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One simple synthesis route to nanocrystalline tantalum carbide via the reaction of tantalum pentachloride and sodium carbonate with metallic magnesium

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Abstract

Nanocrystalline tantalum carbide (TaC) was synthesized via a simple route by the reaction of metallic magnesium with sodium carbonate and tantalum pentachloride in an autoclave at 600 °C. X-ray powder diffraction pattern indicated that the product was cubic TaC, and the cell constant was a=4.451 Å. Field emission scanning electron microscopy image showed that it consisted of particles with an average size of 40 nm. The product was also studied by TGA in the flowing air. It had good thermal stability and oxidation resistance below 450 °C in air. The mechanism of the formation of TaC was also discussed in this paper.

Keywords: Nanomaterials; X-ray techniques; Thermogravimetric analysis; Carbides; Tantalum carbide

1. Introduction

Due to their high hardness, high melting temperature, good high-temperature strength, the carbides of the transition metals are becoming a special group of compounds. They have been used as hard constituents in metal matrix composites for high-temperature applications and as coatings on cutting tools [1–5]. Among these carbides, tantalum carbide is a very important and promising example due to its unique combination of properties, such as its outstanding hardness (about 3000 kg/mm^2) [1], its high melting point (3880 °C) [1], its good resistance to chemical attack and thermal shock [1,6] and high resistance to oxidation [7], its excellent electronic conductivity(42.1 μΩ cm at 25 °C) [8], its superconductivity [6], and its catalytic activity [9].

These particular properties make TaC find a wide range of industrial applications. It is usually used to make cemented-carbide cutting tools [10,11], as a hard coating on metal to increase the corrosion and wear resistance [12].Furthermore, due to their optical, electronic and magnetic properties, it has been also used for optical coatings, electrical contacts and diffusion barriers [13]. Besides, it is used to make low-electron-emissivity parts, crucibles for molten metals, and high-temperature heating elements [14]. It is also expected to be used as a catalyst for ammonia decomposition and hydrogen dissociation [9,15]. These notable physical and chemical properties can be attributed to the mixed covalent-metallic bond [16–18].

Conventionally, TaC was prepared by using graphite or amorphous carbon in a carburization reaction with tantalum or tantalum oxide [1,6,10,19,20], this process is usually carried out at high temperatures (about 1700 °C) [6]. Other methods, such as sol–gel, SHS, alternating-current discharge, high-frequency plasma [21–25], were used to synthesize TaC. Recently, many efforts have been made to synthesize nanocrystalline TaC or particular shape TaC at lower temperatures. For example,

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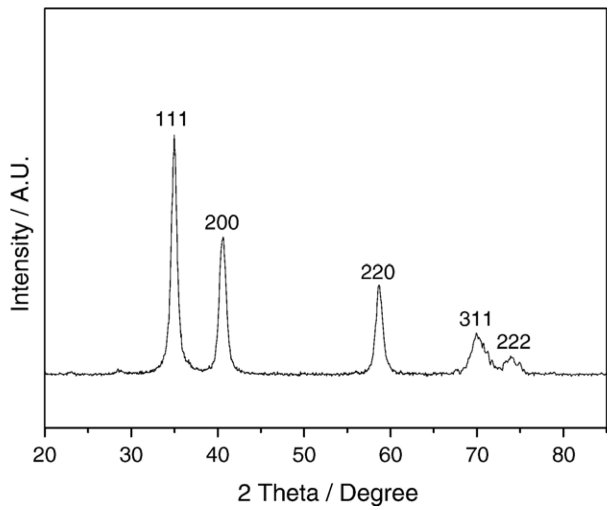

Fig. 1. XRD pattern of the as-prepared sample.

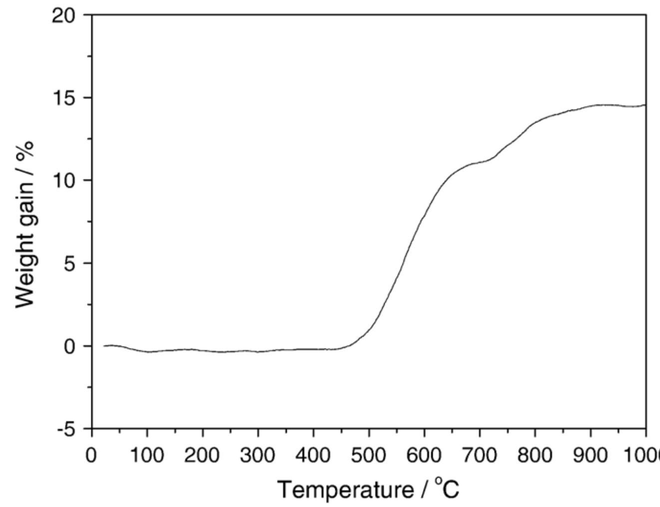

Fig. 3. TGA curve of the as-prepared TaC sample.

