Synthesis of CuCrFeNiTiAl High Entropy Alloy Directly from Elemental Powders through Selective Laser Melting

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ABSTRACT

This study investigated synthesis of CuCrFeNiTiAl high entropy alloy (HEA) from pure elements using selective laser melting (SLM). The objectives are to validate the feasibility of the HEA fabrication from elemental powder materials, and to examine the effect of various process conditions in SLM, such as laser power, point distance and laser exposure time, on the microstructures formed. The as-built samples under high, medium, and low energy densities were characterized by X-ray diffraction (XRD), and the microstructures were observed using scanning electron microscopy (SEM). The XRD results showed that five major crystal structure phases (hexagonal, monoclinic, orthorhombic, body-centered cubic and rhombohedral) were present in all samples. Fine-grained phases were noticed on the formed surface with non-uniform microstructural distribution. Such phases in high and low energy density samples were observed polygonal while round-shaped microstructures were observed for samples prepared under medium energy density conditions. Also, grain size was proportional to energy levels of the fabrication process. Large size and clustered structures are prominent in samples produced under high energy density.

INTRODUCTION

High entropy alloys are composed of five or more principal constituent elements with equimolar or near-equimolar ratio. HEAs are engineered to possess a unique random solid solution (RSS) crystalline structure, in which each of the constituent elements has an equal probability of occupying a given lattice site. In an HEA, the entropy of the RSS is maximized to stabilize it against the formation of intermetallic. The concept of HEA has introduced an excellent way to fabricate advanced materials with superior properties including superior mechanical properties, excellent wear and corrosion resistance and shown significant potential for industrial application where superior performance, reliability and endurance are expected in extreme operating conditions (high temperature, high pressure etc.). Therefore, the fabrication and properties of HEA have generated significant interest from scientific community.

