ABSTRACT

Present study concerns following aspects of mechanical alloying and nanocrystalline materials: (a) mechanics of planetary ball milling, (b) thermodynamic properties of the nanocrystalline materials, (c) synthesis of intermetallic phases by MA, and (d) application of the nanocrystalline intermetallic phases.

A theoretical model of the milling dynamics has been developed by adopting a single Cartesian reference frame. The model identifies the optimum conditions of planetary ball milling for obtaining the maximum efficiency of milling,. The analysis predicts a dimensionless parameter to insure the detachment of the ball from the vial wall. It is shown that condition of an effective impact occurs only above a certain level of vial to disc speed ratio. Finally, comparison between the theoretical and experimental results shows that the difference between the total power of impact and power consumed for the elastic deformation of the ball plays an important role to determine the kinetics of the process.

An approximate geometric model of the nanocrystalline grain allows to calculate the variation of excess free volume of grain boundary atoms as a function of grain size. Subsequently, the variation of thermodynamic parameters like negative hydrostatic pressure and bulk modulus have been determined as a function of excess free volume of grain boundary atoms or in turn, grain size, by considering isothermal equation of state for metals. The analysis has also suggested a limit for the mechanical stability of polycrystalline materials, which satisfies the value of theoretical limit of negative hydrostatic pressure predicted for metals in an earlier analysis. An attempt has also been made to explain the 'inverse of Hall-Petch' relationship and enhanced diffusivity observed in nanocrystalline materials by correlating the variation of thermodynamic properties with the change in grain size.

Ball milling experiments carried out with elemental powder blend of appropriate composition in the Nb-Al systems have demonstrated that the formation of $NbAl_3$ is the only intermetallic phase that can be synthesized by MA. In this regard, the difficulties in the formation of Nb_3Al and Nb_2Al have been critically examined. The occurrence of a bcc $\rightarrow$ fcc transformation of Nb during MA has been

established for the first time with the help of the x-ray diffraction study, wet chemical analysis, resistivity measurement and positron annihilation study. A thermodynamic analysis has also been proposed to substantiate the feasibility of this allotropic transformation. In a similar ball milling experiment conducted on the Cu-Al system, a kinetic analysis has been carried out by using the modified iso-concentration contour migration technique. It has been predicted that the kinetics of MA of Al in Cu is equivalent to the same occurring by volume diffusion at some effective elevated temperature (T_{eff}). The predicted ratio of T_{eff} to the liquidus temperature of the concerned composition in the present study shows a reasonable agreement to the earlier predicted results for other Cu-based systems. Milling experiments carried out in the Cu-Al binary systems to establish the metastable phase equilibrium have indicated the difficulties in the formation of phases occurring through the peritectoid reactions under equilibrium. Moreover, ball milling of the elemental powder blend has indicated the occurrence of a metastable bcc phase over a wide range of composition However, a subsequent isothermal annealing experiment has resulted into the formation of equilibrium phases. Attempts have also been made to study the effect of ternary addition of some transition metals on the phase evolution during ball milling and subsequent isothermal treatment of the ball milled product.

With a view to improve the wear resistance without deteriorating the conductivity of pure Cu, an attempt has been made to disperse hard nanocrystalline aluminides on the surfaces by electrolytic codeposition. It is demonstrated that surface hardness may be significantly enhanced in this method without any detriment to the conductivity of the bulk. In this regard, it is noted that the selection of the electrolytic medium depends on the intermetallic particles to be codeposited. A theoretical model has been suggested to optimize the rate of electrodeposition of metal from the electrolyte and concomitant codeposition of particles from the suspension in the electrolyte under the assumption of maximum density of dispersion.