($Hf_{1-x}Ta_x$)C-based Carbide Composites for High-Temperature Applications

Dae-Gwon Ha, Ji-sun Han, Sang-won Seo, Shinhoo Kang*

Dept. of Material Sci. and Eng., Seoul National Univ., Seoul, Korea

*e-mail of Corresponding Author (shinkang@snu.ac.kr)

ABSTRACT

HfO_2, Ta_2O_5 and graphite were used to synthesize ($Hf_{1-x}Ta_x$)C solid-solution nano-carbide powder via high energy ball milling and carbothermal reduction. Sintering of ($Hf_{1-x}Ta_x$)C specimens was performed by Spark Plasma Sintering(SPS). Those are demonstrated to suitable for developing ($Hf_{1-x}Ta_x$)C solid-solution composites. In this study we will present the microstructure, mechanical properties of ($Hf_{1-x}Ta_x$)C solid-solution carbide and discuss the results with respect to the variation of ($Hf_{1-x}Ta_x$)C (x= 0.05-0.3) compositions.

INTRODUCTION

Hafnium carbide (HfC) and Tantalum carbide (TaC) are promising candidate materials for high temperature applications such as hypersonic flight vehicle, because they are ultra high temperature ceramics (UHTCs). They have extremely high melting temperature (> 3800 ^{O}C), high hardness (HfC: 20 GPa, TaC: 19 GPa), high electrical conductivity and excellent chemical stability.[1] However, their strong covalent bonding and low self-diffusion coefficient makes them hard to densify.[2] High temperature (> 2000 ℃) and high pressure are required to achieve full densification and severe sintering condition causes grain growth and detriments of properties.

To overcome this problem, various research have been reported. First, utilizing sintering aid such as Ni, Fe, Co, B_4C, C, $MoSi_2$, $TaSi_2$.[3, 4] In most cases, these sintering aids form liquid phase during sintering stage that enhance the mass transportation at low temperature and filling the pores. Nevertheless, liquid phase is fatal to extremely high temperature condition, disrupting the structure of carbide composite. Another attempt is that synthesizing nano-size carbide powders via carbothermal reduction or wet-chemistry methods.[5] These nano carbide powders could facilitate the densification, but still it is not enough to achieve good sinterability at relative low temperature (< 2000 ^{O}C) and also the oxygen impurities developed from synthesizing process or raw material is detrimental to densification and properties.[6]

On the other hand, the research about HfC-TaC solid solution has been reported because its properties have been predicted to surpass the monolith HfC and/or TaC such as melting temperature.[7] But HfC-TaC solid solution study is in the beginning stage indicating lack of its properties data and most reports only focus Ta-rich HfC-TaC solid solution carbide, especially ($Hf_{0.2}Ta_{0.8}$)C because it is expected to have the highest melting temperature among the various compositions of HfC-TaC solid solution carbides (around