Development of W_{mesh}, $W_{short\ fibers}$ and $W_{3D\text{-}mesh}$ reinforced High Entropy Alloy Composites with Enhanced Toughness for Fusion Applications

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1. Introduction

The high melting point, high strength, low erosion and sputtering and suitable conductivity make tungsten (W) capable of sustaining high temperature, mechanical load and plasma environment, therefore W is being considered as a potential material in future fusion applications [1,2]. However, W shows some limitations as well. Its strength decreases at >1000°C, it shows a high ductile to brittle transition temperature and it also suffers from irradiation embrittlement at elevated temperature [3]. These constraints limit the application of W and ask for the innovative W-based materials [4] for forthcoming fusion reactors.

Several studies on new W-based materials are in progress. However the shortcomings in conventional alloys such as unstable passive layer [5], low workability [6] and high energy for activating dislocation's mobility [7] turns the research towards high entropy alloy (HEA) based materials [8] which shows good hardness and strength along with the good creep, fatigue and wear resistance [7].

The effect of W-fibers (reinforcement) in W-matrix has been studied by producing composite samples via chemical vapor deposition (CVD) and hot isostatic pressing (HIP). The W-fibers show ductile fracture which reduces brittleness of W-matrix [9-12]. However, CVD results in low density materials due to premature ending of deposition of matrix [9], whereas HIP shows secondary grain growth [12]. The limitations of CVD and HIP emphasize upon the utilization of Spark Plasma Sintering (SPS) for the development of new composites for high temperature applications.

This paper presents the synthesis and characterization of HEA(WTaTiCrV)/W_{mesh} and HEA(WTaTiCrV)/$W_{whiskers}$ composites by spark plasma sintering. Comparison of various designs of composites has been presented for the selection of better candidate material for fusion applications.

2. Methods and Results

2.1 Experimental

The composite samples were fabricated by SPS, at 1500°C, of powder mixture (having W, Ta, Ti, V and Cr), reinforced with W_{mesh}, $W_{3D\text{-}mesh}$ and $W_{short\ fibers}$, Various weight percent of reinforcements were added in in order to analyze the effect of type and weight fraction. Fig. 1 shows the sintered samples schematically.

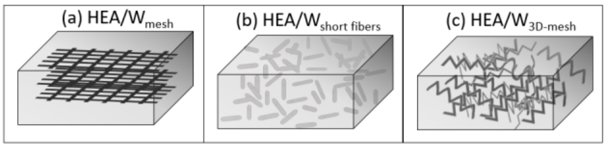

Fig. 1. (a) W_{mesh} (b) $W_{short\ fibers}$ and (c) $W_{3D\text{-}mesh}$ reinforced HEA (WTaTiCrV) composites.

The reduced activation property was ensured by avoiding Mo, Cu and Nb addition [13]. SPS was carried out at 1500°C. Microstructural characterization was done by x-ray diffraction (XRD), scanning electron microscopy (SEM). Hardness and toughness were analyzed by using micro Vickers's and Single Egde Notch Beam (SENB) tests.

2.2 Results

The XRD analysis of $W_{mesh,}$ $W_{whiskers}$ and $W_{3D\text{-}mesh}$ reinforced HEA (WTaTiCrV) composites shows BCC lattice, as shown in Fig. 2. Single BCC peaks of matrix and reinforcements were observed due to similar BCC structure of matrix and reinforcement.

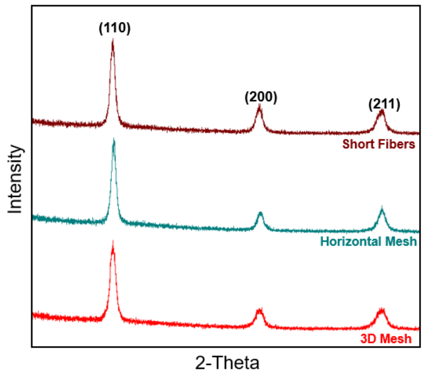

Fig. 2. XRD patterns of HEA (WTaTiCrV) composites reinforced with 9wt% of W_{mesh}, $W_{wiskers}$ and $W_{3D\text{-}mesh}$.

The uniform distribution of constituent elements, along with Ti-rich phase was observed in the matrix via SEM-EDS. No void or porosity between matrix and reinforcements is also evident, see Fig. 3.

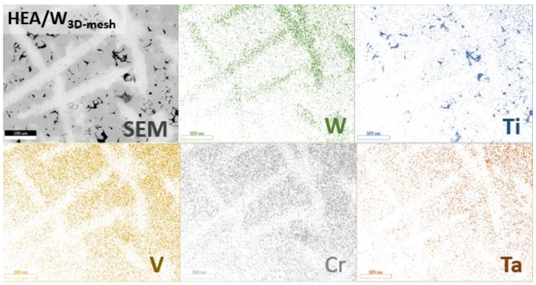

Fig. 3. Microstructure and elemental maps of $W_{3D\text{-}mesh}$ reinforced HEA (WTaTiCrV) based composites.

The minor and abrupt change in hardness values with respect to type and weight fraction of reinforcement was observed because hardness is dominated by the matrix materials. However, a slight reduction in hardness with 23wt.% and 30wt.% meshes was clear as the fraction of W_{mesh} encountering the indenter increases with increasing weight fraction. The hardness of composite remained in the range of 620 HV – 750HV.

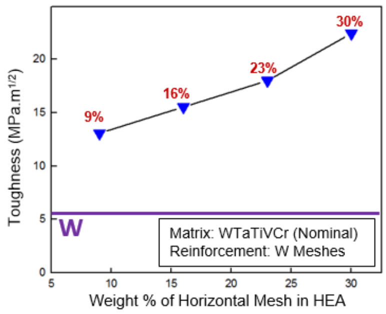

Fig. 4. Effect of weight% of W_{mesh} on the toughness of HEA composite.

Single edge notch beam test was carried out to determine the toughness of composite samples. The increase in toughness up to 22.4 MPa.$m^{1/2}$, with increasing content of meshes were observed (as shown in Fig. 4), which is almost four times more than the toughness of pure W.

3. Conclusions

The mixing followed by SPS successfully development reduced activation high entropy alloy based composite samples. Fully dense composite materials exhibited enhanced hardness and toughness. Four times more toughness (than pure W) was observed with 30wt.% reinforcement. The enhanced mechanical properties shows the potential of HEA/W_{mesh} composites for future fusion applications.

Acknowledgment

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