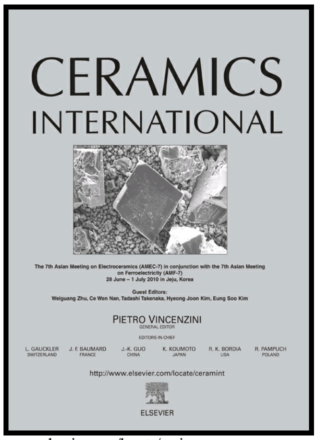

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Graphene nanosheets toughened TiB_2-based ceramic tool material by spark plasma sintering

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Abstract: One kind of TiB_2/TiC composite ceramic tool material toughened by graphene nanosheets was fabricated by spark plasma sintering. Effects of graphene nanosheets on microstructure, mechanical properties and toughening mechanisms were investigated. The results indicated that TiB_2/TiC with 0.1wt.% graphene nanosheets sintered at 1800℃ with the holding time of 5min obtained full densification and optimal mechanical properties. Its fracture toughness and Vickers hardness were 7.9±1.2MPa·m$^{1/2}$ and 20.0±0.7GPa, respectively. Excess graphene nanosheets had no effects to toughness improvement. Fracture toughness was increased by 31.7% in comparison with the TiB_2/TiC without graphene nanosheets. Toughness enhancement mainly benefited from crack bridging, also slip-stick effect of graphene made it hard to detach and effectively restrained crack extension.

Keywords: TiB_2; Graphene; Spark plasma sintering; Mechanical properties; Toughening mechanism

1. Introduction

As one of the ultrahigh temperature ceramics, titanium diboride (TiB_2) has many unique physical and mechanical properties, like high hardness, high elastic modulus, excellent wear resistance and good chemical stability. So, TiB_2-based ceramics are suited to be made into wear-resistant parts working in extreme environments, and they have great potentialities to be used as cutting tool materials [1-4]. However, their applications in metal cutting are limited due to the poor sintering capability and low fracture toughness.

High melting point, low self-diffusion coefficient and strong covalent bonding make the TiB_2 ceramics difficult to be completely densified. In order to obtain full densification, high sintering temperature and external pressure applying on the green compact are required [5-7]. At present, hot-pressed sintering (HP) and spark plasma sintering (SPS) are two effective sintering technologies to prepare the dense TiB_2-based ceramics. Many researchers had fabricated the dense TiB_2-based ceramics by HP [8-18], such as Zou and Song prepared TiB_2/TiC/Ni and TiB_2/TiC/WC/Ni/Mo ceramic tool materials by HP, and the relative density reached 99.4% and 99.3% respectively [8-10]. However, in hot-pressed sintering of TiB_2 ceramics, high sintering temperature (1650~2100℃), long holding time (0.5~2h) and low heating rate (≤50℃/min) are commonly needed in order to get full densification. These benefit the abnormal grain growth and limit the improvement of mechanical properties. Besides, high sintering temperature and long sintering cycle consume a bulk of energy, leading to the low preparation efficiency. Compared to HP, spark plasma sintering has rapider heating rate (100~200℃/min) and much shorter holding time (5~10min). Recently many studies have focused on preparation of TiB_2 ceramics by spark plasma sintering [19-24], and it has been considered as an effective way to prepare fully dense TiB_2-based ceramics.

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