THE EFFECT OF THE VANADIUM CONTENT ON THE MICROHARDNESS OF $CoCrFeNiMnV_X$ HIGH-ENTROPY ALLOYS IN THE TEMPERATURE RANGE OF 77-293 K

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ABSTRACT

The main purpose of this work was to investigate the micromechanical properties of $CoCrFeNiMnV_x$ (x = 0, 0.25, 0.4, 0.5, 0.75, 0.85, 1.5, 2.0) high-entropy alloys in the coarse-grained state at temperatures of 77-293 K.

Dependences of Vickers microhardness on temperature $H_V(T)$ were obtained for all mentioned alloys except the alloy with x = 2 for the reason of its brittleness. The microhardness of the sigma phase at T = 293 and T = 77 K is about 9.5 GPa and 12.5 GPa, respectively.

1. THE HOMOGENEITY OF THE SAMPLE STRUCTURE

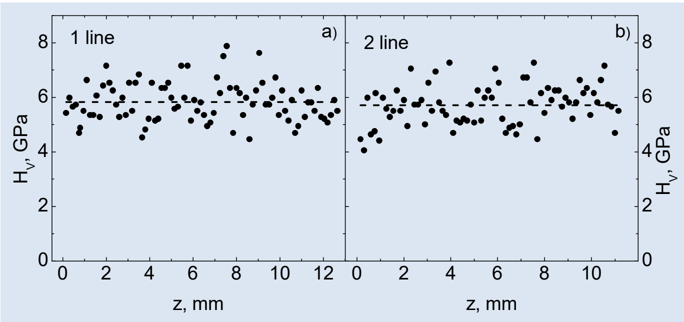

Fig. 1

The microhardness of the two-phase $CoCrFeNiMnV_{0.85}$ alloy was measured along two parallel straight lines (axis z in Fig. 1). The distance between these lines was about 1.5 mm, and the distance between the indentations was Δz = 0.15 mm. It is evident from Table 1 and Fig. 1 that the values of average (sample mean) microhardness calculated by 85 prints for line 1 and by 75 prints for line 2 are very close to each other, which is facilitated by the large sample size and indicates the macrohomogeneity of the $CoCrFeNiMnV_{0.85}$ alloy sample.

Line number	Sample size n	Sample mean $\bar{H}_V$ [GPa]	Standard deviation s_d [GPa]	Standard error of the mean s_e [GPa]	Coefficient of variation $\frac{s_d}{\bar{H}_V}$ [%]
1	85	5.824	0.716	0.078	12.2
2	75	5.707	0.741	0.086	13.0

Table 1. Sample microhardness characteristics of $CoCrFeNiMnV_{0.85}$ HEA, n is the number of measurements of the H_V value.

2. THE INFLUENCE OF TEMPERATURE AND VANADIUM CONTENT ON THE MICROHARDNESS OF ALLOYS $CoCrFeNiMnV_X$

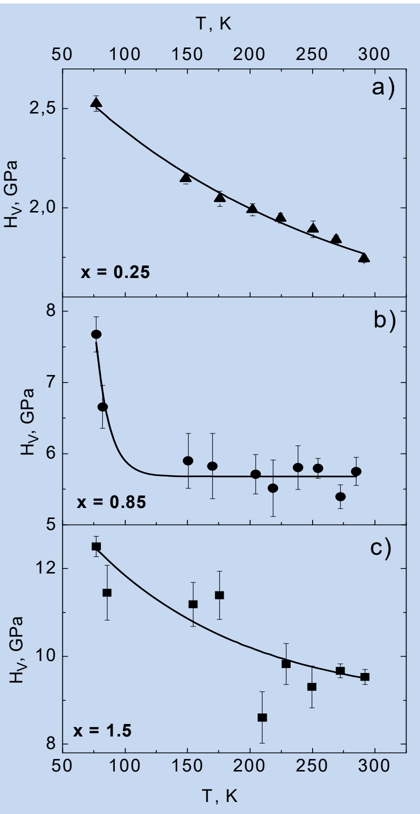

Fig. 2

$CoCrFeNiMnV_{0.25}$ alloy is mainly single-phase with FCC crystal lattice. With temperature decrease from 293 K to 77 K the microhardness of $CoCrFeNiMnV_{0.25}$ alloy monotonically increases by about 45% (Fig. 2a) that indicates the thermally activated character of plastic deformation of the material under the indenter.

The $CoCrFeNiMnV_{1.5}$ alloy is also mainly single-phase one with a tetragonal lattice, and the whole volume of the alloy is mainly intermetallic sigma phase. The value of microhardness of $CoCrFeNiMnV_{1.5}$ alloy increases monotonically by about 32% with temperature decrease from 293 K to 77 K (Fig. 2c).

A completely different behavior of microhardness was observed in the case of the two-phase alloy $CoCrFeNiMnV_{0.85}$. From Fig. 2b it is evident that in a wide temperature range (150-293 K) the average microhardness remains practically unchanged.

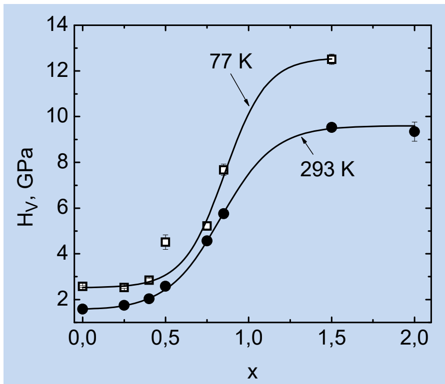

Fig. 3

At x ≲ 0.25 the lattice basically remains FCC, and the microhardness changes slightly with increasing x. However, with a further increase in the vanadium content the formation of a new phase, the intermetallic sigma phase with a tetragonal lattice, takes place. The new hard precipitates act as athermal barriers to the motion of dislocations. A sharp increase in the microhardness, starting from x ~ 0.5, is due to an increase in the volume fraction of the sigma phase from ~ 20 % up to approximately 100 % in alloys with x = 1.5-2.