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Removal of Heavy Metals and Organic Contaminants from Aqueous Streams by Novel Filtration Methods

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Research Objective

Graphite nanofibers are a new type of material consisting of nanosized graphite platelets where only edges are exposed. Taking advantage of this unique configuration our objective is:

- To produce graphite nanofibers with structural properties suitable for the removal of contaminants from water.
- To test the suitability of the material in the removal of organic from aqueous solutions.
- To determine the ability of the nanofibers to function as an electrochemical separation medium the selective removal of metal contaminants from solutions.

Research Progress and Implications

This report summarizes work after 1.5 of a 3-year project. During this period, efforts have been concentrated on the production, characterization and optimization of graphite nanofibers (GNF). This novel material has been developed in our laboratory from the metal catalyzed decomposition of certain hydrocarbons (1). The structures possess a cross-sectional area that varies between 5 to 100 nm and have lengths ranging from 5 to 100 mm (2). High-resolution transmission electron microscopy studies have revealed that the nanofibers consist of extremely well-ordered graphite platelets, which are oriented in various directions with respect to the fiber axis (3). The arrangement of the graphene layers can be tailored to a desired geometry by choice of the correct catalyst system and reaction conditions, and it is therefore possible to generate structures where the layers are stacked in a “ribbon”, “herring-bone”, or “stacked” orientation. The research has been directed on two fronts: (a) the use of the material for the removal of organic contaminants, and (b) taking advantage of the high electrical conductivity as well as high surface area of the material to use it as electrode for the electrochemical removal of metal pollutants from aqueous streams.

(a) Use of GNF in the Removal of Organic Contaminants from Water.

In the first part of this project the suitability of graphite nanofibers for the adsorption of selected organic molecules from aqueous solutions was tested by allowing a solution of a given organic to interact with selected samples of GNF. In a typical experiment, 0.2 g of the carbonaceous solid was placed in a solution containing 0.5 mL of a ethyl or butyl alcohol in 60 mL of deionized water. The material was continuously stirred and maintained at room temperature for up to 160 hours. Care was taken to prevent loss of the alcohol due to evaporation by keeping the container covered. The uptake of alcohol by the carbon was monitored as a function of time by taking samples of the solution at various periods of time that were analyzed by Gas Chromatography. Identical experiments were conducted using an active carbon sample possessing a surface area ~ 7.5 times that measured for GNF.

Carbon nanofibers possessing a high degree of crystalline order have been found to exhibit excellent adsorption characteristics for the removal of small amounts of alcohol from aqueous solution. A comparison with active carbon shows that even though the nanofibers have a surface area that is 7 times lower their performance for this separation process is far superior to that displayed by the former material. A further feature to emerge from this work is the finding that pre-treatment conditions have a critical impact on the subsequent adsorption behavior; while prolonged immersion in hydrochloric was found to be extremely beneficial, a similar treatment in nitric acid virtually nullified the advantages of using nanofibers for the process.

(b) Use Of GNF for the Extraction of Metallic Contaminants from Aqueous Streams

The potential of GNF for the removal of metals from aqueous solutions was tested in a specially built plug flow cell, which consists of two chambers filled with the carbon material. Details of the design of the cell are well documented in the literature (4,5). In this arrangement, nanofibers in one of the chambers function as the cathode, whereas the material placed in the second compartment acts as the anode. A saturated calomel electrode was used as reference. Water is purified by flowing a solution through the cell where the metal ions are removed from solution via an electrochemical reduction process that occurs on the nanofibers present in the cathode. Once the nanofibers are saturated with the metal, the contaminant can be collected in conjunction with the carbonaceous material or, if desired, discharged into a more concentrated solution by switching the voltage. This process allows for both the purification of water as well as the recovery of the metal in a higher concentration for further application. These experiments were performed by applying a potential to the cell, which is controlled by a CMS300 PC3 potentiostat. Concentration of ions were determined by an induced coupled argon plasma (Leeman Plasma-Spec).

Preliminary work indicates that when a 170 ppm copper sulfate in 0.0166 M sulfuric acid solution (ion source) is passed over a 2.0 gram GNF bed, 2 cm in length, then up to 97% of the copper content is eliminated from the solution at a -8.5 V.

References

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Planned Activities

- We plan to use GNF for the removal of a variety of organic contaminants from aqueous solution and at the same time, develop methods for the recovery of these chemicals.
- In a complementary series of experiments efforts will be focused on the examination of various nanofiber surface treatments in an attempt to enhance their adsorption capacity.
- An investigation of the adsorption efficiency of GNF as a function of increasing the surface area of the material from 50 to 600 will be carried out.
- The effect on adsorption characteristics of organics resulting from an expansion of the GNF lattice via insertion of selected groups within the layers will be conducted.
- Finally, we shall explore the impact of increasing the degree of crystallinity of the GNF on the use of the material as an electrode in electrochemical devices.