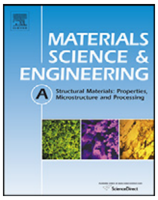
Materials Science and Engineering A 536 (2012) 1–7

Contents lists available at SciVerse ScienceDirect

Materials Science and Engineering A

journal homepage: www.elsevier.com/locate/msea



Micro-structures and mechanical properties of Nb/Re layered composite produced by CVD

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ARTICLE INFO

Article history:
Received 9 September 2010
Received in revised form 1 September 2011
Accepted 20 September 2011
Available online 28 September 2011

Keywords:
Chemical vapor deposition
Nb/Re
Layered composites
Micro-structures
Mechanical properties

ABSTRACT

In this work, the relatively light niobium/rhenium (Nb/Re) layered composites were produced by chemical vapor deposition (CVD). The micro- structures including the thickness of diffusion layer, phase compositions and interphase thickness in niobium/rhenium composites were studied by SEM and XRD. The phases were consisted of Nb solid solution, χ and Re solid solution. It was observed that increasing of annealing temperature would result in more thick diffusion layer and χ zone. Prolonging annealing time at the same temperature has no profound effect on the formation of interphase χ. Tensile tests indicated that the strength of the as-deposited followed the rule of mixture. For Nb/20 vol.%Re layered composites in which the thickness of phase χ was 1.4 μm, the tensile strength and elongations were about 516 MPa and 8%.

1. Introduction

Niobium (Nb) hafnium alloy (Nb–Hf, C103) with a fused silicide coating for oxidation protection is one of the most common material systems currently utilized in spacecraft engine for apogee insertion and attitude control. Thermomechanical properties obtained in previous studies show that the tensile strength of C103 is around 480 MPa at room temperature; however it is only 33 MPa at 1600 °C. In addition, C103 material system has an upper working temperature of 1450 °C. This limitation would degrade engine performance [1–7]. Recently, extensive R&D efforts are ongoing to develop novel high temperature material systems. Nb–W–Mo–Zr (Nb521) alloy being underway may offer higher tensile strength of 80 MPa at 1600 °C. Other composite systems, such as rhenium (Re) coated with iridium (Ir) and hafnium carbide (HfC)/tantalum carbide (TaC), are also being studied. Properties testing have proved that Re/Ir is the most developed of these high-temperature materials [4,7]. Liu [7] reported that the Ir/Re satellite engines had been successfully applied in USA in 2000. However, advanced aerospace and commercial applications are challenging materials suppliers to develop light composites with improved high temperature performance. Based on these demands, a relative light-weight Nb/Re layered composite with a novel high strength has been studied in this work. High strength of these materials derives from the strength of rhenium layer, as well as the low density is attributable to the Nb (8.57 g/cm^3). But the Re metals prepared by cold rolled sheet (RS), chemical vapor deposition (CVD), heat isotropic pressure (HIP) and powder metallurgy (PM) differ widely in mechanical properties [8–10]. Mittendorf [9] explained the inconsistency of these properties attributed to the different microstructures inherent which were produced by these four process methods.

In general, the improvement in strength is normally at a cost of significantly reduced ductility and toughness. Additionally, it is still a challenge to manufacture refractory metal matrix layered composites using the severe plastic deformation because of their high non-deformability. Therefore, the novel techniques such as plasma spraying and explosion cladding are also under study [11–16]. As a potential and low-cost method in engineering applications, less effort has been dedicated to the production of Nb/Re layered composites by CVD. In this study, CVD process was successfully used to fabricate Nb/Re layered composites of 20%Re volume fractions. Tensile strengths of Re and Nb deposited via CVD are around 760 and 284 MPa, and elongations are about 26.5% and 17.6%, respectively. According to the rule of mixture, the tensile strength and density of Nb/20 vol.%Re system would be around 379 MPa and 11.3 g/cm^3 in theory. In the present study, the main objectives are to investigate the micro-structures and superposition effects in Nb/Re layered composites and effect of phase χ on mechanical properties.

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0921-5093/$ – see front matter.
doi:10.1016/j.msea.2011.09.070

