GRAPHENE OXIDE (GO) NANOSTRUCTURES FOR FILTRATION OF CHROMIUM^{+3} AND CHROMIUM^{+6} IONS FROM AQUEOUS SYSTEMS

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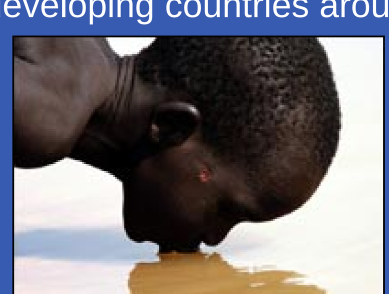
ABSTRACT

In this project, we will be exploring the ability of graphene oxide and reduced-graphene oxide to filter heavy metals from solution. For this experiment, we chose chromium, both the trivalent and hexavalent species, to filter. The process starts with the production of graphene oxide (GO) from natural flake graphite, then uses a modified Hummer's method[1] to produce graphite oxide and subsequent ultrasound exfoliation of the graphite oxide solution to GO. Successive reduction of the GO was accomplished using hydrazine in a 3:1 weight ratio. Next, in various concentrations, solutions of GO are filtered through 0.22 µm pore size filter discs from EMD Millipore and the filter apparatus described in detail in the section titled "GO Filter Disc Production". (The following steps are proposed as the project is ongoing.) The set-up shown in the section "Sample Collection" will be used to collect approximately 15 ml of filtrate for analysis. The analysis, to be completed by an inductively coupled plasma mass spectrometer (ICP-MS), will be looking for traces of the chromium ions. Sample plots have been shown to illustrate expected ICP-MS output.

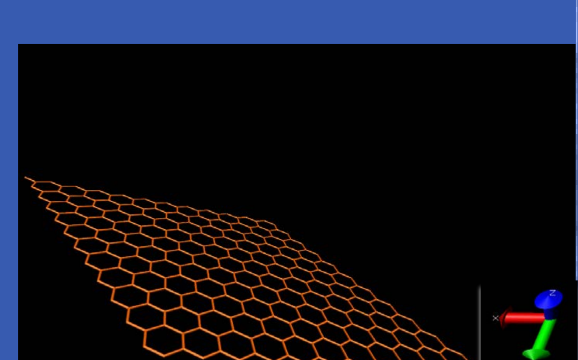
INTRODUCTION

Water is vital. It is vital to society, people, and life in general. Without a source of clean water, living systems break down and life as we know it ceases. Through man's progression towards modern society, we have done much to the environment in which we live. One thing, heavy metal pollution, is a threat to all living systems. Through bioconcentration and bioaccumulation, these heavy metals achieve a foothold in the environment and are very difficult to remove. Of particular concern in the United States is Chromium 6+, or hexavalent chromium. Chromium-6 is carcinogenic and is found in 31 out of 35 cities that were tested in the US. In California, the only state that requires testing for chromium-6, water utilities have detected the compound in tap water supplying more than 31 million people. In addition, at least 74 million people in nearly 7,000 communities across the country drink tap water polluted with "total chromium", as reported by water utilities[2]. This research aims to show that graphene, a two dimensional structure, is capable of removing these heavy metals from water; thus, making this substance a candidate for superior water filters for homes, industry, and developing countries around the world.



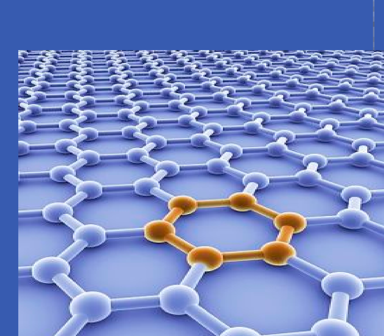
GRAPHENE

Graphene is a single layer of sp^2 hybridized carbon atoms packed in a honeycomb lattice. Geim and co-workers synthesized graphene in 2004 through mechanical exfoliation (Nobel Prize in Physics, 2010)[3,4].



