Design and Development of Light Weight High Entropy Alloys

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Motivation

Investigate the influence of titanium content and experimental parameters on the microstructure and mechanical properties of an $Al_{1.5}CrFeMnTi_x$ alloy where x = 0.1, 0.15, 0.2, and 0.25 (weight percentages of 0.023, 0.034, 0.045, and 0.056 respectively). Low density and high strength are ideal.

Materials and Methods

Mechanical Alloying(MA)

MA is a cold-welding process that uses balls (tungsten carbide) and centrifugal force to create a homogenous mixture through fracturing and reforming of grains.

Spark Plasma Sintering (SPS)

SPS is a solid-state sintering method that uses pressure and electric current simultaneously to consolidate powders into solid materials while maintaining small grain sizes.

Parameters

$Al_{1.5}CrFeMnTi_x$	
Milling time (hrs)	12
Ball to Powder Ratio (BPR)	10:1
Rotations per Minute (RPM)	250
SPS Temp (°C)	1000
SPS Time (min)	5
SPS Pressure (MPa)	50

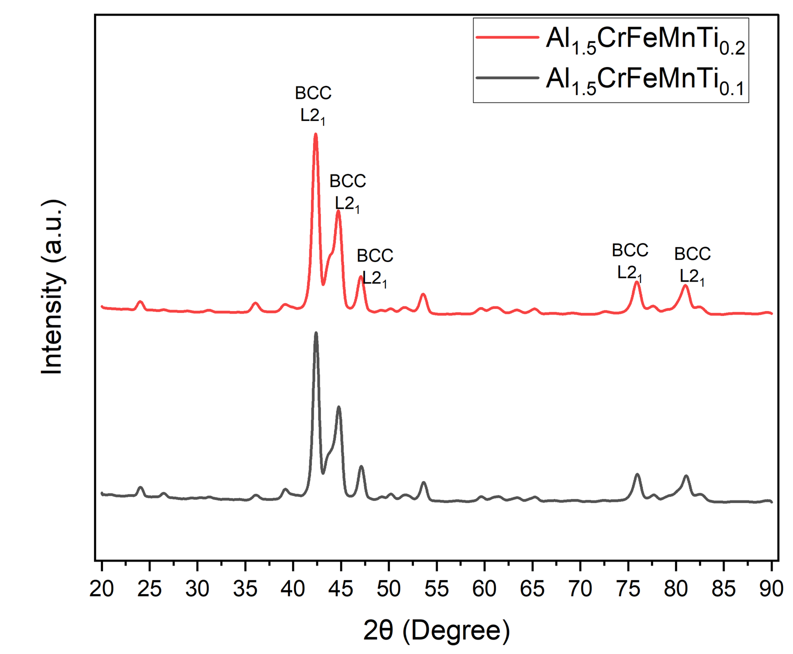
High Entropy Alloys (HEA)

HEAs constitute a wide range of alloys containing at least five metallic elements in close molar ratios. The complex composition of HEAs counterintuitively leads to a less complicated phases, usually FCC or BCC. Due to their unique properties such as distorted lattice structures and slow diffusion rates, HEAs have possible applications in aerospace and defense.

