ABSTRACT

The ability of mechanical alloying (MA), a non-equilibrium material processing route involving high energy ball milling, in the synthesis of binary and ternary aluminides in the Al-Ni-Fe system has been evaluated. The intensive ball milling has led to the generation of nanocrystalline aluminides (10-30nm) with extended phase fields within 20h of milling. The extended phase field of AlNi (25-65at.% vis-à-vis the equilibrium value of 45-58at.%) could be explained thermodynamically making use of the Miedemma's empirical model for enthalpy calculations and the excess grain boundary free energy arising out of ultrafine grain size of the products. The present work could successfully delineate the energy as well as parametric domains for the formation and disordering of AlNi by ball milling, thus providing means for identification of efficient milling conditions. It could be established that under the milling energy domain used in the present study, the total energy factor dominates over the ball impact energy per collision. In a further insight into the synthesis process, the present effort led to the generalized conditions for alloying mechanism operating during MA. While a continuously diffusive mechanism of mixing was apparent in the generation of disordered alloy phases and ordered phases with low negative heat of formation, a discontinuous additive mixing mode could be identified in the evolution of ordered phases with highly negative heat of formation ($\leq$ -40kJ mol^{-1}). The disordering of highly ordered AlNi during MA was also investigated, which was attributed to the synergistic role of contamination during milling and/or ternary additions of Fe/Cr and deformation induced defects. The reordering and the thermal stability of the nanocrystalline AlNi were analyzed in detail. Investigations revealed that the kinetics of reordering of mechanically disordered AlNi follows an Avrami-type kinetic expression. The nanocrystalline structure of AlNi was found to show thermal instability against grain coarsening at and above a temperature of ~0.4T_S (where T_S is the solidus temperature in K).