Structure and properties of CoCrFeNiMnBe high-entropy alloy films obtained by liquid quenching

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Introduction

In recent decades, a new class of metal compounds has been developed - the so-called high-entropy alloys (HEAs) with multiple principal elements. HEAs have received more and more attention due to their unique structure and excellent properties in hardness and wear resistance, exceptional high-temperature strength, good structural stability, radiation, and corrosion resistance. Each principal element in HEA should have a concentration between 5 and 35 at.%. Because of the high mixing entropy of HEAs (12-19 J/(K·mol)), they usually consist of some simple solid solutions, instead of complex phases.

Materials and methods

The as-cast samples of CoCrFeNiMnBe high-entropy alloy were prepared with a Tamman high-temperature electric furnace in the argon gas flow using a copper mold. The as-cast ingots were thereafter remelted and the nanostructured films were obtained from the melt by the means of liquid quenching (LQ) technique, which consisted of rapid cooling of melt drops upon their collision with the internal heat-conducted surface of a rapidly rotating (~8000 RPM) hollow cylinder. The estimated cooling rate was ~10^6 K/s. The X-ray diffraction analysis (XRD) was carried out using a DRON-2.0 diffractometer with monochromatized Cu *Kα* radiation. The diffraction patterns were processed using QualX2 software.

Results

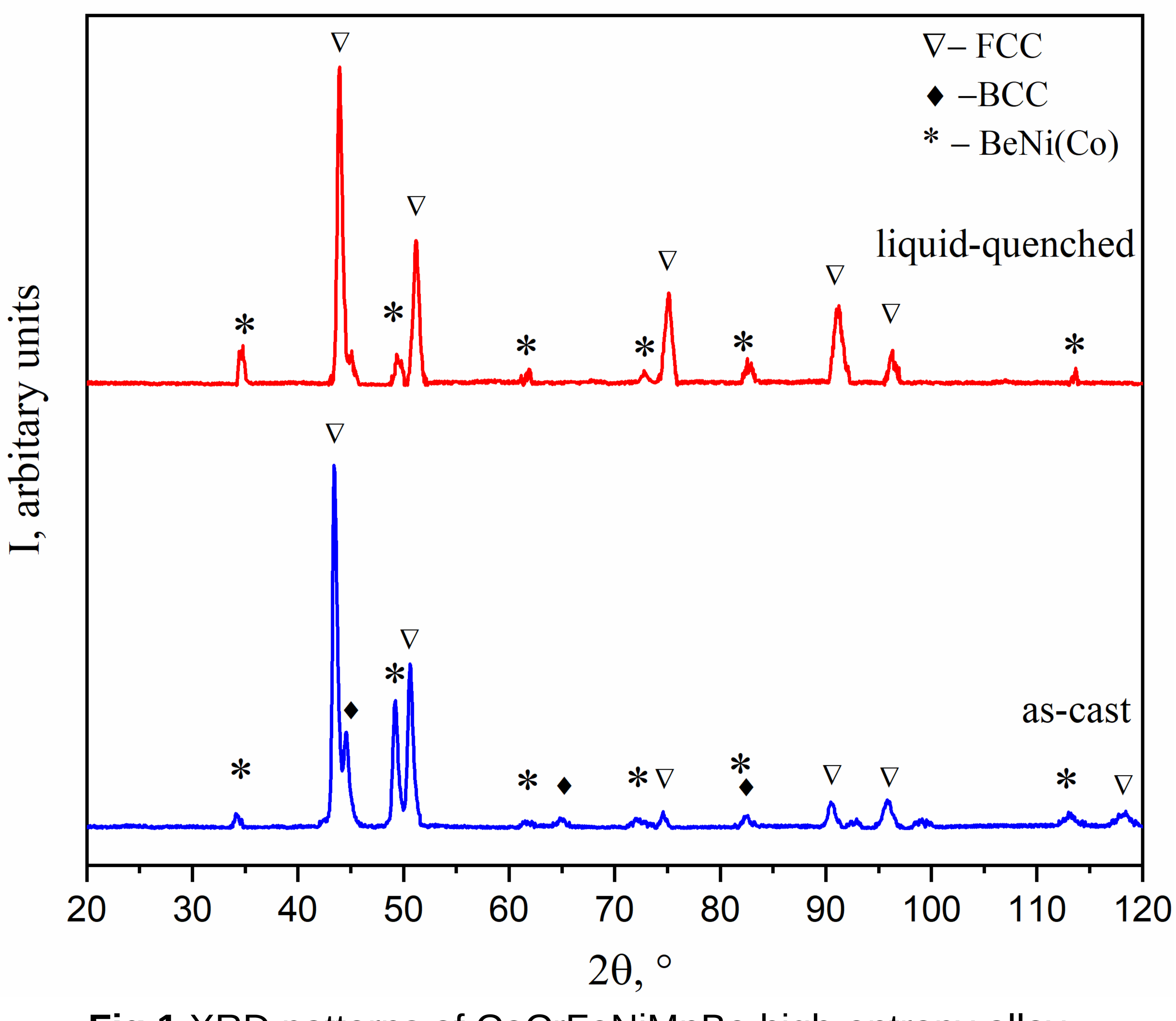

Fig.1 XRD patterns of CoCrFeNiMnBe high-entropy alloy

The analysis of the XRD patterns (Fig.1) allowed us to establish that the investigated HEA in the as-cast state has a multiphase structure in which there is the FCC phase with lattice parameter *a*=0.3588 nm and the coherently scattering domain size (crystallite size) estimated by the Sherer formula *L* =20 nm, BCC phase (*a*=0.2872 nm, *L* =19 nm), and B2 type intermetallic compounds BeNi(Co) (*a*=0.2616 nm, *L* =20 nm). At the same time, the LQ sample has a structure consisting of the FCC phase (*a*=0.3599 nm, *L* = 15 nm) and the BeNi(Co) phase (*a*=0.2610 nm, *L* = 18 nm). The microhardness in the as-cast state is Hμ=3400 MPa, while in the LQ state Hμ=5600 MPa. So, the addition of Be significantly improves the mechanical characteristics of the studied HEA as compared with the original Cantor alloy (CoCrFeNiMn). The fact that the LQ HEA of the Co-Cr-Fe-Ni-Mn-Be system is characterized by higher values of Hμ than as-cast alloys is not unexpected, since the microstructure and the phase composition of the as-cast alloy after decomposition are in a more equilibrium multiphase state, while LQ alloy yields a higher level of microstrains, dislocation density and smaller grain sizes.

The magnetic properties of the films were examined by a vibrating sample magnetometer. For the as-cast CoCrFeNiMnBe HEA the saturated magnetization (Ms), and coercivity force (Hc) were 5.1 A·m^2/kg and 2800 A/m, while for the LQ films – 2.7 A·m^2/kg and 4000 A/m respectively.

Conclusions

In this study, a new CoCrFeNiMnBe high-entropy alloy films have been synthesized by the means of liquid quenching technique. The addition of Be significantly improves the mechanical characteristics of the studied high-entropy alloy as compared with the Cantor alloy (CoCrFeNiMn), moreover the liquid-quenched high-entropy alloy films of the Co-Cr-Fe-Ni-Mn-Be system is characterized by higher values of Hμ than as-cast alloys. Both as-cast and liquid-quenched CoCrFeNiMnBe samples are characterized by the presence of ferromagnetic properties.