Presented in 63 National Metallurgists' Day-Annual Technical Meeting, Indian Institute of Metals, Kolkata, 16 November 2009

Sintering characteristics of mechanically alloyed Al–Ni–Ti amorphous powder consolidated by pressure-less, pressure-assisted and spark plasma sintering

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Extended Abstract

The present work investigates on the possibility of development of amorphous-based nanocomposites by mechanical alloying followed by consolidation. The elemental powder blend of $Al_{88}Ni_6Ti_6$ was subjected to high energy ball milling for 120 h in cemented carbide grinding media at a mill speed of 300 r.p.m. by means of a Fritsch Pulverisette-5 planetary ball mill to obtain a fully amorphous powder. The thermal stability of the mechanically alloyed amorphous powder was studied using a differential scanning calorimeter (STA 409C, NETZSCH, Germany) and also by high temperature X-ray diffraction in vacuum (<1 Pa), and it was found to be stable up to ~500°C. Using the information of thermal stability, an attempt was made to consolidate the powder to produce bulk Al-rich nanocomposites having densities near to the theoretical density. The powder was compacted under uniaxial pressure of 1500 MPa and then sintered at 800°C and 850°C for 5 h in high purity (impurity level <10 ppm) helium atmosphere. The as-milled amorphous powder was also consolidated by hot pressing for 20 min at 500°C at a pressure of 625 MPa. Besides, the as-milled alloy powder was SPSed at 450°C or 500°C for 10 min using an SPS unit (Model 1050, Sumitomo Coal Mining Co. Ltd.) under a pressure of 76.4 MPa or 446 MPa. The phase evolution of the 120 h milled sample and sintered specimens was studied by X-ray diffraction (XRD), FESEM and TEM analysis.

The amorphous $Al_{88}Ni_6Ti_6$ alloy powder fully decomposed to a non-equilibrium mixture of crystalline phases during pressure-less sintering at temperatures ≥800°C, whereas some amount of amorphous phase was detectable along with the intermetallic phases after hot pressing at 500°C. In contrast, specimens consolidated by the SPS method showed nano-sized intermetallic

phases dispersed homogeneously in the amorphous matrix as revealed by XRD and TEM analysis as shown in Fig. 1 and Fig. 2. The spark plasma sintered compacts (500°C, 446 MPa, 10 min) achieved a relative density (with respect to theoretical density) of ~95.8%, compared to 87.6% in the hot pressed (500°C, 625 MPa, 20 min) and 86.2% in the pressure-less sintered (850°C, 5 h) compacts. The spark plasma sintered compacts showed greatly superior mechanical properties (e.g. microhardness of 7.9 GPa) compared to the hot pressed (5.9 GPa) and pressure-less sintered compacts (4.8 GPa), due to the presence of nano-features and better densification.

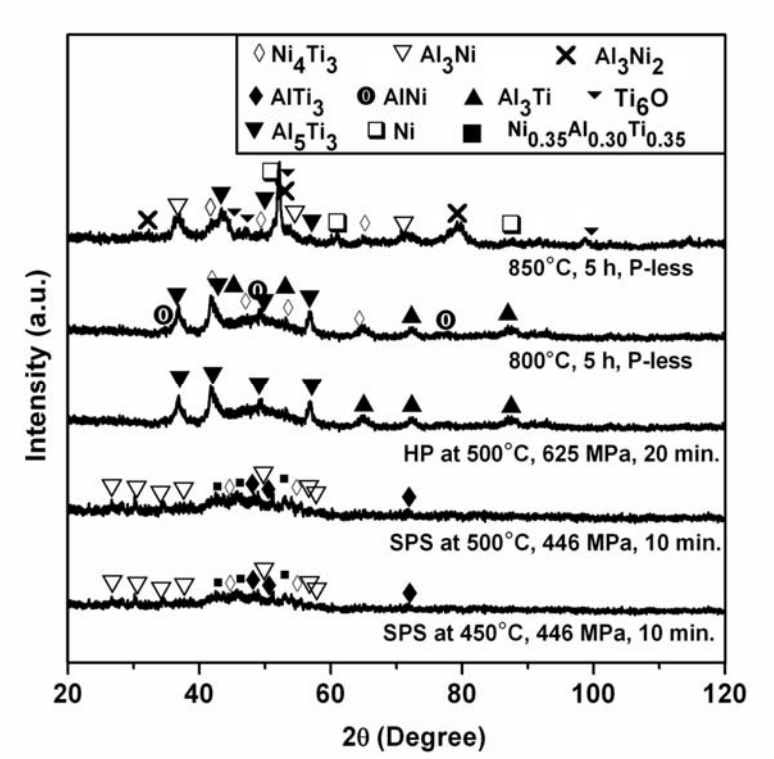

Fig. 1: XRD profiles of the amorphous powder of $Al_{88}Ni_6Ti_6$ recorded at different temperatures demonstrating the formation of different phases.

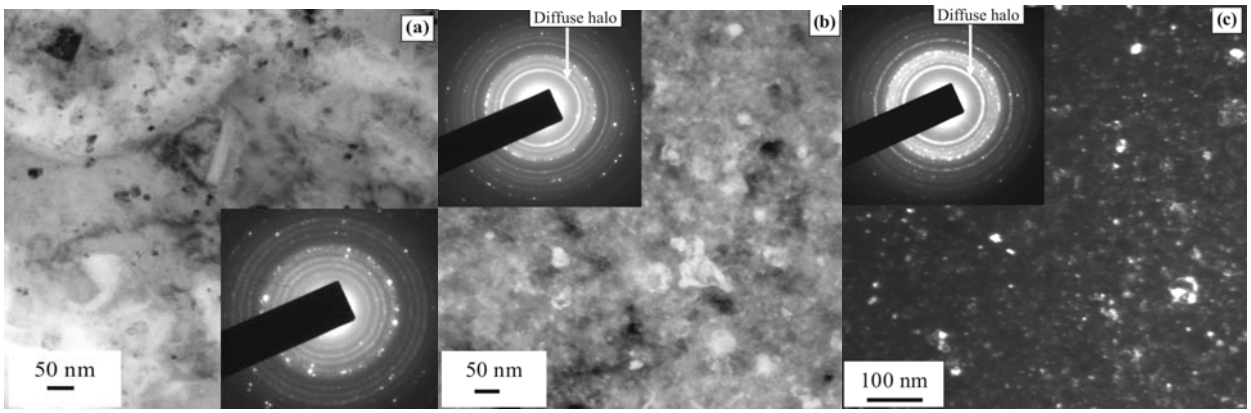

Fig. 2: TEM micrographs and corresponding ED patterns of the sintered compacts of $Al_{88}Ni_6Ti_6$ showing particle size and nature of crystallinity of the consolidated specimens: (a) conventionally sintered at 850°C, (b) hot pressed at 500°C and (c) SPSed at 500°C.