Abstract

Present investigation attempts to develop W based heavy alloys (WHAs) of W-Cu and W-Ni-Al by mechanical alloying (MA) through high energy ball milling followed by sintering. Powder blends of W-Cu, W-Al, W-Ni, W-$Ni_{50}Al_{50}$/NiAl and W-$Ni_{75}Al_{75}$/Ni_3Al were milled in a Fritsch Pulverisette-5 planetary ball mill using WC (tungsten carbide) milling media and toluene as the process controlling agent to generate nanostructured products. The ball-milled powders were characterized using x-ray diffraction (XRD), transmission electron microscope (TEM), scanning electron microscope (SEM) and differential scanning calorimeter (DSC). The milled powders were compacted under 400 MPa load and sintered in a tubular furnace under reducing/inert gas atmosphere. Characterization of the mechanically alloyed powder shows that lattice strain possibly hindered the growth of W crystallites during heat-treatment of W-Cu milled products, while similar correlation was not found in the case of W-Ni-Al system. In W-20 wt. % Cu composition milled for 20 h, sintering at 900^oC for 6 h resulted in ~ 90 % densification and the Cu particles, due to its lower melting point, appeared to coalesce to form copper rich pools.

No significant increase in the solid-solubility of either Al or Ni in W was achieved by MA. During the MA of W-$Ni_{50}Al_{50}$ system intermetallic NiAl could be formed in-situ. Ni_3Al formed in W-$Ni_{75}Al_{25}$ system only after the milled compositions were annealed at 600^oC or above. The sintering data of milled W-20 wt. % $Ni_{50}Al_{50}$ (W - 48.2 vol. % $Ni_{50}Al_{50}$) and W-20 wt. % $Ni_{75}Al_{25}$ (W - 41.4 vol. % $Ni_{75}Al_{25}$) indicated that NiAl phase has a better potential to act as a sintering promoter compared to Ni_3Al; but they cannot be considered as a WHA due to the large volume fraction of lighter $Ni_{50}Al_{50}$ in the nanocomposite, which led to lesser overall density and resulted in a brittle sintered product. In contrast, neither pre-synthesized nanostructured solid NiAl in W-20 vol. % NiAl nor pre-synthesized and liquefied Ni_3Al in W-20 vol. % Ni_3Al were able to serve as a good sintering aid to W and provide the extent of densification obtainable in the case of a standard WHA of W-7 wt. % Ni-3 wt. % Fe (W – 13.5 vol. % Ni – 6.5 vol. % Fe) composition.

Keywords: tungsten heavy alloy (WHA), mechanical alloying, nanocomposites, nickel aluminides, liquid phase sintering, W-Cu system, W-Al, W-Ni, W-Ni-Al, W-Ni-Fe.