene are: a) the D-line, located at 1350 1/cm, b) G-line at 1580 1/cm and c) 2D-line (or G'-line) located at ~2675 1/cm.

The number of microscopic defects in the graphene can be determined by the intensity of the D-line. The spectrum of perfect, defect-free graphene does not have a D-line. The D-line can also originate from the grain boundaries, chemical doping, and several other factors. We consider single-layer graphene to be of appropriate quality if the ratio of the intensities of the D and G lines does not exceed 0.3.



Raman spectrum of monolayer graphene grown on copper foil and transferred onto a silicon dioxide wafer

Raman spectroscopy can also reveal the thickness of multilayer graphene. Note that the Raman spectrum of multilayer graphene strongly depends on the relative orientation of graphene layers.

There are two options: graphite-like graphene with AB-stacking order between layers and the turbostratic graphene with random interlayer orientation. The 2D-line of the multilayer graphene with graphitic stacking between layers is broadened and slightly shifted when compared to the shape and position of the 2D-line of monolayer graphene. For the turbostratic multilayer graphene, only the ratio of the G and 2D line changes with thickness.

When doing Raman spectroscopy of graphene, it is important to keep the laser power relatively low. If the laser power is too high, it can cause local overheating of the sample, which in turn causes growth of the intensity of the D-line. The laser power should not exceed the level of few mW when the laser is focused into a spot that is few micrometers in diameter.

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