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The role of sintering additives on synthesis of cermets by auto-combustion

Mahieddine Ali-Rachedi [a], Wisseme Ramdane [a], Dominique Vrel [b,*], Abdelaziz Benaldjia [a], Patrick Langlois [b], Mohamed Guerioune [a]

[a] Laboratoire d'Etude et de Recherche des Etats Condensés (LEREC), Département de Physique, Université Badji Mokhtar BP12 Annaba, Algeria
[b] LIMHP, Université Paris 13, CNRS, UPR1311, 99 av. J-B. Clément, 93430 Villetaneuse, France

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ABSTRACT

The purpose of this work is to decrease or eliminate porosities in SHS products with sintering additives. The Ti–C system has been synthesized for its advantages for refractory, abrasive and structural applications. We attempted to densify TiC by using Nickel addition; this metal is introduced through a secondary reaction $3NiO+2Al$. This mixture reacts exothermically and the heat is released according to $3NiO+2Al \rightarrow Al_2O_3+3Ni$. So, the introduction of the Al_2O_3 diluent with the starting reactants is necessary because of the explosive character of the thermite reaction. Thus, doping method is finally used to fabricate materials by SHS method (self-propagating high temperature synthesis). Final products were analysed by X-ray diffraction and scanning electron microscopy.

1. Introduction

In the last decades the combustion synthesis known as self-propagating high temperature synthesis (SHS), gathered the attention of the international scientific community as an innovative method for the synthesis of cermets by thermite reaction [1]. In the SHS method, a compacted pellet of reactant materials is ignited by an external heating source. Heat released from exothermic reactions creates a self-propagating combustion front. By passing in this combustion wave, reactants are converted to final products [2]. In the SHS technique, temperature gradients can be very high and reaction times extremely short. The SHS method has successfully been used to produce a large variety of powders and composite materials, which are hard and wear-resistant and, as it can be used in a small-scale processing unit, the technique does not require major investments in facilities or equipment. Products with high purity, which is largely due to the expulsion of volatile impurities under the extremely high temperatures in the wave, high production rate and low energy consumption are some advantages of this method. The reaction products are generally porous, but densification can easily be obtained. Temperature in the reaction front is related to the reaction enthalpy and to parameters related to heat transfer, such as compaction of the raw materials, specific surface, and reaches up to a few thousands degrees [3]. Several authors [4–7] carried out a theoretical study on the ignition of combustion reactions. They found out that the successful ignition of a self-propagating reaction depends on first the high rate of heat accumulation to initiate the exothermic reaction and secondly the appropriate rate of heat redistribution to propagate it. Moreover, the activation energy is considered to be the most important parameter in the ignition process, followed by reaction enthalpy and heat loss effects. This model is based on the assumption that the ignition is composed of two phenomena, initiation and self-propagation. Their analysis did not distinguish between the two different processes [1]. When the heat losses are low, the combustion waves are enabled to travel. A high rate of heat loss compared to the heat release rate, gives rise to a critical situation preventing from combustion. In such cases, the combustion may be stimulated by preheating, or by other means of additional energy supply to the combustion zone, such as doping the green mixture with reactive additives [8]. The SHS reactions in which the product is multi-phased have been studied for a wide variety of reasons. For example, the synthesis of TiC from the elements is economically less attractive than that from TiO_2 according to the following reaction,

$$TiO_2 + 2Mg + C \rightarrow TiC + 2MgO$$

and the subsequent dissolution of the MgO phase in the product. Such a reaction can be viewed as the sum of two sequential reactions, the first is a thermite reaction in which titanium oxide is reduced by the Mg metal and the second involves the reaction between titanium and carbon to form the desired product. In many cases, the addition of a second phase (to form a composite) is made to improve the properties of the dominant phase (matrix) [9].

Production of TiC and its composites, using a SHS route, has been the subject of many recent works [10,11], where the production of TiC

* Corresponding author.
E-mail addresses: m.ali-rachedi@univ-annaba.org (M. Ali-Rachedi), vrel@limhp.univ-paris13.fr (D. Vrel).

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