Johnsson [26] synthesized TaC whiskers via a carbothermal reduction process. Takamasa Ishigaki et al. [27] reported a new thermal plasma processing to synthesize nanosize TaC powders through the condensation of reactant species from a vapor phase.

In this paper, nanocrystalline cubic TaC has been synthesized via co-reduction of tantalum pentachloride and sodium carbonate with metallic magnesium in an autoclave at 600 °C. In this reaction, tantalum pentachloride is the tantalum source and sodium carbonate is the carbon source.

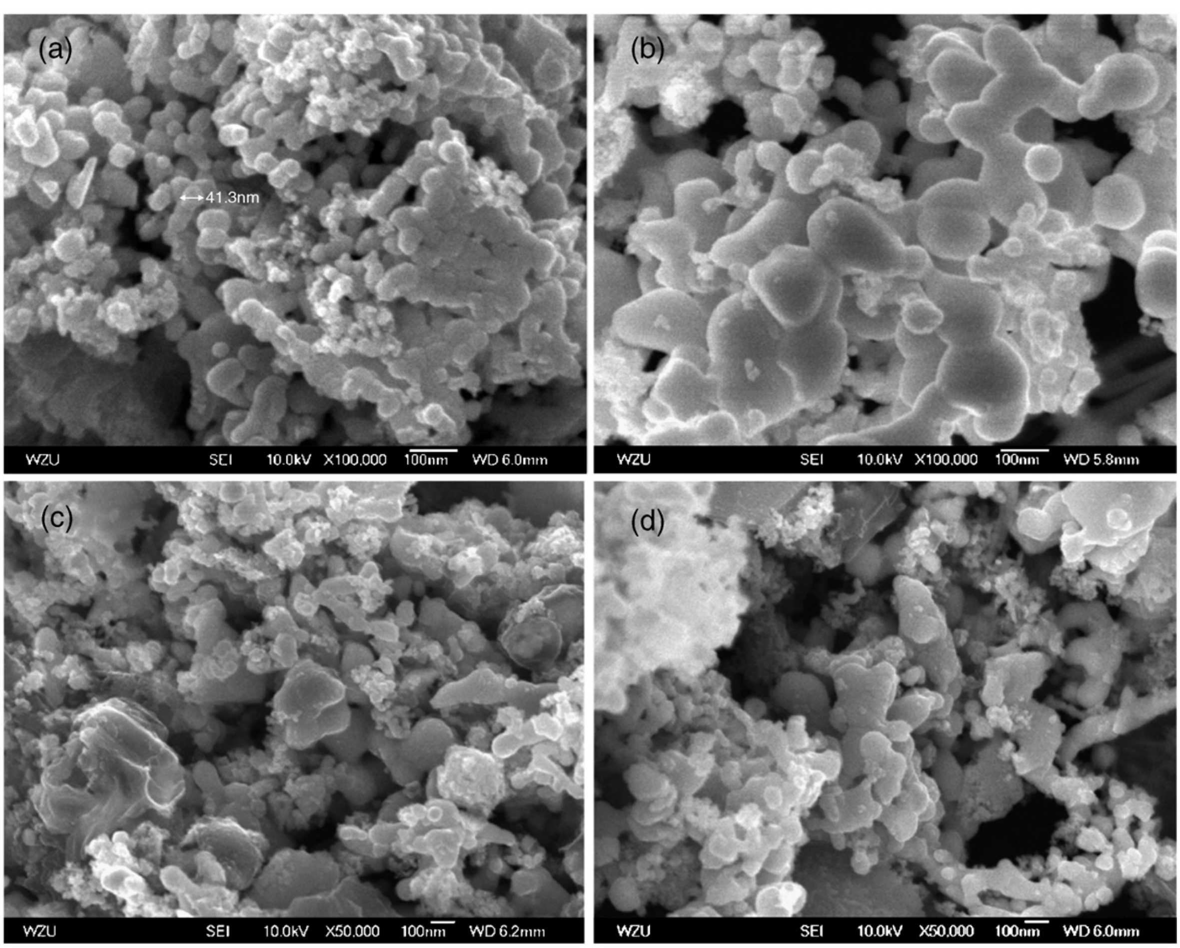

Fig. 2. SEM images of the samples prepared under different conditions. (a) 600 °C, 8 h; (b) 700 °C, 8 h; (c) 600 °C, 6 h and (d) 600 °C, 10 h.