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ULTRANANOTECH PVT. LTD.

Materials Beyond Imagination

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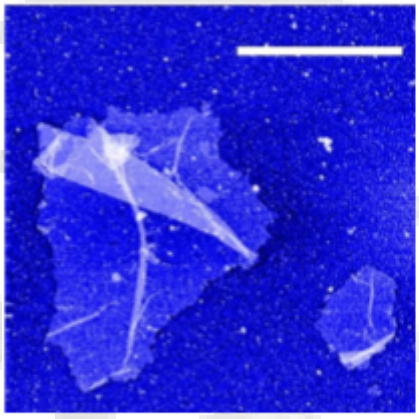
GRAPHENE OXIDE

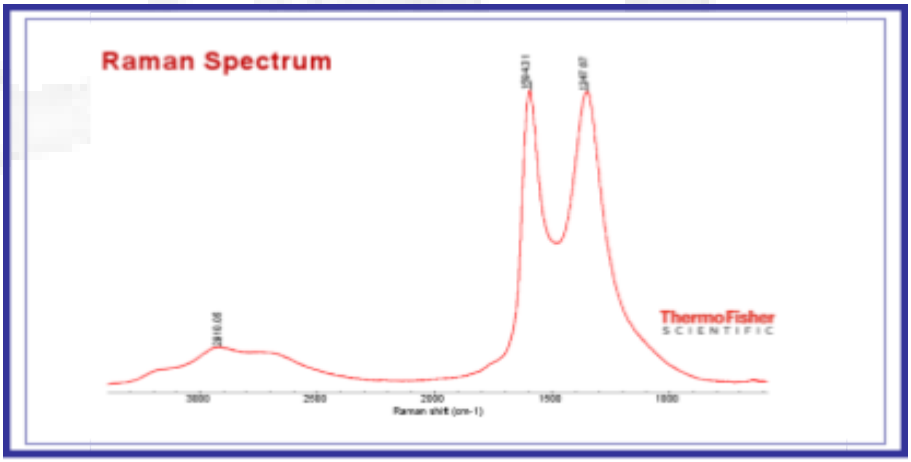
Production of Graphene Oxide:

Graphene Oxide is the oxidized form of graphene produced by oxidizing crystal graphite with a mixture of sulfuric acid, sodium nitrate, and potassium permanganate (the Hummers method). Structurally, Graphene Oxide can be visualized as a graphene sheet with its basal plane decorated by oxygen-containing groups. Due to high affinity to water molecules by these groups, Graphene Oxide is hydrophilic and can be dissolved in water. The solubility in water makes the deposition of the thin films of the Graphene Oxide straightforward. Graphene Oxide is a poor conductor but its treatment by light, heat, or chemical reduction can restore most properties of the famed pristine graphene. Conventionally, the reduction is done by hydrazine. The are other "green methods available, such as introduction of bacteria containing cytochromes.



AFM image and height profile of the Graphene Oxide deposited onto functionalized mica. The image was generated by SmartSPM™ (AIST-NT, Inc.).

Courtesy of Dr. Andrey Krayev



Courtesy of Dr. Mark H. Wall

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Specifications:

- Composition: Carbon (79%), Oxygen (20%)
- Flake size: 0.5-5 microns.
- Thickness: 1 atomic layer - at least 60%.
- Color: Brown

Graphene Oxide: Potential Applications

Transparent Conductive Films: One of the major areas where graphene oxide can be expected to be used is in the production of transparent conductive films. Graphene Oxide films can be deposited on essentially any substrate, and later converted into a conductor. Such coatings can be used in flexible electronics, solar cells, liquid crystal devices, chemical sensors, and as an indium tin-oxide (ITO) replacement. ITO is the current material of choice for touch screen devices.

Composites and Paper-like Materials: Graphene Oxide mixes readily with many polymers, forming nanocomposites, and greatly enhances the properties of original polymer; this includes elastic modulus, tensile strength, electrical conductivity, and thermal stability. In its solid form, Graphene Oxide flakes tend to attach one to another, forming thin and extremely stable paper-like structures that can be folded, wrinkled, and stretched. Such free-standing Graphene Oxide films are considered for applications including molecular storage, ion conductors, and nanofiltration membranes.

Energy-Related Materials: Graphene Oxide and its reduced forms have an extremely high surface area; because of this, these materials are under consideration for usage as electrode material in batteries and double-layered capacitors, as well as in studies of hydrogen storage, fuel cells, and solar cells[1]. Graphene Oxide can more easily be scaled up than other graphene materials, and therefore may soon be used for energy-related purposes. Its ability to store hydrogen will, in the future, prove very useful for the storage of hydrogen fuel in hybrid cars. Graphene Supermarket offers Reduced Graphene Oxide with Brunauer-Emmett-Teller (BET) Specific Surface Area as high as 833 m^2/g.

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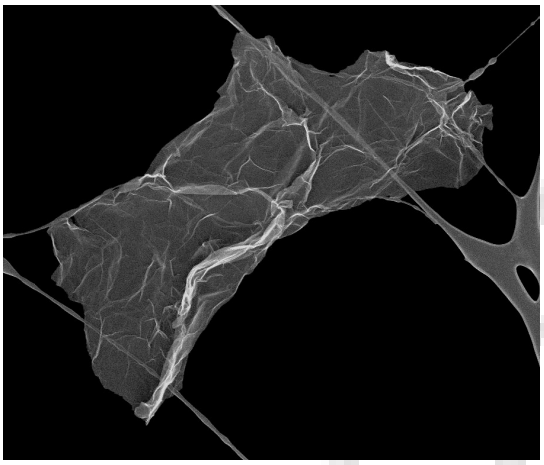

SEMimage of an individual Graphene Oxide flake

Applications in Biology and Medicine: Graphene Oxide was found to be fluorescent, which opened a route for applications in bio-sensing, early disease detection, and even assisting in carrying cures for cancer. Graphene Oxide has been successfully used in fluores-cent-based biosensors for the detection of DNA and proteins, with a promise of better diagnostics of HIV. Furthermore, Graphene Oxide is tested as a drug carrier as well. It is likely superior to many other anticancer drugs because it does not target healthy cells, only tu-mors, and has a low toxicity[2].

Antibacterial Materials: The growth of E. Coli bacteria may be sup- pressed when disrupted by Graphene Oxide. Because production of Graphene Oxide is inexpensive, it may be mass produced when its applications come to market. When this happens, it will open many doors for developing antibacterial materials, and may assist in heal-

ing wounds by killing bacteria that may affect them. These materials can be made into a thin paper used for packaging meats, which will prove more sanitary than current packaging methods[3].

Graphene Oxide Sheets at Interfaces: Graphene Oxide's properties include the ability to act as a surfactant, similar to how soap or shampoo would make a stain disperse in water. This ability can be used as an agent for dispersion of insoluble materials such as carbon nanotubes[4].