



Formation study of nanostructured $\text{Cr}_{100-x}\text{Co}_x$ ($x = 10, 90$) alloys

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ABSTRACT

$\text{Cr}_{90}\text{Co}_{10}$ and $\text{Cr}_{10}\text{Co}_{90}$ mixtures were mechanically alloyed in order to obtain nanocrystalline alloys. The obtained powders were characterized using scanning electron microscopy (SEM) and X-ray diffraction (XRD). The structural parameters such as the lattice parameters, the crystallite size, the microstrains and the defect density of the different phases were deduced from the Rietveld refinement of the XRD patterns using the MAUD program.

For the Co-rich mixture the evolution with milling time of the SEM micrographs shows a tendency of particle agglomeration. However, in the case of the Cr-rich mixture, the particles tend to the fragmentation. The Rietveld refinement of XRD patterns of the $\text{Cr}_{10}\text{Co}_{90}$ mixture reveals the formation of disordered hcp and fcc Co(Cr) solid solutions. In the case of the $\text{Cr}_{90}\text{Co}_{10}$ mixture, only a disordered bcc Cr(Co) solid solution is obtained. The changes in the morphology and the structure of the two mixtures are explained on the basis of the mechanical and structural properties.

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1. Introduction

Co-rich Cr–Co based alloys are of great importance for biomedical applications. Owing to their excellent biocompatibility, mechanical properties wear and corrosion resistance, these alloys have been used for many years as dental and surgical implants [1]. Cr-rich Cr–Co based alloys are the basis of many steels, high-temperature alloys and magnetic materials. As thin films, these alloys are widely used as magnetic recording media of computer hard disks [2].

Mechanical alloying (MA) is a widespread technique to synthesize nanostructured powdered materials. Owing to the introduction of a large number of crystal defects, MA minimizes the effect of product barriers on reaction kinetics and provides the conditions required for the promulgation of solid state reaction at low temperature. Formation of stacking faults and shear bands is responsible of the grain refinement in MA process. Their appearance may strongly affect the nature of ordering during plastic deformation, deformation texture and the nature of phase transitions. Consequently, the study of the microstructure

of nanostructured materials is essential for the development and application of nanomaterials.

The objective of this paper is to study the microstructure evolution of nanocrystalline $\text{Cr}_{90}\text{Co}_{10}$ and $\text{Cr}_{10}\text{Co}_{90}$ alloys synthesized by mechanical alloying. The influence of the composition on the microstructural properties is discussed.

2. Experimental procedure

Mixtures of powders of Cr (99.5%, grain size = 60 μm) and Co (99.5%, grain size = 17 μm) were mechanically alloyed using a planetary mill (Fritsch P7) with Cr steel vials and balls. The rotation speed of the vials was fixed to 1000 rpm and the powder to ball weight ratio to 3/35. The ball milling was realized under argon atmosphere and was interrupted every hour for 30 min. The evolution of the particle morphology during MA was followed by means of a scanning electron microscope. Structural analysis was performed by XRD using $\text{Cu K}\alpha$ radiation ($\lambda = 1.5406 \text{ \AA}$) with a step size of $2\theta = 0.02^\circ$ and a counting time of 20 s. The XRD patterns were analyzed using the MAUD program [3] which is based on the Rietveld method and the Warren–Averbach methods in combination with the Fourier analysis [4,5]. This whole profile fitting method can accurately modeled the XRD patterns and quantify the constituent phases and a number of structural parameters such as the lattice parameter a , the crystallite size (L), the root mean square (r.m.s) of microstrains $(\sigma^2)^{1/2}$, and the stacking faults probability SFP . The instrumental broadening was determined and eliminated from the total broadening of XRD profiles using a standard corundum Al_2O_3 having no size and strain broadening. The detailed refinement procedure was reported in a previous work [6].

3. Results and discussion

Fig. 1 shows the morphology of the powders for both mixtures at different milling times. The initial powder particles are different

