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TAILORING THE MICROSTRUCTURE OF TUNGSTEN CARBIDE (WC) DERIVED FROM BIOPOLYMER-BASED COMPOSITES

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Biography

I passed my Bachelor of Engineering in Mechanical Engineering with distinction from Indian Institute of Science Engineering and Technology, Shibpur (Formerly Bengal Engineering and Science University) in 2013. I had acquired research experiences in the field of microfabrication, microfluidics and nanotechnology in several research labs in India and USA. I worked as undergrad summer scholar in Indian Institute of Technology Kharagpur in 2011. Two research projects I completed in the BioMEMS laboratory of University of California, Irvine in 2012 as an exchange scholar. I worked as research associate for 6 months in Nanotechnology laboratory of Indian Institute of Technology Kanpur in 2013. Currently I am a student member of American Electrophoresis Society. My research interest includes microfabrication, carbon electrode dielectrophoresis, separation and manipulation of pathogenic cells for easy detection, nanomaterial synthesis, and carbon material synthesis from bio-precursors.

Overview:

Naturally occurring biopolymers such as cellulose, chitin, carrageenan, and starch are mostly abundant in nature. These biopolymers decompose to carbon upon heat treatment around 900 °C in inert atmosphere. Hence these biopolymers can be used as the carbon precursor in carbide synthesis, thereby replace the petroleum based precursors to establish an inexpensive, sustainable, and environment-friendly process of carbide synthesis. However, the microstructures of these carbide depend on the bio-precursors and the properties of the carbides depend on the carbide microstructures. Here we characterize the microstructures of tungsten carbide synthesized using different biopolymers such as cellulose, chitin, carrageenan and starch.

Motivation

Metal carbides are one of the interesting family of materials due to their unique properties such as high melting temperature, high chemical resistant, low thermal conductivity, low friction coefficient and high hardness. In industrial production, the resources used as carbon precursor for carbide synthesis include petroleum-based carbon, such as carbon black, petroleum coke and asphalt, coal products, graphite mining and other mineral resources [1–4]. These carbon precursors belong to non-renewable resources, which is a big concern for the sustainability of the world. Hence it is important to find renewable carbon precursors. There are several biopolymers such as cellulose, chitin, carrageenan which are renewable and mostly abundant in the nature. These biopolymers can be used as carbon sources in carbide synthesis as they produce carbon upon heat-treatment in inert atmosphere. The carbide synthesized using these biopolymers feature different microstructures based on the form of the biopolymers. It is important to characterize the microstructures of these carbides as the properties of the carbide depend on the microstructure.

State of the Art

The biopolymer route for carbide synthesis has been demonstrated before. For example, Prener and Schenectady demonstrated the use of sucrose as the carbon precursor to form silicon carbide [5]. Chitosan, a naturally occurring polysaccharide, has been used by few researchers as a carbon precursor to obtain metal carbides via carbothermal reduction reaction [6–8]. But there is no detail characterization of the microstructures reported based on these wide range of biopolymers.

Intellectual Merit

The intellectual merit of this work is the use of different forms of abundant biopolymers as the carbon source in carbide synthesis. Here we characterize the microstructures of tungsten carbide synthesized from cellulose, chitin, iota-carrageenan, starch, and bio-epoxy. We also suggest the potential applications of these tungsten carbides based on their microstructures.

Broader Impact

The use of biopolymers can replace the use of non-renewable petroleum resources. This allows the carbide synthesis process inexpensive, sustainable, and environment-friendly. Based on their microstructures, these carbides can be used in different applications ranging from battery to aerospace applications.

Research Approach

The biopolymers decompose to carbon upon heat-treatment at 900 °C in inert atmosphere. If the biopolymers are infiltrated with metal precursor, the biopolymers transform into metal carbide upon heat treatment at 1300 °C in vacuum. Here we use cellulose in form of chromatography paper and bacterial cellulose, chitin from shrimp shells, iota-carrageenan food additive, starch from rice paper and commercial grade bio-epoxy as carbon sources. Aqueous solution of ammonium meta-tungstate (AMT) is used here as the tungsten precursor. The biopolymers are infiltrated with different concentration of AMT and heat-treated in vacuum at 1300 °C for 3 hours. The material composition of heat treated material is characterized by x-ray diffractions (XRD). The grain size of the heat treated materials is estimated from the XRD patterns. The microstructures are characterized by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The porosity for these synthesized materials is measured by nitrogen adsorption-desorption.

Findings to Date

Till now it has been demonstrated that tungsten carbide can be synthesized using the aforementioned biopolymers. The SEM image analysis shows that tungsten carbide from each bio-precursor features different microstructure than the other. The microstructure differs depending on the concentration of the AMT for each bio-precursor.

Conclusions

It can be possible to establish an inexpensive, sustainable, and environment friendly process for carbide synthesis. Using this process any metal carbide synthesis can be possible by changing the metal precursor. These carbide materials can be used in different applications ranging from structural materials to electrode materials depending on their microstructures.

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