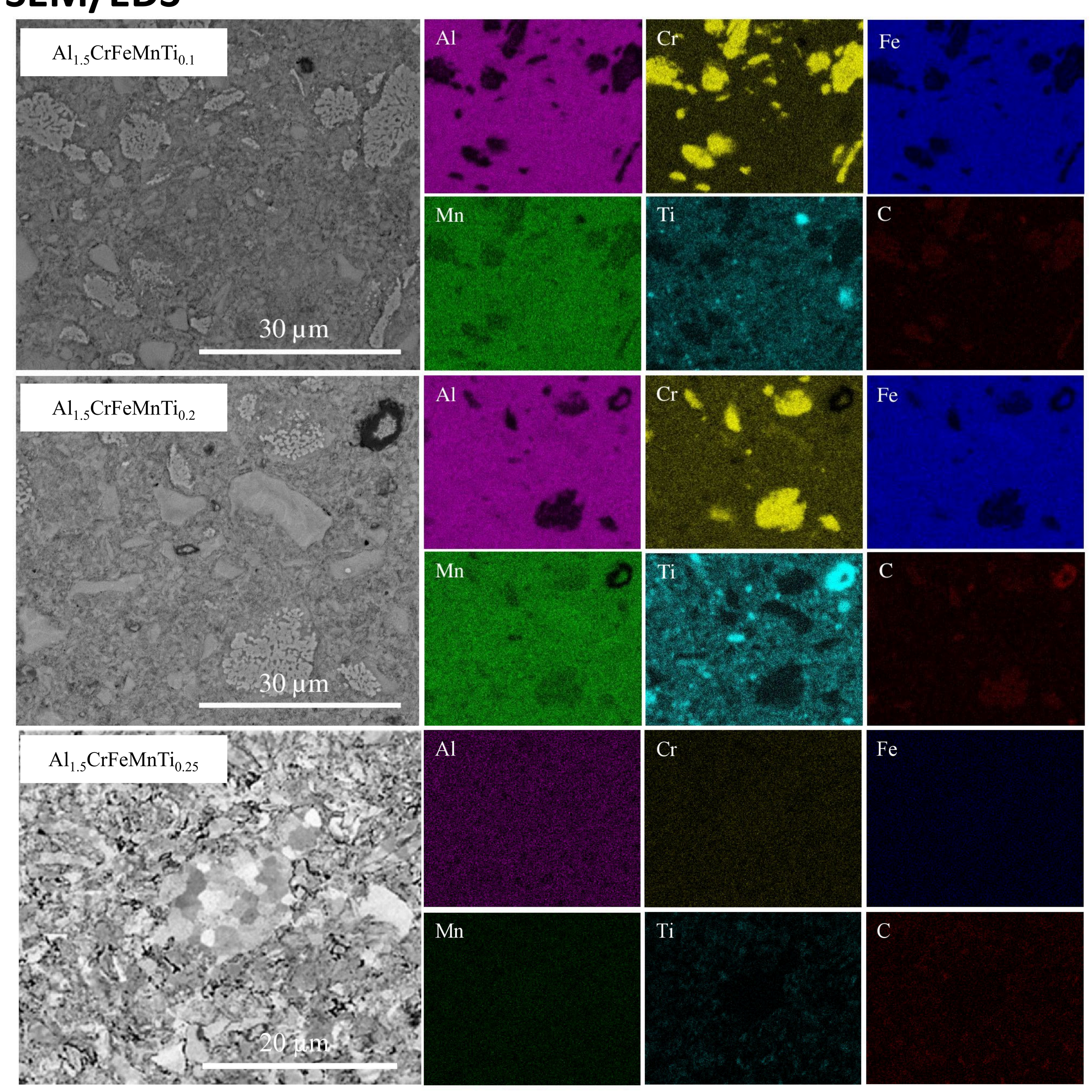
Results

X-Ray Diffraction (XRD)

$Ti_{0.1}$ and $Ti_{0.2}$ have similar XRD peaks, all of which are sharp and easily visible.
A majority of phases present are either ordered BCC and/or $L2_1$.



