ABSTRACT

The present work was focused on synthesis of aluminium based multicomponent glassy alloys (viz. $Al_{86}Ni_8Y_6$, $Al_{86}Ni_6Y_6Co_2$, $Al_{86}Ni_6Y_{4.5}Co_2La_{1.5}$) via mechanical alloying and consecutive spark plasma sintering (SPS). These aluminium rich powders yielded fully amorphous structure after 140 h, 170 h and 200 h of milling, respectively, as confirmed by broad hump in XRD patterns, featureless TEM images and corresponding fully diffused SAD patterns. Requirement of longer milling time was attributed to the ductile nature and high stacking fault energy of Al, which prolonged the cold welding and work hardening phenomena. DSC thermograms indicated that with increase in milling time transformation peaks shifted to lower temperatures and number of transformation stages increased, which is attributed to the increase in defect concentration and strain energy. Amorphous powders were consolidated via a novel sintering technique, spark plasma sintering (SPS) at varying sintering temperatures (250-500^{o}C) and pressures (100-400 MPa). In the case of various temperature sintered samples, alloys sintered up to 350^{o}C exhibited retention of at least 70% amorphous phase as confirmed by XRD, TEM and DSC method of amorphous phase fraction estimation; whereas samples sintered at 450ºC or 500^{o}C exhibited higher amounts of nanocrystalline FCC-Al along with various nano-sized intermetallic precipitate (viz. Al_3Ni_2, Al_2Y, $Al_{13}Co_4$, $Al_{11}La_3$, Al_4Ni_3, $Al_{0.9}Ni_{1.1}$, Al_3Y, $Al_{4.85}Co_{5.15}$ etc.) formation resulting from abnormal crystallization at the expense of the parent amorphous phase. It was found that with the increase in the number of components, the tendency of devitrification increased, which is attributed to higher probability of atom coupling during sintering based on Stokes-Einstein equation as confirmed by XRD patterns of 500^{o}C sintered $Al_{86}Ni_8Y_6$, $Al_{86}Ni_6Y_6Co_2$ and $Al_{86}Ni_6Y_{4.5}Co_2La_{1.5}$ alloys. The former two ternary and quaternary alloys retained XRD hump overlaying crystalline FCC-Al peak, whereas the five-component alloy showed a huge number of XRD peaks without appreciable hump. Increase in SPS pressure resulted in better retention of amorphous phase, with the formation of various intermetallic phases by short range ordering in $Al_{86}Ni_8Y_6$ bulk alloy. Micro-and nano-indentation hardness increased with the increase in sintering temperature and pressure attributed to various reasons, such as (i) better inter-particle bonding, (ii) high relative density and (iii) uniformly distributed *in situ* nanocrystals in the amorphous matrix. Coefficient of friction decreased with increase in sintering temperature due to decrease in surface roughness resulting from lower porosity and better inter-particle bonding.

Keywords: Mechanical alloying, Spark plasma sintering, Amorphous alloys, Phase evolution, HRTEM, Mechanical property