Mechanical properties of high-entropy $CoCrFeNiC_x$ alloys at 77 K and 300 K

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Motivation

Four-component equiatomic alloy CoCrFeNi, which has high ductility and toughness in the region of nitrogen temperature, is promising for use in cryogenic technique. However, the strength characteristics of this alloy need significant improvement.

In this work, an attempt was made to increase the strength characteristics of the Co-Cr-Fe-Ni-C HEA by alloying with an interstitial element, namely carbon.

Materials and methods

Material: high-entropy alloy (HEA) $Co_{25-x}Cr_{25}Fe_{25}Ni_{25}C_x$, produced by arc-melting,

- annealed at 1100 °C for 5 hours, rolled into a strip 0.5 mm thick with intermediate annealing.

Samples: Dogbone-shaped samples (the cross-section of the working part of the samples was 0.5 mm², the length of the working part was 8 mm) tested in deformed (50% reduction at rolling) and annealed states (1050 °C, 1 hour)

Mechanical tests: 300 K, 77K, deformation rate 10^{-3} s^{-1}

Figures

a – concentration dependences of the limits of proportionality σ_0 (curves 1,3) and strength σ_B (curves 2,4) at 300 K for deformed (curves 1,2) and annealed (curves 3,4) samples

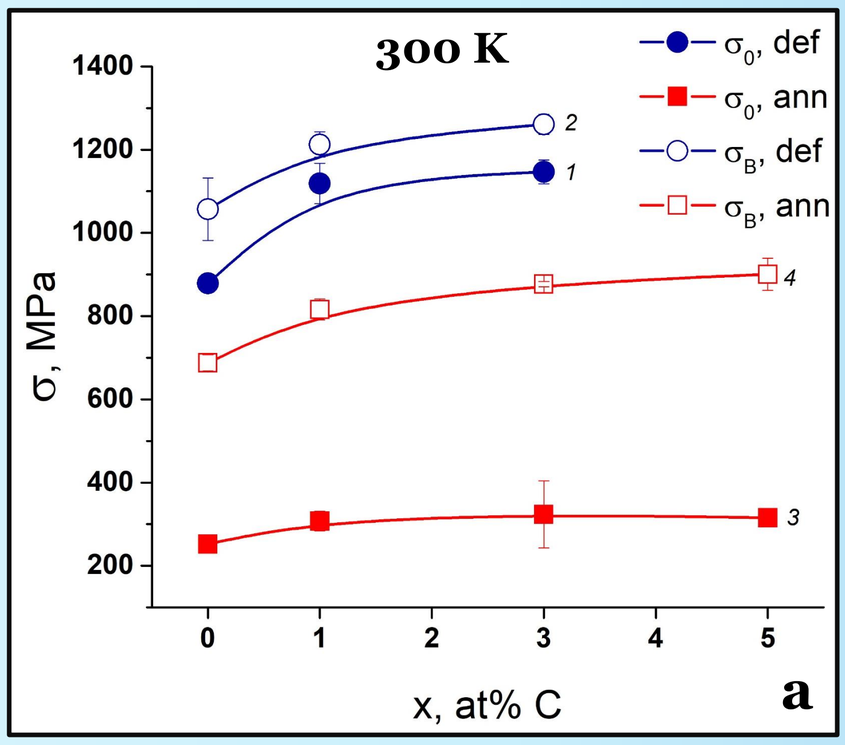
b – concentration dependences of the limits of proportionality σ_0 (curve 1) and strength σ_B (curve 2) at 77 K for annealed samples