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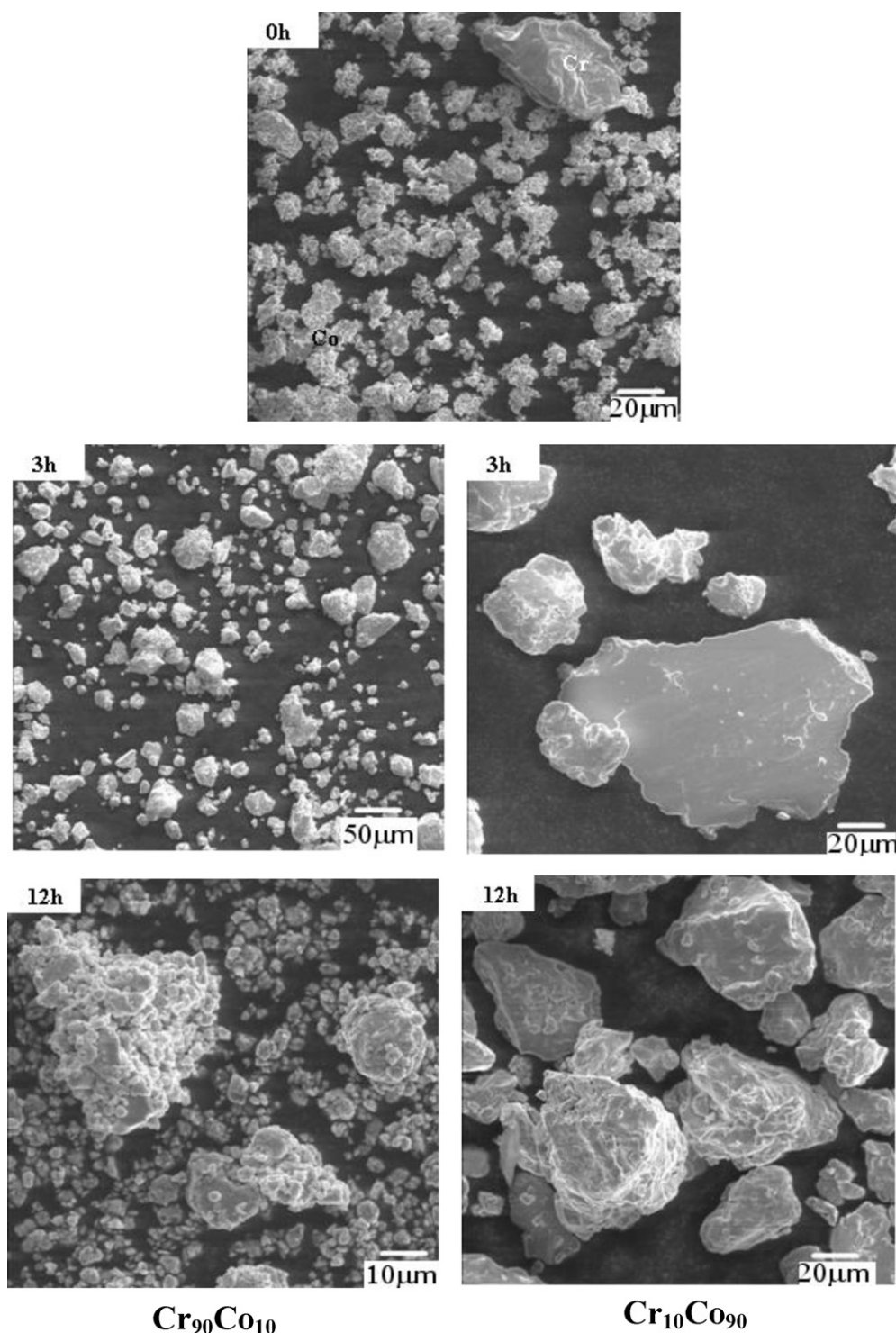


Fig. 1. Morphology of the $\text{Cr}_{90}\text{Co}_{10}$ and the $\text{Cr}_{10}\text{Co}_{90}$ powder particles for different milling time.

in shape and size, Cr particles being larger than Co particles. Due to the plastic deformations induced during milling, the shape of the powder is modified for both mixtures. We note here different tendencies of the two mixtures. For Cr-rich composition ($\text{Cr}_{90}\text{Co}_{10}$), the powder particles are intensively reduced and fractured. In contrast for the Co-rich composition ($\text{Cr}_{10}\text{Co}_{90}$), the powder particles are flattened and agglomerated. This different behavior may arise from the difference in the mechanical properties of the Co and Cr elements. In fact, cobalt is a ductile element and has a Young

modulus lower than that of chromium which increases its aptitude to plastic deformations. However, chromium is a fragile element and therefore it has a fracture tendency when a collision force is applied. As milling proceeds, the particle size is reduced and the ductile particles of cobalt became fragile due to the hardening work. After 12 h of milling the morphology of powder mixtures consists of relatively small particles.

The XRD patterns of $\text{Cr}_{100-x}\text{Co}_x$ powder mixtures milled for several times are presented in Figs. 2 and 3. It can be easily seen that

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