ABSTRACT

Alloys of aluminum are the most widely used materials for structural components in aerospace applications. These crystalline alloys, in age-hardened condition, can achieve a maximum strength up to 550-600 MPa. It is predicted that the strength of Al-alloys could be enhanced by 2-3 times in amorphous or nanocrystal dispersed amorphous condition. This construes that structures with density of aluminum but strength of steel could be possible by attaining the unique microstructure of amorphous or nanocrystal dispersed amorphous aggregate. Though several quaternary and higher order Al-alloys could be made amorphous by rapid solidification, continued efforts are warranted to develop relatively simple binary or ternary Al-alloys with low density and amorphous or nanocrystal + amorphous composite microstructure.

In the present work, an attempt has been made to develop two types of ternary Al-alloys by a solid-state synthesis method called mechanical alloying. Besides carrying out this mechano-chemical synthesis of amorphous or nanocrystal dispersed amorphous composite by high energy planetary ball milling, an extensive characterization of the microstructural evolution has been undertaken to identify the phases, study the mechanism of solid-state amorphization and determine the optimum composition range to achieve the desired microstructure. Besides experimental studies and characterization, model based calculations have been carried out to predict the enthalpy or Gibbs energy of formation of the possible phases. In this regard, a suitable modification has been proposed to the well-known Miedema model to extend its scope to ternary alloys in the entire composition range. Furthermore, the effect of grain size reduction of the crystalline phase on the stability and phase equilibrium has been investigated.

Mechano-chemical synthesis of both Al-Cu-Nb and Al-Ti-Si was carried out by planetary ball milling in steel or WC-media in wet (toluene) condition at a ball to powder weight ratio 10:1 with a rotational speed of 300 rpm. The milled product was characterized at appropriate stages by X-ray diffraction (XRD), high-resolution electron microscopy (HRTEM), electron diffraction spectroscopy (EDS), positron annihilation

spectroscopy (PAS), nuclear magnetic resonance (NMR) study and wet chemical analysis. The influence of milling parameters, composition of the powder blend and milling media were also investigated.

The prediction from the thermodynamic calculations was compared with the relevant experimental data for validation. This exercise, aimed to predict the microstructure or phase aggregate evolved by mechanical alloying, was based on the concept of metastable equilibrium dictated by enthalpy or Gibbs energy of mixing or formation under certain simple assumptions. In these calculations, it has been demonstrated that interfacial energy component plays an important role in determining the phase equilibrium particularly when the grain size of the concerned phases reduces to true nanometric range (< 50 nm).

An interesting phase transition, mainly polymorphic transition of hcp $\rightarrow$ fcc Ti was marked during high energy ball milling. This transformation was investigated in details to ascertain the role of milling parameters, impurity and thermodynamic factors on this hitherto unknown pressure driven structure instability and transformation of elemental titanium.

In summary, the present work mainly concerns with mechano-chemical synthesis of amorphous or nanocrystal dispersed amorphous Al-alloys with detailed microstructural characterization, thermodynamic analysis and phase transition studies. However, powder consolidation into bulk component and mechanical characterization of the alloys were beyond the scope of the present study.