ABSTRACT

The transformations occurring in the sub-stoichiometric Ti(C,N) – W - Al system processed by high energy ball mill were investigated. The milling parameters included the milling time and the temperature comprising milling at subzero temperature and above 25˚C. Two sub-stoichiometric Ti(C,N) stocks were selected, the $Ti(C_{0.5}N_{0.05})$ containing more interstitial elements than the $Ti(C_{0.5}N_{0.5})_{0.6}$.The transformation stages and mechanisms of alloying are discussed with respect to the changes in crystal structures of the powder constituents. The milling atmosphere had an effect on the lattice strain of milled products, and hence on the kinetics of solid state dissolution between the powder constituents, but it did not affect the fracturing process.

The release of the stored crystallite lattice strain energy was the major determinant in mechanical alloying, with particle size reduction playing a necessary, but less significant role. The strain energy and the fine particle size contributed to the increased chemical reactivity with oxygen of the powders milled for shorter times. The affinity of the powders with oxygen decreased after W dissolution in Ti(C,N), and the subsequent decrease in lattice strains.

The annealing behaviour of $Ti(C_{0.5}N_{0.05})$ - 40wt% W and $Ti(C_{0.5}N_{0.5})_{0.6}$ - 40wt% W mechanically alloyed powders were investigated using XRD, TEM, SEM and DTA techniques. It was observed that the reaction start and finish temperatures between constituents were lower in the system that had higher residual lattice strains after milling. The compositions of the intermetallic compounds and the solid solutions formed were

dependent on the milling conditions and the annealing temperature. Thermal alloying was observed during annealing of $Ti(C_{0.5}N_{0.05})$ - 40wt% W mechanically alloyed products, whereas de-mixing of W-rich phases from the metastable solid solution occurred during annealing of the $Ti(C_{0.5}N_{0.5})_{0.6}$ - 40wt% W milled powders.

The effects of Al addition and milling at subzero temperatures on the transformation of $Ti(C_{0.5}N_{0.05})$-W powder mixtures were investigated. Addition of Al powder improved the kinetics of solid solution between powder constituents. The effect of Al was ascribed to the increase of lattice strain during short milling time followed of relaxation at longer time, and to the fast diffusion of atoms. Also, it was noticed that the high viscosity of the process control agent could inhibit the alloying process.
Multiple three-component compounds could be formed. Aluminium preferably reacted with tungsten. The W(Al,C) and W(Al,Ti) formed were stable, thus solubility of W in $Ti(C_{0.5}N_{0.05})$ in the presence of Al was limited.
The evolution of the morphologies of Ti(C,N)-W mixtures show that fracturing of hard particles dominated in the early stage of milling in the absence of Al, whereas with Al, plastic deformation of particles and cold welding of Ti(C,N) and W particles by the softer Al prevailed at the same time.

Longer milling time improved the homogeneity and the formation of nanostructured binder pools in the sintered products. Lower oxygen contents in sintered PcBN were achieved by mechanically alloying Ti(C,N), W and Al in the high energy ball milling stage. Low level of Co in the infiltration layer was also achieved when sintering PcBN

with this type of binder. A link was established between the addition of Al at the attrition milling stage and high oxygen content in the sintered PcBN, thus should be avoided.

The pressure and temperature applied during sintering or annealing had a strong effect on the compositions and the crystal structures of the phases formed in the mechanically alloyed binder. The lattice strains of the binder and the PcBN were higher in the sintered materials prepared with the $Ti(C_{0.5}N_{0.5})_{0.6}$-W binder than in those made using the $Ti(C_{0.5}N_{0.05})$-W alloys.

KEYWORDS

Mechanical alloying; ball milling; titanium; tungsten; aluminium, lattice strain; atmosphere; temperature