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ABSTRACT

Competition between the formation and decomposition of a solid solution in binary alloys during high-pressure torsion

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During severe plastic deformation (SPD) of solid solutions, two processes occur simultaneously. First, it is the decomposition of a solid solution with the precipitation of particles of the second phase. Secondly, it is the dissolution of the existing precipitates of the second phase in a solid solution. These two processes compete with each other. At a certain stage of the SPD, a steady-state appears. In this state, the decomposition of the solid solution and the dissolution of the particles of the second phase come into dynamic equilibrium. As a result, a steady-state concentration of c_{ss} of the second component is formed in the solution. This concentration can be found in the equilibrium phase diagram, on the solvus line of the solubility limit of the second component in a solid solution at a certain temperature T_{eff}. This T_{eff} temperature is commonly referred to as the effective temperature. Earlier, on copper alloys, we found that the value of T_{eff} is different if different components are dissolved in copper. The T_{eff} linearly increases with increases of the activation enthalpy H_D of the bulk diffusion of the second component. This is due to the activation nature of mass transfer in SPD.

We studied the effect of high pressure torsion (HPT) on the structure of the Al-10 wt. % Mg alloy. In a sample annealed at a temperature of 420 °C, the HPT leads to a noticeable decomposition of the solid solution. In a sample annealed at a temperature of 300 °C, a decrease in the concentration at HPT also occurs, but it is less than in the first case. Finally, in a sample annealed at a temperature of 200 °C, there is practically no change in the concentration in the solid solution. This means that for Al–Mg alloys c_{ss} = 3±0.3 wt. % Mg. A comparison with the literature data for equal channel angular compression (ECAP) of Al-Mg alloys gives approximately the same c_{ss} value for ECAP. This means that the effective temperature of T_{eff} in the Al–Mg alloys is close to 200°C.

As is known, with SPD, there is a strong decrease in grain size. At the same time, new grain boundaries (GBs) with a large specific area are emerging. Segregation of the second component may be observed in the GBs. To form these segregations, atoms of the second component are needed. If there are particles of the second phase in the sample, then they supply these atoms. If there are no particles of the second phase, but only a solid solution, then the atoms of the second component leave the solid solution and segregate in new GBs. Then the concentration in the solid solution observed by X-ray diffraction decreases. This process should be taken into account when defining c_{ss} and T_{eff}.