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INVESTIGATION OF THE STRUCTURAL AND MECHANICAL PROPERTIES OF THE HIGH-ENTROPY Alloy $Al_{0.25}Ti_{0.25}CrFeNi$ AFTER HEAT TREATMENT

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INTRODUCTION & AIM

High-entropy alloys (HEAs) represent a new class of metallic materials composed of five or more principal elements in near-equiatomic ratios. This innovative design concept promotes the formation of stable solid solutions with simple crystal structures, such as FCC, BCC, or HCP lattices. As a result, HEAs exhibit exceptional mechanical and functional properties, including high strength, hardness, ductility, and stability under extreme conditions. These unique characteristics make them promising candidates for advanced structural and engineering applications. Current research is directed toward the development of dual-phase high-entropy alloys combining the advantages of both FCC and BCC structures. In these systems, the FCC matrix provides good ductility, while the BCC phase contributes to high strength and hardness. The formation of the BCC strengthening phase is mainly achieved through aluminum addition, whereas titanium is introduced to further enhance the strength of both structural constituents. These alloys are designed to achieve an optimal balance between strength and ductility, as well as microstructural stability under thermal and mechanical loading. This approach makes dual-phase HEAs promising candidates for demanding engineering applications where both mechanical performance and processability are critical. The aim of the present work is to characterize the microstructure and mechanical properties of the $Al_{0.25}Ti_{0.25}CrFeNi$ alloy in both the as-cast and annealed conditions.

METHOD

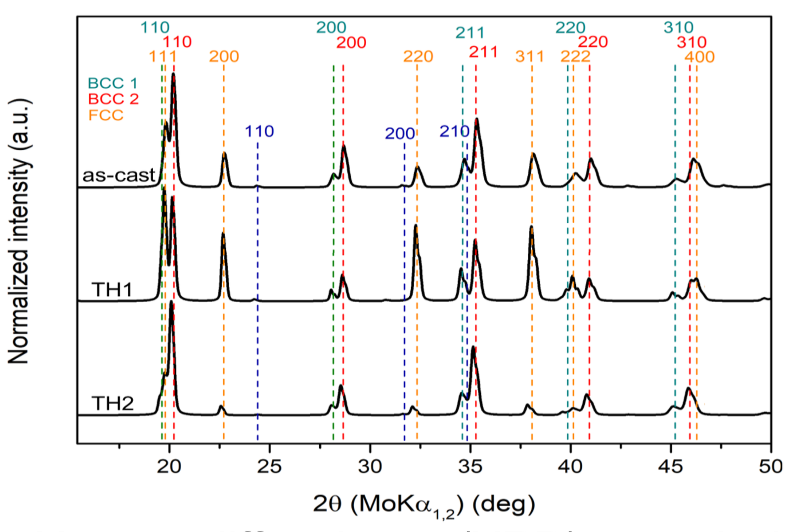
The $Al_{0.25}Ti_{0.25}CrFeNi$ alloy were prepared from high-purity elemental metals (≥99.9 wt.%) by arc melting in a Mini Arc Melter MAM-1 (Edmund Bühler GmbH, Germany) under an argon atmosphere. Each ingot was remelted five times to ensure chemical homogeneity. The nominal compositions are listed in Table 1. The alloys were studied in the as-cast state and after annealing at 1000 °C (HT1) and 1100 °C (HT2) for 4 h, followed by water quenching.

Tab. 1 The Chemical compositions of alloy $Al_{0.25}Ti_{0.25}CrFeNi$ (at. %)