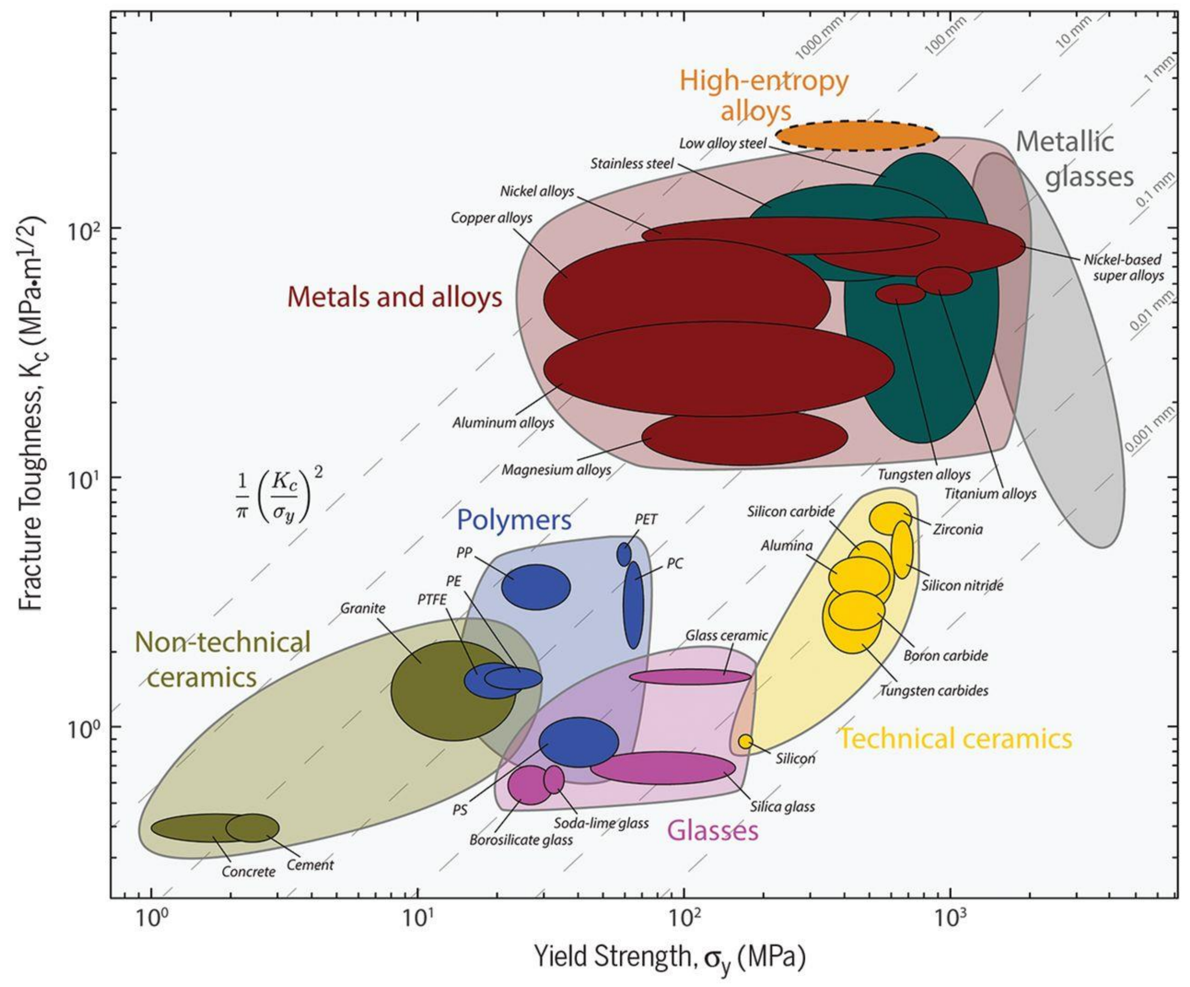


Fig. 1: Ashby map presenting fracture toughness as a function of tensile yield strength including HEAs and other material systems

BACKGROUND

- ❑ Currently, HEA is a quick growing multi-disciplinary research field.
- ❑ HEA systems have opened an infinite space for designing novel materials.
- ❑ RSS of HEA is found more stable than traditional FCC & BCC structures.
- ❑ HEAs have a far broader range of applications than conventional alloys.

MATERIALS AND METHODS

Materials Selection	Selective Laser Melting	Microstructure Analysis
Powder Composition Selection	Parameters Setting	Crystal Structure Analysis
Powder Mixing in V-type Blender	3D Model Design	Elemental Distribution Analysis

Table 1: Powder mixing protocol

	Al	Cu	Cr	Fe	Ni	Ti
Weight %	2.5	22.36	18.2	19.59	20.61	16.72
Molar Ratio	0.05	0.19	0.19	0.19	0.19	0.19

Table 2: Energy density (J mm^{-2}) of test series

Point Distance (µm) →		60	55	50	45	40
P (W)↓	**Exposer (µS)↓**					
100	**20**	0.37	0.40	0.44	0.49	0.56
125	**35**	0.81	0.88	0.97	1.08	1.22
150	**50**	1.39	1.52	1.67	1.85	2.08
175	**65**	2.11	2.30	2.53	2.81	3.16
200	**80**	2.96	3.23	3.56	3.95	4.44

