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# CRYSTALLIZATION OF AMORPHOUS $Al_{85}Ce_8Ni_5Co_2$ HPT-ALLOY

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**Abstract.** Discs of $Al_{85}Ce_8Ni_5Co_2$ amorphous alloy were produced by high pressure torsion under different hydrostatic pressure. It was found that the formation of nanocrystalline fcc-Al is independent of the applied pressure. The different crystallization sequences upon linear heating of the as-quenched ribbon and the deformed discs are compared.

## 1. INTRODUCTION

Aluminum based metallic glasses have been known for their excellent mechanical properties and as precursors for nanocomposite materials [1,2]. Recently, high pressure torsion (HPT) [3] induced nanocrystallization has received enhanced attention [4,5]. It was found that these techniques can induce the precipitation of Al-nanocrysals predominantly in shear bands [4]. Earlier studies on an amorphous $Al_{85}Ce_8Ni_5Co_2$ melt-spun ribbon have been revealed its two-stage crystallization sequence without any primary precipitation [6]. In the present work, the microstructure of severe plastically deformed amorphous $Al_{85}Ce_8Ni_5Co_2$ alloy will be discussed.

## 2. EXPERIMENTAL

Ingot of $Al_{85}Ce_8Ni_5Co_2$ was synthesized by induction melting a mixture of high purity (99.9%) Al, Ce, Ni and Co metals. Fully amorphous ribbon was obtained using a single roller melt spinning technique in inert atmosphere. The ribbon was cut into small pieces (flakes), and then loaded between anvils of the HPT device. The shear deformation was performed by subjecting the flake to five whole rotations under hydrostatic pressure of 2, 4, and 6 GPa. The HPT process results in several porosity free discs with a diameter of 10 mm and thickness of about 120 μm. Microstructure was examined by a Philips X'Pert diffractometer (XRD) and a double crystal diffractometer with a fine focus rotating copper anode (Nonius, FR 591). Further details on experimental setup are given elsewhere [7].

## 3. RESULTS AND DISCUSSION

Fig. 1 shows the XRD patterns corresponding to the as-quenched $Al_{85}Ce_8Ni_5Co_2$ ribbon and the discs obtained at different hydrostatic pressures. The pattern of the ribbon consists of a broad symmetric halo indicating a typical homogeneous amorphous phase. Severe plastic deformation of the amorphous phase results in the appearance of additional crystalline peaks superimposed on the halo. The intensity of these peaks is practically independent from the applied pressure and their positions coincide with fcc-Al. In a recent work, transmission electronmicroscopy studies confirmed the formation of high density α-Al nanocrystals with size of 5-10 nm in HPT discs [5]. Linear heating DSC curve of the as-quenched ribbon exhibits two dis-

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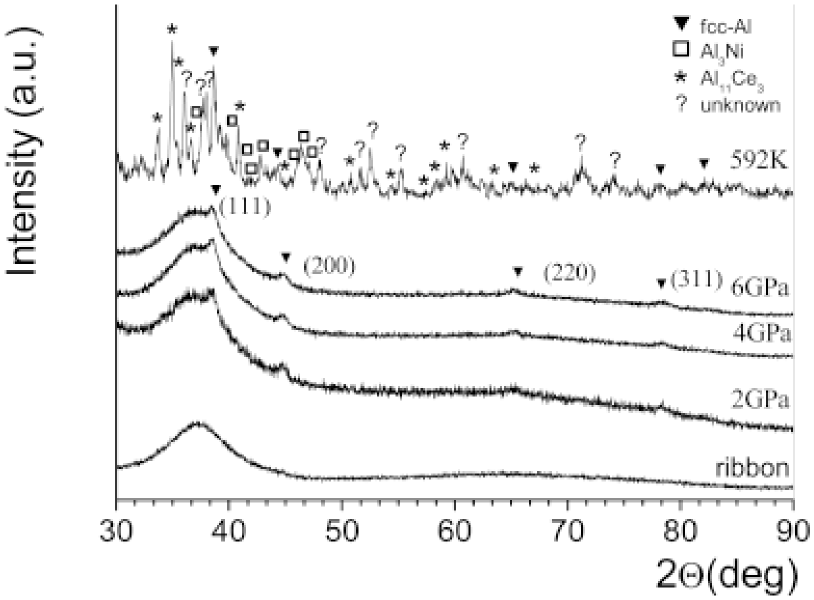


**Fig. 1.** XRD patterns of the as-quenced $Al_{85}Ce_8Ni_5Co_2$ ribbon, plastically deformed HPT discs (2, 4, and 6 GPa) and ribbon after linear heating up to 592K.