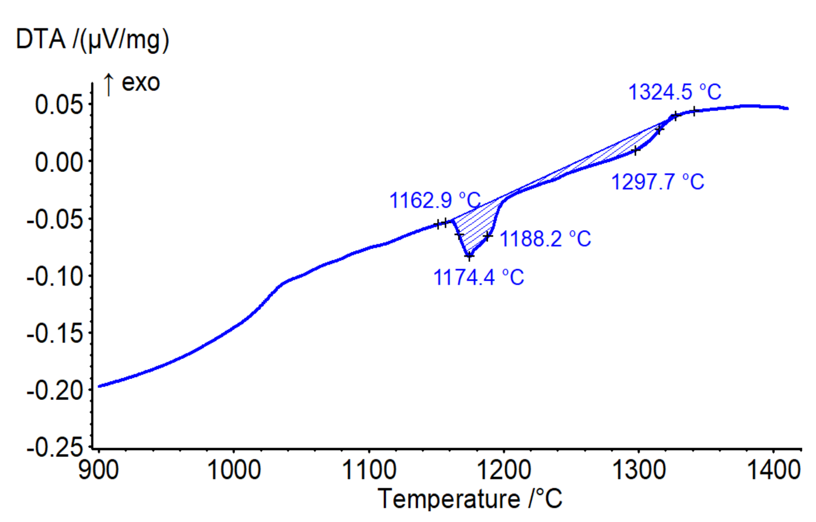
Al	Ti	Cr	Fe	Ni
7,4	7,3	26,4	28,2	30,7

Phase identification: X-ray diffraction (Rigaku Rapid II)
Metallographic preparation:, grinding, polishing, and etching (marble)
Microstructural characterization: Scanning electron microscopy (TESCAN MIRA 3 LMU), whit an energy-dispersive spectroscopy (EDS)
Mechanical testing: Vickers hardness (Struers Duramin-5, HV 0.1)
Compression tests using Tinius Olsen H300KU (strain rate 1 × 10^{-3} s^{-1})

RESULTS & DISCUSSION

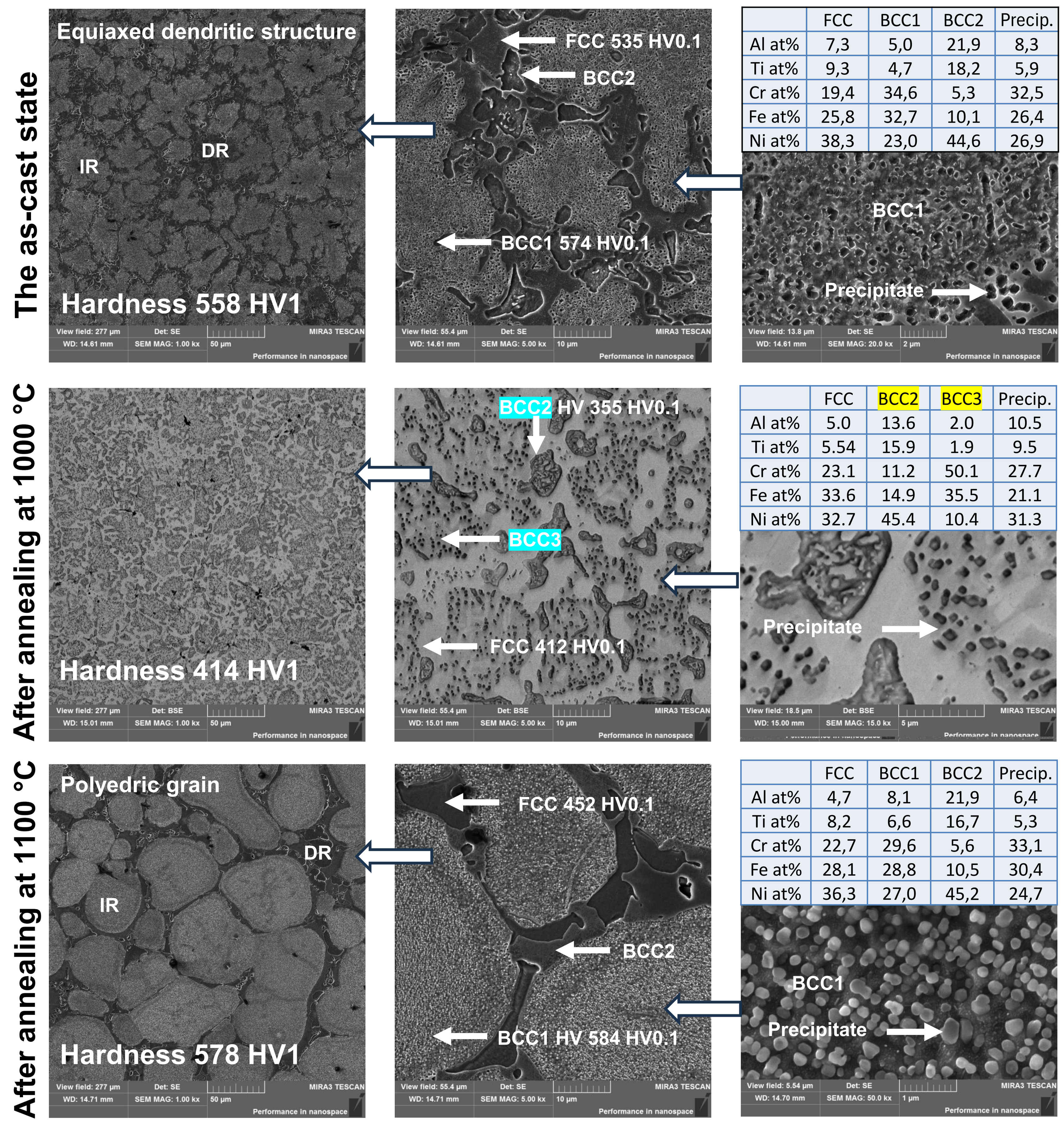


X-ray diffraction (XRD) analysis revealed four phases in the alloy: one FCC, two BCC, and one cubic phase with Pm$\bar{3}$m symmetry.