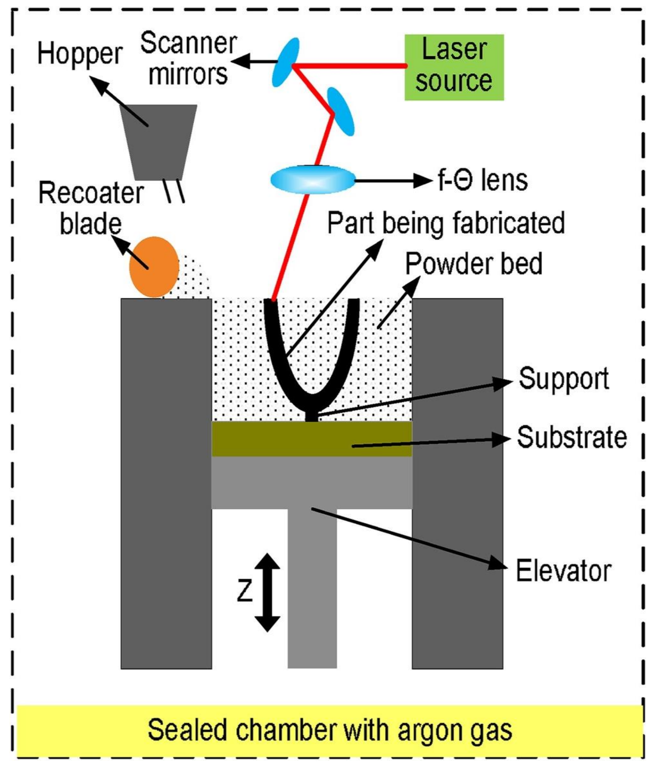
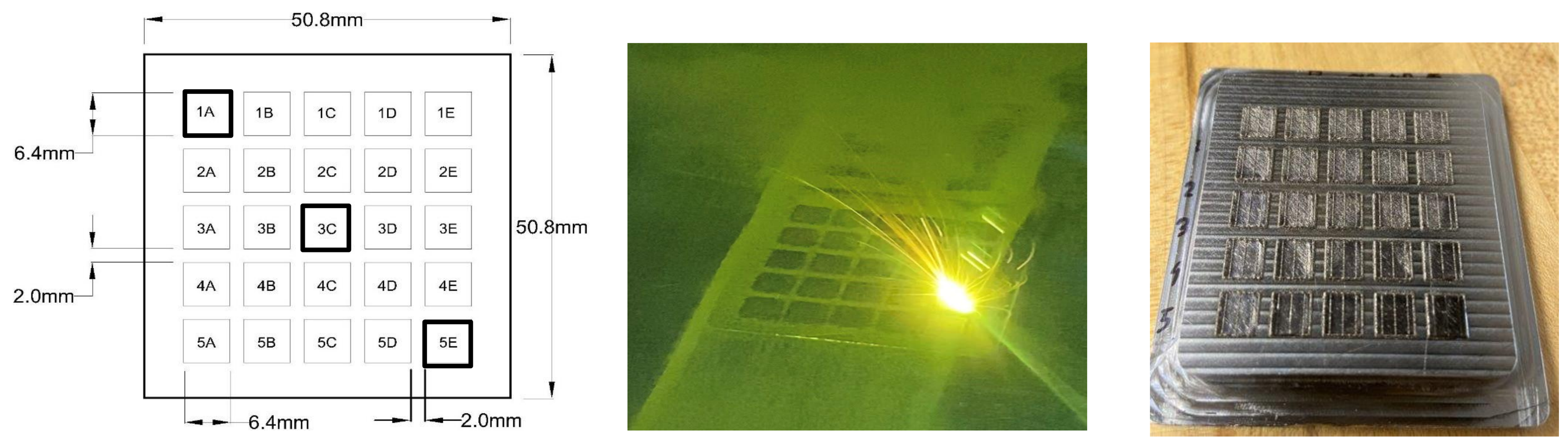