Some properties of graphene include:

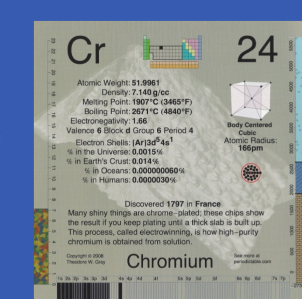
- Conceptualized as the building block of graphite, carbon nanotubes, and fullerenes
- Itinerant massless Dirac fermions
- High mobility of its charge carriers
  - Ballistic conduction
- Excellent mechanical strength
  - Young's modulus of 1.0 ± 0.1 TPa
- High thermal conductivity
- Able to withstand high temperatures[3,5]



CHROMIUM

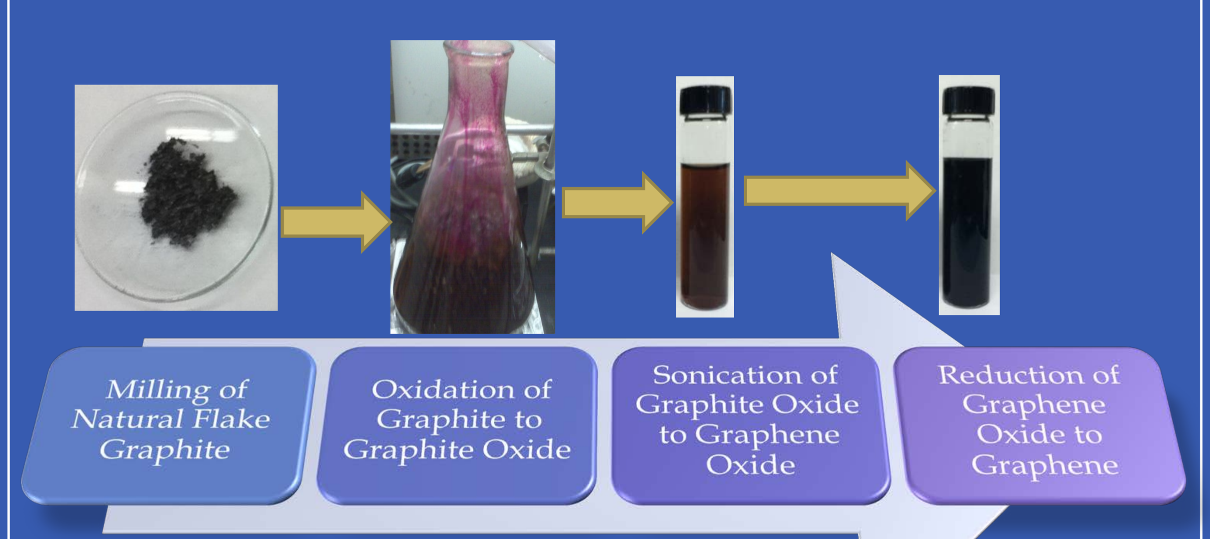
The name chromium is derived from the Greek word "chrōma", meaning color, because many of its compounds are intensely colored; however, pure Cr is a white, hard, lustrous, and brittle metal.

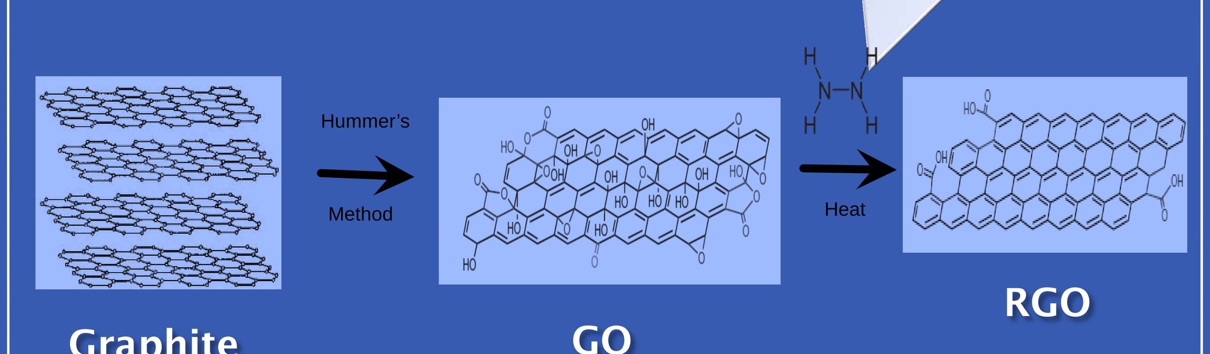
First discovered in the mineral crocoite (lead chromate) which is famous for its deep yellow color and is used extensively in paints.