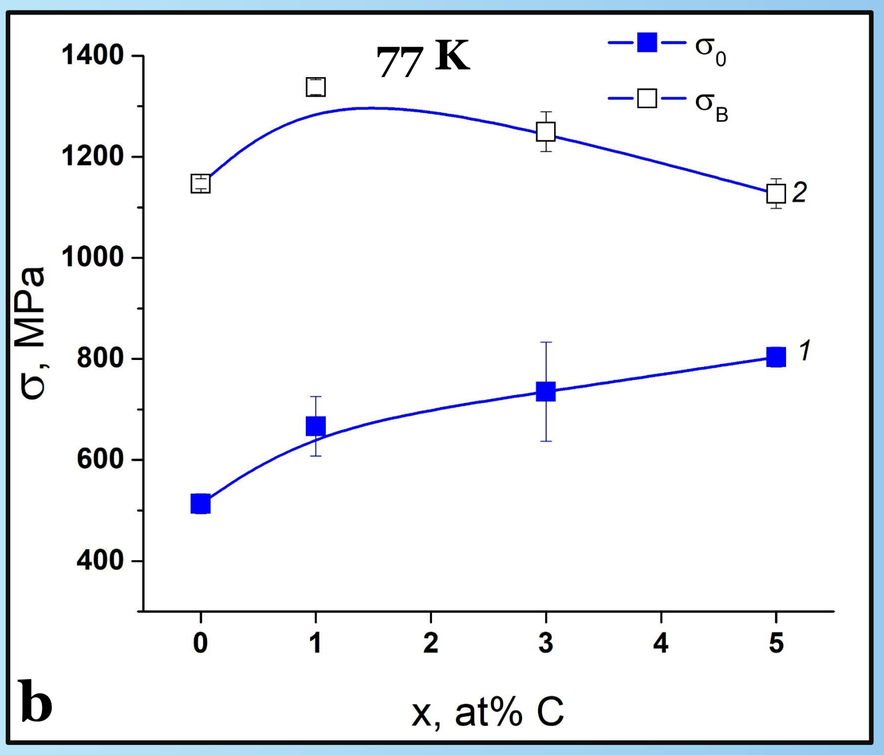
c – concentration dependences of uniform ε_e (curves 1,2,3) and maximum elongation ε_{max} (curves 4,5) at 300 K and 77 K for deformed (curve 1) and annealed (curves 2-5) samples

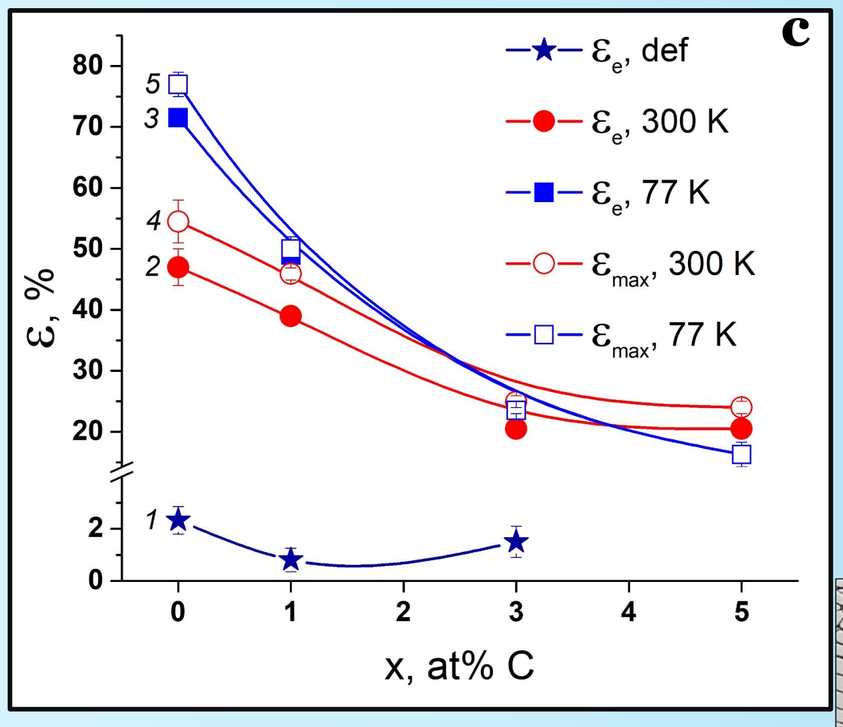
d – structure of the as-cast alloys with different carbon content:

