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THE EFFECT OF NITROGEN ON THE STRUCTURE AND MECANICAL PROPERTIES OF THE $FE_{40}MN_{40}CR_{10}CO_{10}$-BASED ALLOYS

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Abstract

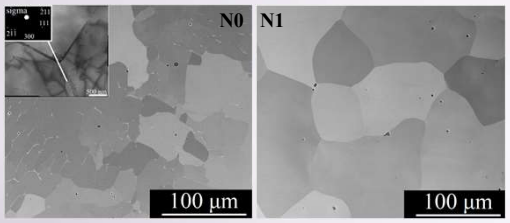
High-entropy alloys (HEAs) with a face-centered cubic (FCC) structure are currently considered as promising structural materials. The Co-Cr-Fe-Mn-Ni system alloys demonstrated encouraging properties, for example, high ductility and fracture toughness at room and cryogenic temperatures, but generally they have low strength. The $Fe_{40}Mn_{40}Cr_{10}Co_{10}$ alloy is particularly interesting as a single-phase solid solution with impressive mechanical properties. Thermomechanical processing can be effectively used to tailor the microstructure and properties. In addition, alloying with interstitial elements, in particular nitrogen, can lead to significant hardening. Therefore, in this work the effect of nitrogen content (0; 1 at.%) on the structure and mechanical properties of the $Fe_{40}Mn_{40}Cr_{10}Co_{10}$-based alloys after thermomechanical processing was studied.

Materials and Procedure

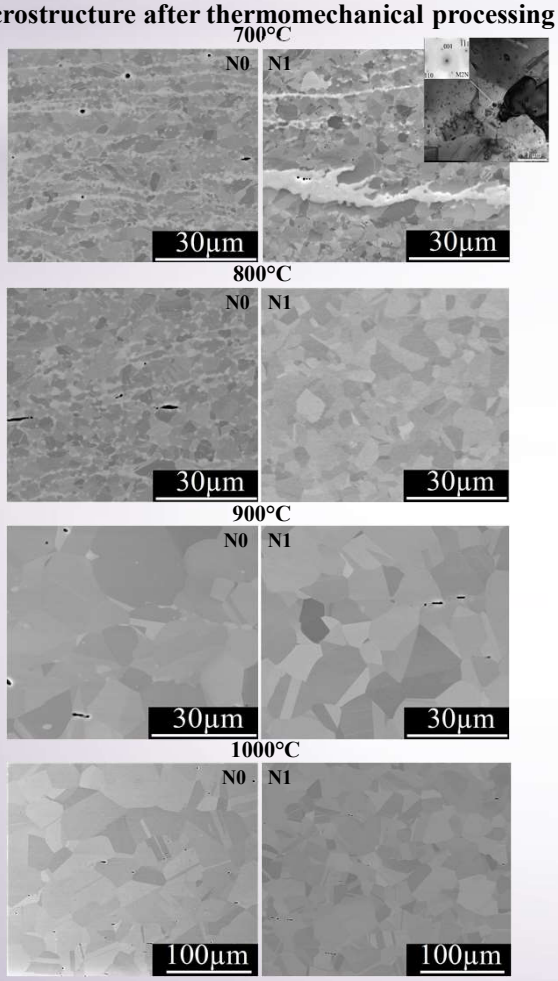
High entropy alloys with the nominal composition of $Fe_{40-x}Mn_{40}Co_{10}Cr_{10}N_x$ (x = 0, 1.0) were produced by vacuum induction melting. The ingots were produced from mixtures of pure (≥99.9% wt.%) constitutive elements. N was added in the form of ferrochrome nitride.

Unidirectional multipass rolling to a total thickness strain of 80% (from 25 to 5 mm) was performed using a reduction per pass of 3–5%. The samples were then annealed in a muffle furnace in an air atmosphere at temperatures of 700 - 1000°C for 1 hour followed by air cooling.

Microstructure in the as-cast state

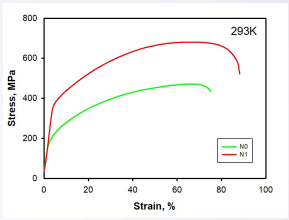


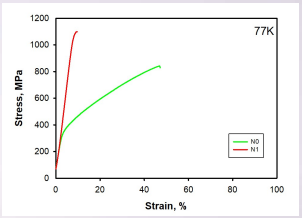
Microstructure after thermomechanical processing



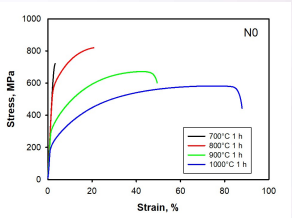
Mechanical Properties of the as-cast alloys

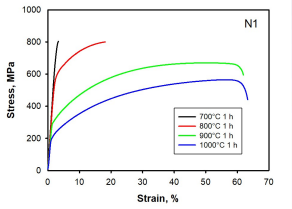
Alloy	Testing T	σ_B MPa	$\sigma_{0.2}$ MPa	δ, %
N0	293K	170	470	70
	77K	320	840	40
N1	293K	350	680	80
	77K	1030	1100	2





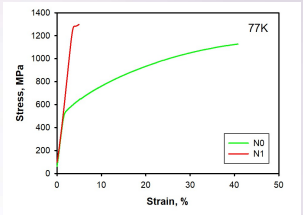
Mechanical Properties after thermomechanical processing





After annealing at 900°C

Alloy	Testing T	σ_B MPa	$\sigma_{0.2}$ MPa	δ, %
N0	293K	300	670	50
	77K	520	1130	40
N1	293K	290	670	60
	77K	1270	1290	2



Conclusions

The $Fe_{40}Mn_{40}Cr_{10}Co_{10}$ alloy had dual-phase structure with FCC matrix and sigma phase precipitates, while N-doped alloy had single-phase FCC structure. Nitrogen alloying increases both strength and ductility at room temperature. Decrease in the testing temperature results in the pronounced increase in strength of the alloys.

Heterogeneous structure formed in the $Fe_{40}Mn_{40}Cr_{10}Co_{10}$ after cold rolling with subsequent annealing. Sigma phase fraction decreased with the increase in the annealing temperature. Some M_2N type nitrides were found in $Fe_{39}Mn_{40}Cr_{10}Co_{10}N_1$ alloy after annealing at 700°C. After annealing at higher temperatures, the alloy had a single-phase FCC structure.