Chromium and its salts are used in the leather tanning industry, the manufacture of catalysts, pigments and paints, fungicides, the ceramic and glass industry, and in photography, and for chrome alloy and chromium metal production, chrome plating, and corrosion control. Chromium (VI) occurrence in soil is often the result of human activities, and since chromium (VI) salts are more soluble than those of Chromium (III), that makes chromium (VI) environmentally mobile. Chromium intake through drinking water can be substantial when levels are above 25 µg/L. In surface waters in the USA, levels up to 84 µg/L have been found[6,7].

GRAPHINE OXIDE AND REDUCED GRAPHENE OXIDE SYNTHESIS

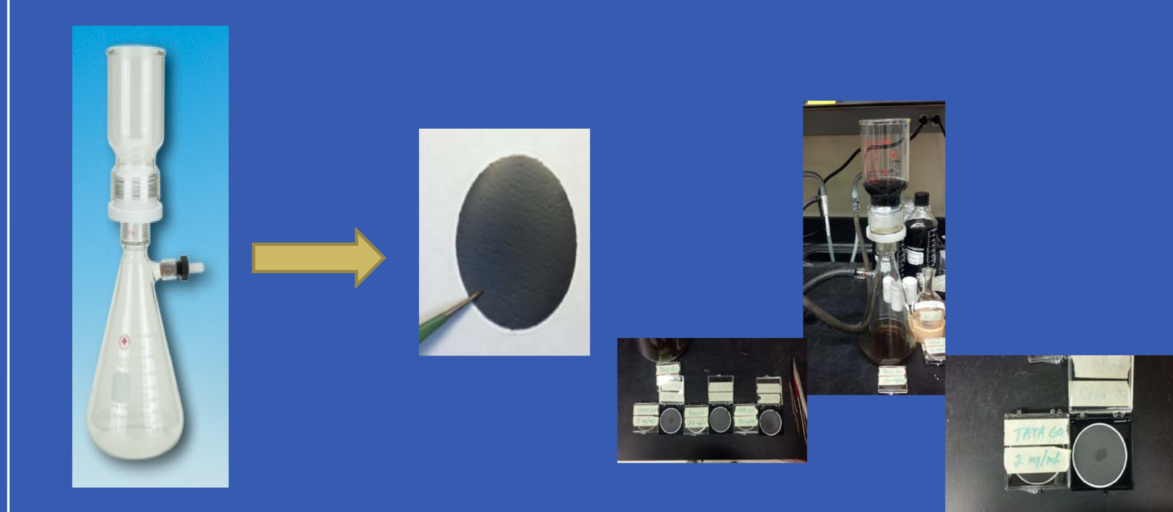




Graphene has been produced through a solution-based method starting with the oxidation of graphite using a modified Hummers method[1] and subsequent reduction with hydrazine. The solid graphite oxide obtained was exfoliated in DI water by ultrasonication for 1 h to form a graphene oxide suspension with a concentration of ~1 mg/mL. Subsequent reduction followed using hydrazine and 200 mL of the sonicated GO solution. A 3:1 weight ratio of reducing agent:GO was used, then stirred and heated at 80°C for 12 hours.