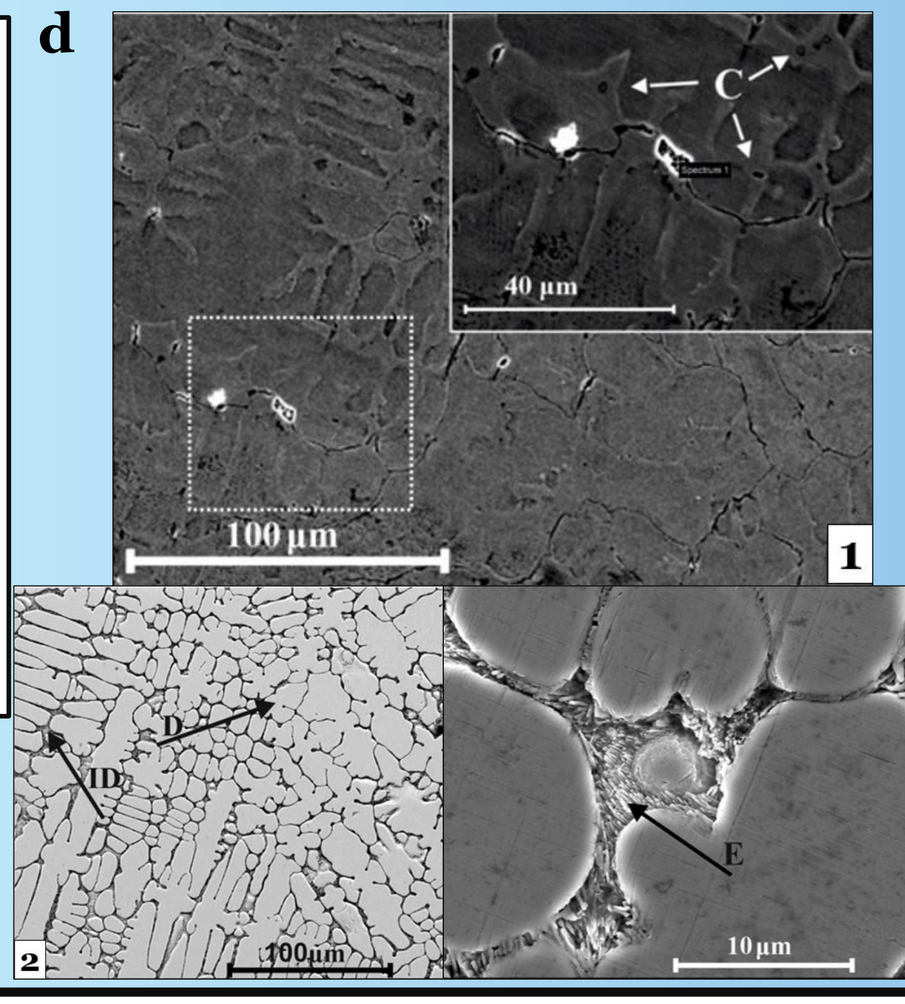
1 – 1 at.%

2,3 – 3 at.%









Results

- Addition of 1 -3 at.% carbon increase σ_0 and σ_B of deformed and annealed samples at 300 K.
- At 77 K σ_0 of alloys increases monotonically and more strongly with increasing carbon concentration, but the tensile strength has a maximum at 1 at.% C.
- Alloying with carbon leads to a noticeable decrease in the ductility of the alloys, but at 1 at. % carbon the plasticity of annealed samples at 77 K remains very high (more than 50%).
- The optimal combination of strength and ductility characteristics of the alloy at 77 K is achieved at a carbon concentration of about 1 at. %. However, at this concentration precipitates of the carbide phase is already observed at the grain boundaries, which can significantly reduce ductility. It is possible that reducing the carbon concentration to 0.75-0.85 at. % will increase the ductility of the alloy without reducing its strength characteristics.