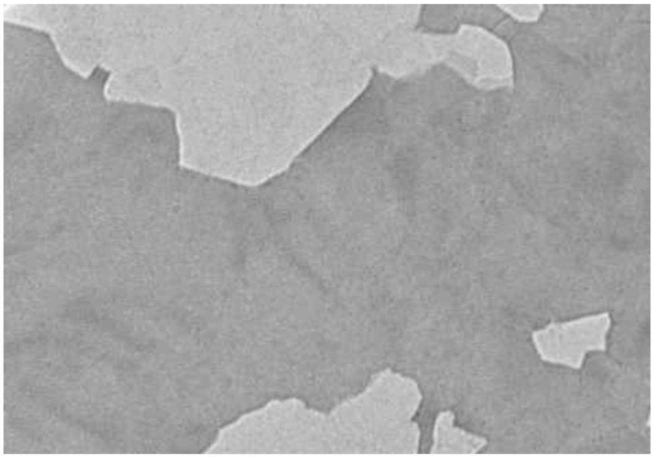
Continuous Wafer-Scale Graphene Films Prepared by Chemical Vapor Deposition: Production and Applications

Graphene, a sheet of carbon atoms arranged in a hexagonal lattice structure, is viewed as the next big thing in high-tech. To be the "miracle material" some claim it to be because of its strength, transparency, and conductive qualities, it needs to be mass produced.



TEM image of suspended graphene film grown on Nickel by CVD and Courtesy: William Glover, Katelyn Murtagh, ZS Genetics. Light area - single area. Darker areas- few-layer thick graphene

Graphene was originally prepared using mechanical exfoliation, gathering it from graphite with a piece of simple scotch tape. However, as methods developed, chemical vapor deposition (CVD) soon became the method most successful for fabricating large areas of high quality graphene. Worldwide, researchers use graphene prepared by CVD, as it allows the graphene to be transferred to substrates such as silicon dioxide, glass, and plastic.

CVD is not a new process, having been used to prepare many different materials. It is used to produce thin films, and requires thermochemical vapor-phase reactions to form the desired deposit on a substrate. CVD graphene is made by flowing hydrogen and methane gases through a furnace heated to about 1000^{o}C with a metal catalyst such as copper or nickel. The methane then decomposes, leaving carbon atoms deposited on the metal. After the process is complete, the copper or nickel can be etched away, leaving graphene that can be deposited onto a substrate such as glass or a silicon wafer.

Graphene which has been prepared by CVD processing may be either monolayer or multilayer, depending on which metal is used. If copper is used to create graphene, more than 95% of the graphene will be monolayer[1]. However, if prepared on nickel, the end result is varying levels of multilayer graphene. This is because nickel can absorb more carbon than copper is able to. Cobalt has also been used to isolate graphene via CVD; however it is used more rarely than copper or nickel.

Graphene of both multi- and mono-layers made via CVD processing have many potential practical applications. These include solar cells, as a transparent conductive coating and replacement for indium tin-oxide (ITO) currently used in touchscreens, for use in TEM grids, and radio-frequency electronics.

Applications of Continuous Graphene Films Prepared CVD

Photovoltaic:

CVD graphene has potential as an organic photovoltaic (OPV) cell, being a low weight substitute for current solar panels in certain applications. Though graphene-based solar cells are not nearly as efficient as silicon (about 1.3 watts to every 14 watts generated in silicon), they would be robust, flexible and cost much less. This means that though for use on a large, flat cell, silicon would remain ideal, graphene-enhanced "fabrics" that collect energy while being aesthetically pleasing, such as curtains, may one day help power your home[2].

Monolayer graphene flowers grown by CVD on copper and transferred onto silicon dioxide/silicon wafer

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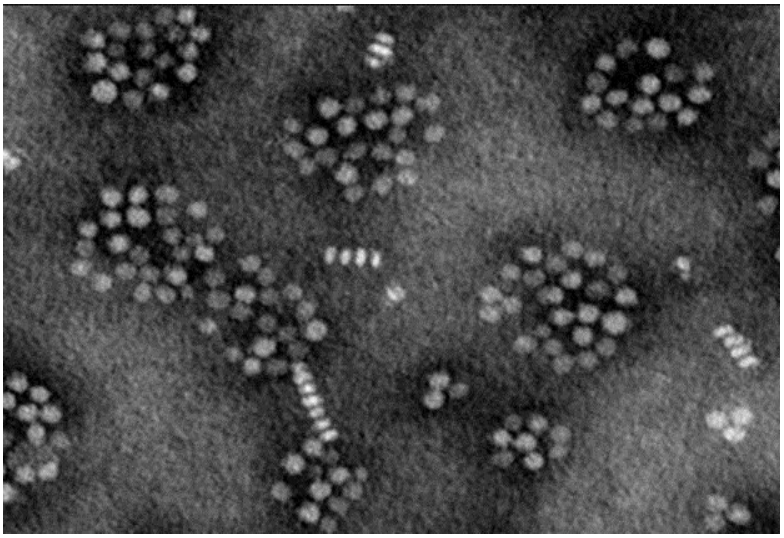
Transparent Conductive Coatings: Graphenes flexibility also gives it an advantage over indium tin-oxide (ITO) not only as an OPV, but in other arenas as well. ITO is currently the material of choice for making touch-screen displays on cell phones, tablets, and other devices. However once you drop one of these devices once, the screens often shatter because ITO is not flexible and cannot absorb the impact. On the other hand, graphene's strength and flexibility mean you could bend your screen, as well as drop it, without damaging it[3].



An ultra-high contrast TEM image of discoidal High Density Lipoproteins on a graphene film. Courtesy of Profs. Bolotin and Jerome, , Vanderbilt University, Dr. Polyakova, Graphene Laboratories, Inc.

Transmission Electron Microscopy: The graphene can also be used for transmission electron microscopy (TEM) grids. Because of its few-atom thickness, the grid is virtually transparent to the electron beam so a clearer, more refined image of the subject is reached. In particular, graphene TEM grids are useful for researching nanostructures and biological molecules that cannot be viewed with conventional grids[4].

Integrated Circuits: As IBM has demonstrated, graphene may also be used in circuits by integrating graphene transistors with other components. The integrated circuits combine the transistor with a pair of inductors onto a silicon carbide wafer. To do this, IBM had to open up a bandgap in the graphene, which was one of the biggest hurdles in creating graphene electronics which can compete with silicon[5].

There are challenges, however, when using CVD processing for graphene mass production. Graphene on copper or nickel is of little use for most commercial purposes; it generally needs to be on a substrate such as plastic, silicon dioxide, or glass for practical applications. Unfortunately, it is not currently possible to use CVD to deposit graphene directly onto these substrates because of the high temperatures required, which would damage the substrate and the graphene. Recently, chemical methods were developed to separate the graphene film from the metal surface and transfer it to the required substrate. However, transferring graphene to these substrates requires expertise and is difficult to do. Fortunately, there are continuous reports on progress in this area. Recently, high-quality large-scale CVD graphene has become commercially available. The Graphene Supermarket (www.graphene-supermarket.com) has scaled their graphene production, now selling graphene sheets as large as 4”x4”. In addition, graphene films transferred onto substrates such as silicon wafers, plastics, and glass is also offered. These advances will allow for advanced research and help facilitate commercial applications of graphene.

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To order graphene prepared by chemical vapor deposition from the Graphene Supermarket, visit www.graphene-supermarket.com. (https://graphene-supermarket.com/CVD-grown-graphene/)

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