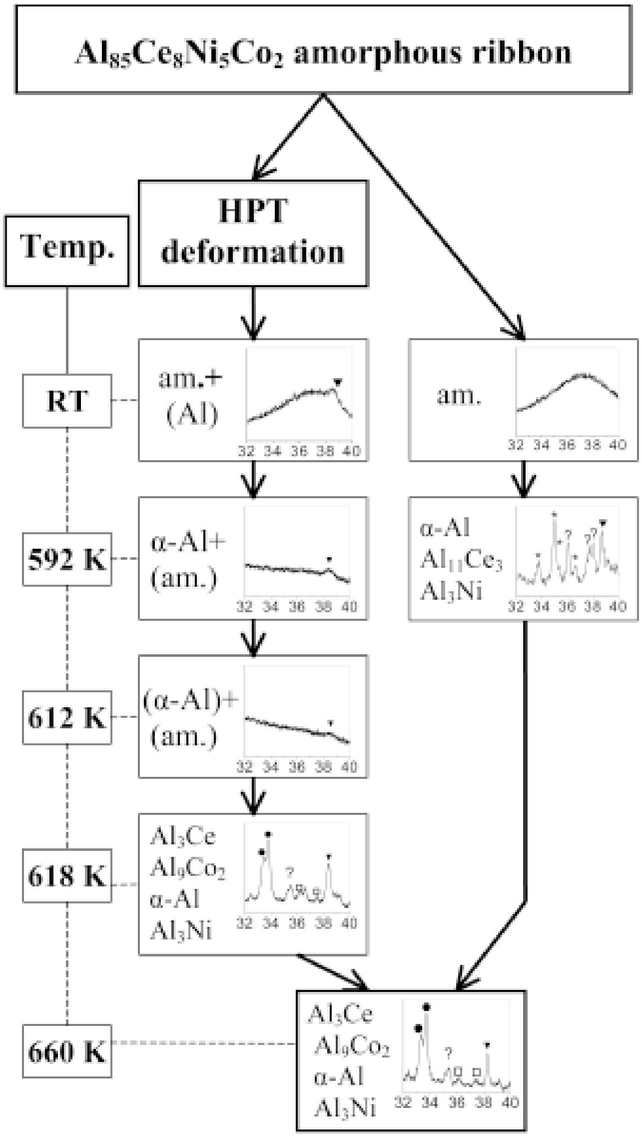


**Fig. 2.** Comparision of the crystallization sequences of the as-quenced $Al_{85}Ce_8Ni_5Co_2$ ribbon and the HPT disc. The α-Al (▼), $Al_3Ce$ (●), $Al_{11}Ce_3$ (*) and $Al_3Ni$ (□) phases are indicated on the XRD insets.

tinct exothermic transformations at 586 and 612K [5]. The XRD pattern obtained after the first crystallization peak (592K) shows the joint formation of α-Al, orthorhombic $Al_{11}Ce_3$, orthorhombic $Al_3Ni$ and unidentified metastable phase (Fig. 1).

The most deformed outer sector of the HPT discs exhibit two exothermic peak as well, however, they shift to higher temperatures [7]. In order to characterize the high temperature behavior of the deformed state, heat treatments on the 6 GPa disc were carried out up to 592, 612 (onset of the first peak), 618 (above the first peak), and 660K (above the second peak).

The different crystallization sequences upon linear heating of the as-quenched ribbon and the HPT disc are summarized by typical range (32-40 deg) of the XRD pattern in Fig. 2. A slight decrease in the intensities of fcc-Al peak of the HPT disc takes place from 592 to 612K indicating thermal dissolution of the athermally induced α-Al phase. The initial composite of α-Al and amorphous alloy decomposes into a mixture of extremely small nuclei of crystalline phases at this temperature. At 618K similar phase mixture (α-Al, hexagonal $Al_3Ce$, orthorhombic $Al_3Ni$, monoclinic $Al_9Ce_2$, as well as unidentified phase) forms as obtained at 660K of the as-quenched ribbon [6]. Interestingly, inspite of the presence of the second DSC peak (618K to 660K), no significant microstructural change takes place in the deformed state.

## 4. CONCLUSIONS

Discs of $Al_{85}Ce_8Ni_5Co_2$ amorphous alloy were severely deformed by HPT. The formation of nanocrystalline fcc-Al in the residual amorphous matrix is independent of the applied pressure. The disc crystallizes into a mixture of phases during its first thermal event, however, in the as-quenched ribbon the same crystalline mixture develops only after the second stage.

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