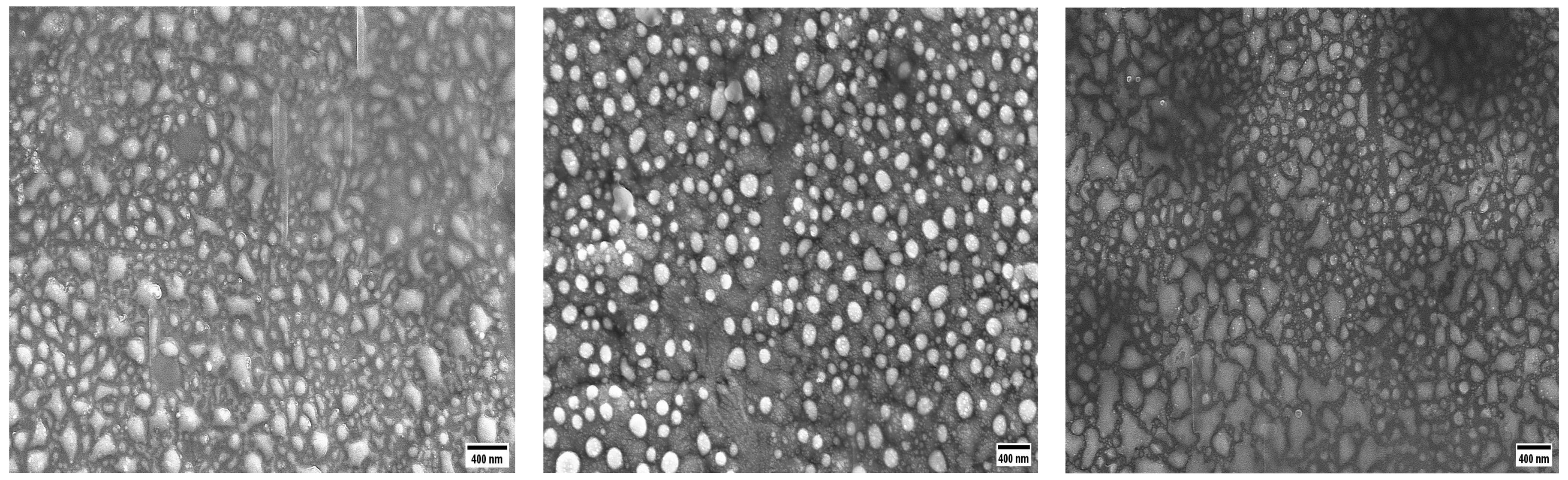
Fig 2: SLM technology



(a) (b) (c)

Fig 3: (a) 2D Design of test series, (b) laser melting process, and (c) SLM printed final part

RESULTS



(a) (b) (c)

Fig 4: Scanning electron microscopy (SEM) pictures of sample (a) 1A, (b) 3C, and (c) 5E