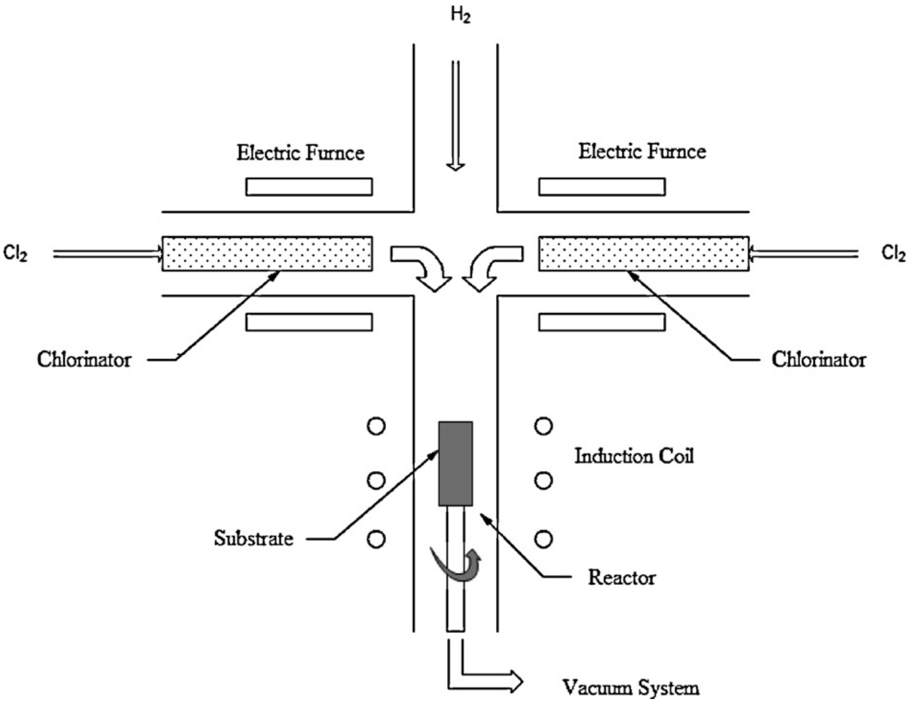

Fig. 1. Schematic diagram of CVDNb/Re apparatus.

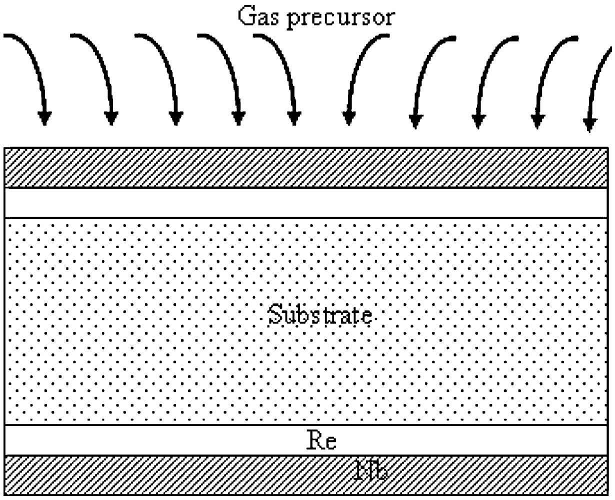

Fig. 2. Schematic of CVD process used in this study.

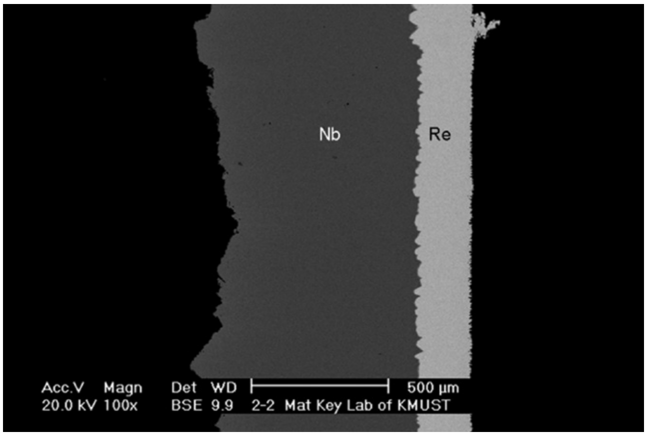

Fig. 3. SEM microstructure of as-deposited Nb/20 vol.%Re composites.

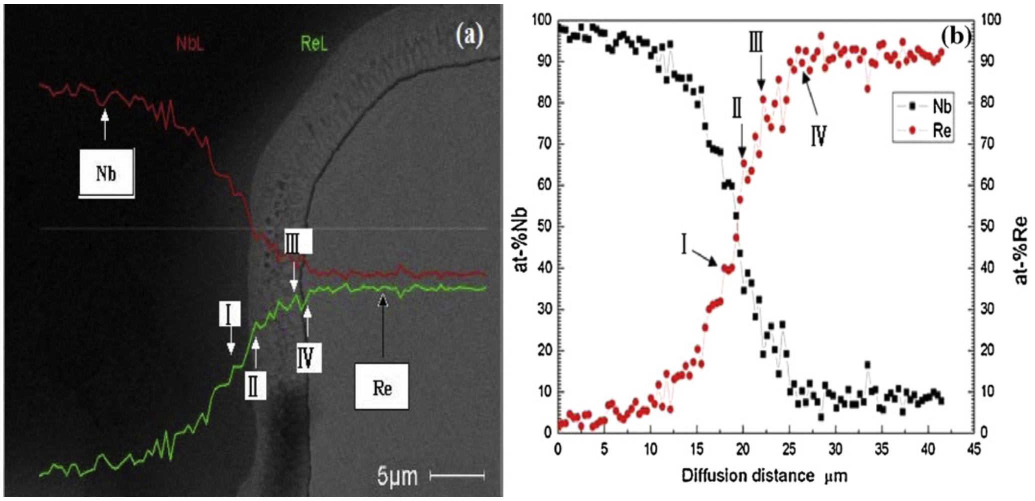

Fig. 4. SEM micrograph and elements distribution of the Nb/Re diffusion interface after annealing at 1800 °C for 2 h.