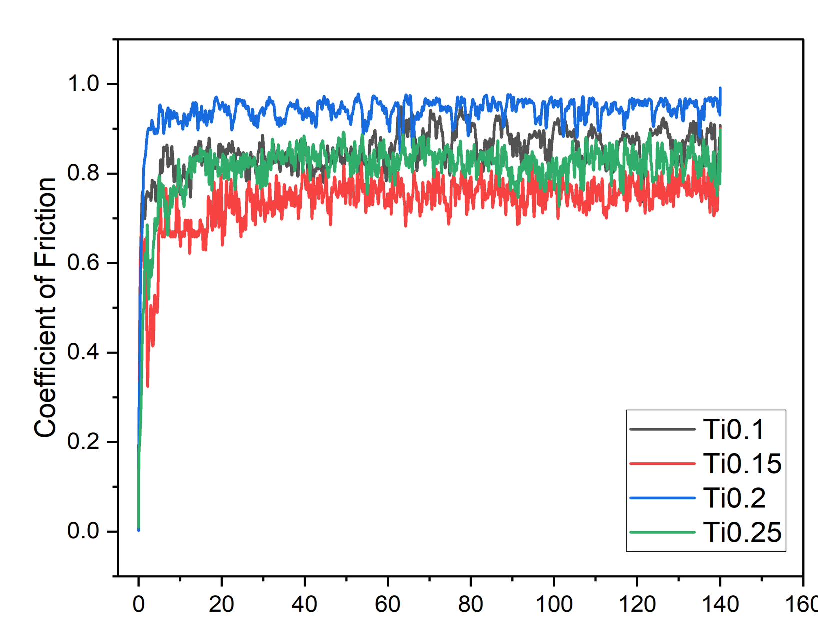
SEM/EDS



EDS images of $Al_{1.5}CrFeMnTi_{0.1}$, $Al_{1.5}CrFeMnTi_{0.2}$, and $Al_{1.5}CrFeMnTi_{0.25}$. Chromium and carbon are separate from the majority Al-Fe-Mn structure forming Cr_3C_2. Titanium is also heavily concentrated in the visibly dark spots. Micro sized grains are present.

Tribological Properties

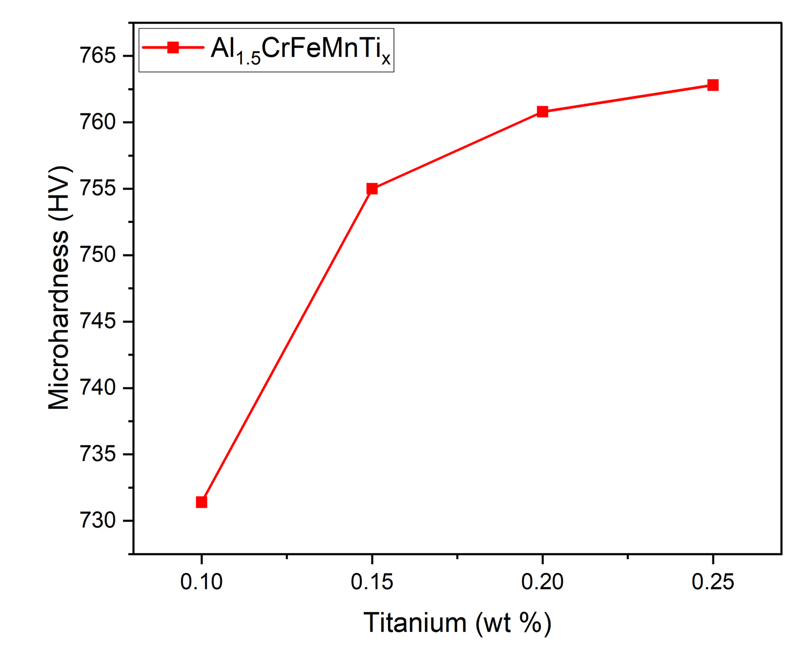
The average coefficient of friction was high overall and influenced by higher titanium concentration. COF did not significantly change with composition.



Mechanical Properties

Alloy	Ti0.1	Ti0.15	Ti0.2	Ti0.25
Hardness (HV 0.5)	731.4	755	760.8	762.8
Density (g/cm^3)	5.78	5.803	5.79	5.789
Relative Density (g/cm^3)	99.11	99.27	99.20	99.51
Coefficient of Friction (μ)	0.8523	0.7258	0.9466	0.8177

Titanium content showed a relationship to hardness as well, as there are large differences between $Ti0._{15}$ and $Ti0._{25}$. The relative density for all samples was above 95%, demonstrating that density was not affected by SPS.



Conclusions

- Milling time significantly affected mechanical properties and grain size.
- Contamination from carbon and oxygen was present.
- MA and SPS form small grains.
- The alloys were at least double phase, and chromium formed a separate phases with carbon forming Cr_3C_2.
- Titanium tended to segregate from the rest of the elements as well.
- Titanium content is directly related to coefficient of friction and hardness.
- COF was very high for all samples, except $Ti_{0.15}$.
- BCC and/or $L2_1$ crystal structures are mainly present.

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