The melting temperature was determined to be 1162,9 °C using DTA, with the alloy showing the melting of two distinct phases.

The as-cast state exhibits an equiaxed dendritic structure with a dominant BCC1 phase containing Cr-rich precipitates. Annealing at 1000 °C led to the breakdown of the dendritic structure and the formation of a new BCC3 phase.After annealing at 1100 °C, spheroidization of the interdendritic regions and homogenization of precipitates occurred.

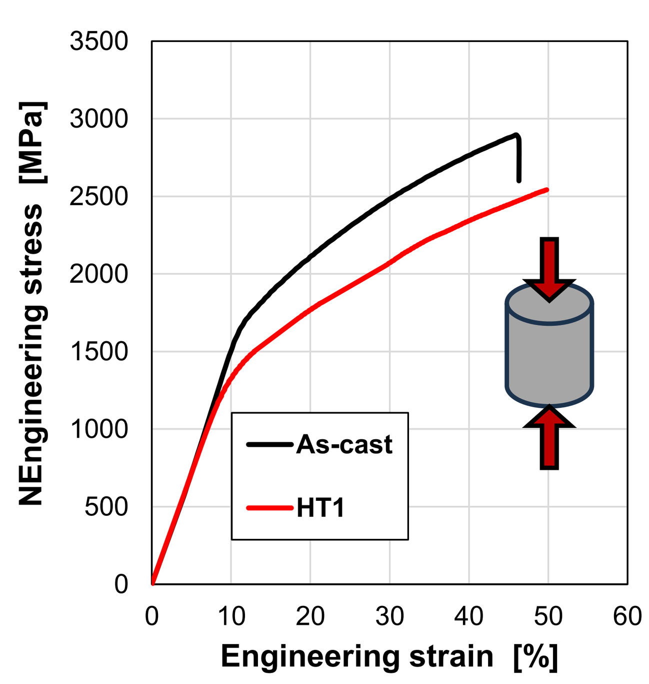


	FCC	BCC1	BCC2	Precip.
Al at%	7,3	5,0	21,9	8,3
Ti at%	9,3	4,7	18,2	5,9
Cr at%	19,4	34,6	5,3	32,5
Fe at%	25,8	32,7	10,1	26,4
Ni at%	38,3	23,0	44,6	26,9

	FCC	BCC2	BCC3	Precip.
Al at%	5.0	13.6	2.0	10.5
Ti at%	5.54	15.9	1.9	9.5
Cr at%	23.1	11.2	50.1	27.7
Fe at%	33.6	14.9	35.5	21.1
Ni at%	32.7	45.4	10.4	31.3

	FCC	BCC1	BCC2	Precip.
Al at%	4,7	8,1	21,9	6,4
Ti at%	8,2	6,6	16,7	5,3
Cr at%	22,7	29,6	5,6	33,1
Fe at%	28,1	28,8	10,5	30,4
Ni at%	36,3	27,0	45,2	24,7

Compression test



The as-cast alloy shows a yield strength of 1606 MPa and an ultimate tensile strength of 2895 MPa, fracturing in a brittle manner. After annealing at 1100 °C, the alloy became even more brittle and failed during water quenching. Annealing at 1000 °C resulted in a decrease of the yield strength to 1247 MPa and a reduction of the maximum stress to 2542 MPa, while improving the alloy's plasticity , the material reached a total deformation of approximately 50 %.

CONCLUSION

The $Al_{0.25}Ti_{0.25}CrFeNi$ alloy was produced by arc melting and characterized in both as-cast and annealed conditions. Structural and mechanical analyses confirmed a multiphase micro-structure consisting of FCC, BCC, and Pm$\bar{3}$m phases. The as-cast alloy exhibited high strength but fractured in a brittle manner. Annealing at 1000 °C led to a decrease in yield and compressive strength. Improved ductility was observed after annealing, indicating enhanced plastic deformation ability. Overall, heat treatment at 1000 °C provides a balance between strength and plasticity.

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