GO FILTER DISC PRODUCTION

To produce the GO filter paper, various concentrations of GO were filtered through 0.22 µm size pore nitrocellulose filter discs, from EMD Millipore, using a vacuum filtration apparatus consisting of a 1000 ml filter flask with threaded top, safe hose connection, 500 ml graduated funnel, nylon adapter and 47 mm (OD) fritted disc, porosity B; all from Ace Glass Company.



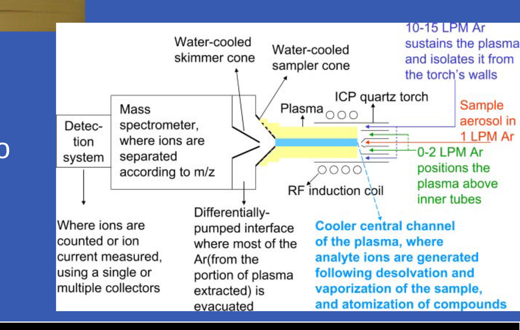
SAMPLE COLLECTION

The set-up shown consists of a 20 ml high pressure angioplastic syringe, a 3-way luer lock assembly, and improvised tubing taper, and an EMD Millipore 47 mm in-line high pressure stainless steel filter holder. The two high pressure pieces in the set-up are required because preliminary tests revealed pressure was a factor in the filtration process for GO. In order to accommodate this requirement, an angioplastic syringe was found to provide a maximum of 30 atm of pressure, so a case of 5 was obtained from the medical supply company Merit Medical. Theoretically, these syringes will provide the pressure needed, and the high pressure filter holder will support the filter discs during the high pressure stage of the collection. This set-up will be used to collect approximately 15 ml of filtrate for analysis.

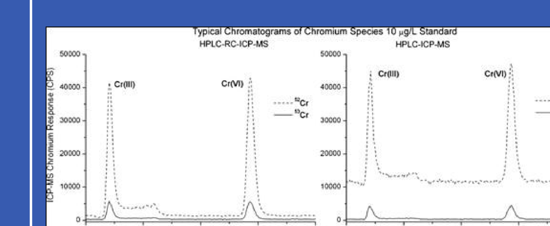
INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY(ICP-MS)

A type of mass spectrometry which can detect metals, and some non-metals, at concentrations as low as one part per trillion. The sample is ionized with inductively coupled plasma and the ions are quantified using a mass spectrometer.

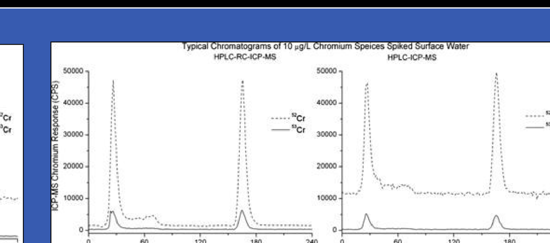
ICP-MS has a greater speed, precision, and sensitivity than atomic absorption techniques. However, this technique is more susceptible to trace contaminants from glassware and reagents. Also, some ions may interfere with the detection of other ions.



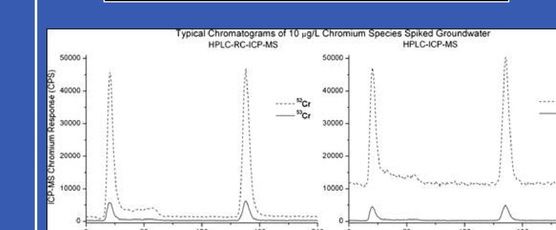
SAMPLE ICP-MS PLOTS



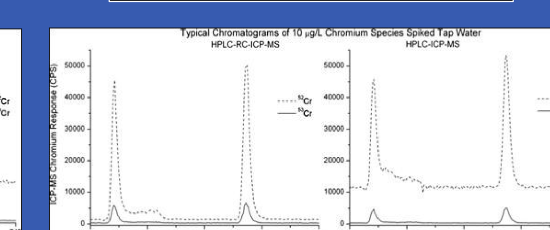
Calibration Standards



Spiked Surface Water



Spiked Groundwater



Spiked Tap Water

ACKNOWLEDGEMENTS

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