RESULTS *cont'd*

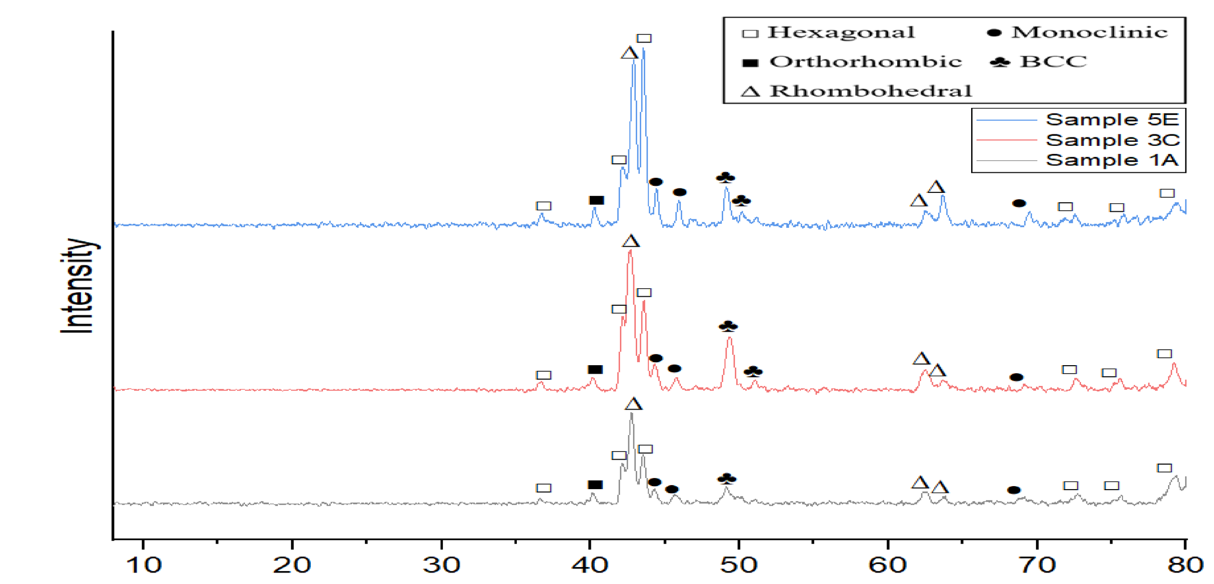


Fig 5: X-ray diffraction (XRD) pattern of CuCrFeNiTiAl HEA samples

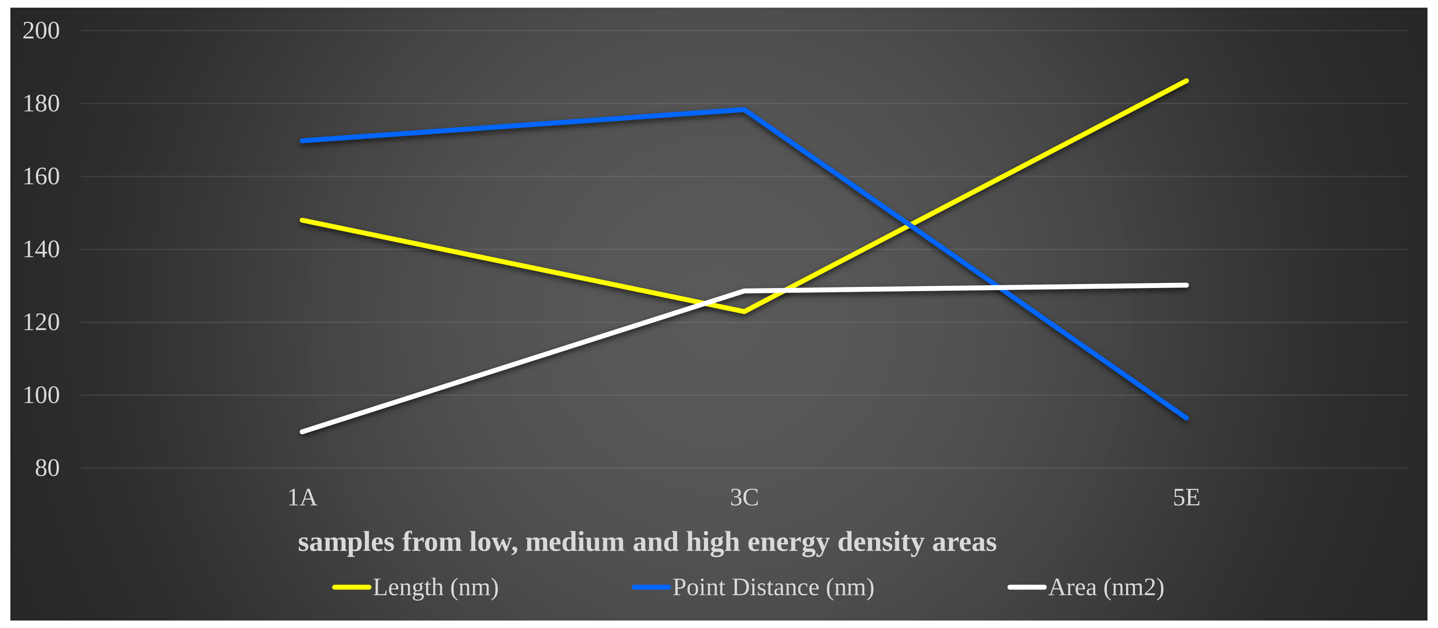


Fig 6: Effect of energy on shape, size and distribution of bright phases

CONCLUSIONS & FUTURE WORKS

- ❑ Five crystal structures were observed, and intensities of peaks increased with increasing laser energy input.
- ❑ Non-uniform microstructural distribution was observed.
- ❑ Fine-grained bright phases dispersed on dark phases were observed in all three samples.
- ❑ Shape, size and distribution of bright phases have a strong correlation with different laser energy densities.
- ❑ Samples were not in equimolar ratio, indicating incomplete diffusion during melting and solidification process. Therefore, future research is suggested to investigate new laser scan strategy, and/or other heating mechanisms to elongate the time of the liquid state of molten pool, thus allowing sufficient diffusion among the elements to form random solid solutions

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