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Mechanosynthesis of rhenium carbide at ambient pressure and temperature

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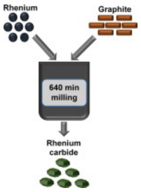
Highlights

- Re_2C was obtained by mechanosynthesis at 640 min from rhenium and graphite.
- Polyhedral shape is the preferential growth morphology of Re_2C.
- Thermogravimetric analysis shows stability of material at up to 800 °C.

Abstract

We report the synthesis of Re_2C at ambient pressure and temperature. The formation of rhenium carbide (Re_2C) from the elements was obtained by mechanochemical treatment after 640 min of milling. The microscopy analysis shows polyhedral particle agglomerates with diameters of less than 600 nm. Thermogravimetric analysis results revealed the stability of material at up to 800 °C as well as chemical and surface analysis of polyhedral particles which show oxidative properties and a surface area of 2.0 $m^2 g^{-1}$, respectively.

Graphical abstract



Introduction

Current research in materials science has been directed towards improving material properties [1]. It is known that the structure and constitution of materials can be better controlled by processing them under non-equilibrium conditions [2] such as rapid solidification, plasma processing, vapor deposition and mechanical alloying (MA) [3], [4], [5]. MA is a technique that allows the synthesis of materials starting from elemental powder mixtures; moreover, it improves the chemical and physicochemical properties thereof. Carbides are of considerable interest for industrial applications due to their wear resistance, high temperature oxidation resistance, high hardness, high toughness and resistance to chemical attack. Their current applications are heat engine components, wear components, armor, corrosion resistant and high temperature burners, among others [6]. Among these, rhenium carbide is one of the most incompressible materials, which make it suitable for several industrial applications [7]. Nevertheless, it was established that rhenium does not form any carbide, neither at ambient pressure nor at low temperature. The Re–C phase diagram shows the limited solubility of carbon into rhenium [8]. Maximum solubility is reached at 11.7 at.% C at the eutectic temperature (2500 °C) and it falls sharply with the temperature (4.2 at.% C at 1800 °C). However, rhenium carbide obtained at high pressure and temperature was reported in 1971 by Popova and Boiko [9]; they used 6 GPa and 800 °C in a molar mixture of Re:C = 1:1 and determined the crystal structure of ReC by X-ray diffraction. In 1972, Popova et al. [10] reported the synthesis of ReC with cubic structure, obtained from a powder mixture of rhenium and graphite in a pressure range of 16 to 18 GPa and 1000 °C. In 2008, Juarez-Arellano et al. [11] reported the formation of a hexagonal phase of Re_4C_2 in conditions of 12 GPa and 1400 °C in a mixture of equal parts rhenium and graphite. Moreover, the synthesis of rhenium carbide with a stoichiometry Re:C = 2:1 is reported in 2009 by Juarez-Arellano et al. [12]; they used laser heating in diamond cells at high pressure (10 to 70 GPa) and high temperature (1000 to 3727 °C) from leaves of rhenium (25 μm thick) and graphite as starting materials. The Re_2C phase has been studied by Zhao et al. [13] who in 2010 reported its synthesis under conditions of pressure from 2 to 6 GPa and temperature of 600 to 1600 °C from rhenium powder and carbon black as precursors using a cubic press. Also in 2014, Dyachkova et al. [14] reported the Re_2C phase, obtained from the mechanical blending of rhenium and carbon at high pressure treatment of 6 to 10 GPa and at a high temperature of 1800 °C. In summary, high pressure and moderate temperatures (above 550 °C) are required for the synthesis of Re_2C. Mechanosynthesis rhenium carbide at room-temperature was reported by Matteazzi et al. in 1991 [15], but only they obtained a partial carburization of rhenium. In this study, we report the synthesis of rhenium carbide (Re_2C) at ambient pressure and temperature starting from rhenium powder and graphite through a high energy ball milling process. The synthesized material was characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), thermogravimetric analysis (TGA), infrared spectroscopy (FTIR) and surface properties (BET).