High Mechanical Performance Eutectic Medium-Entropy-Alloy Nanocomposite

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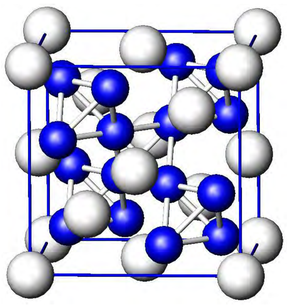
Introduction

- Laves phase alloy



- The largest group of intermetallic compounds.
- Great candidates for engineering applications.
- High strength are attractive, however, the principal shortcoming is their pronounced brittleness at ambient temperatures. (*Stein. F. et al. 2004*)

- Eutectic high entropy alloy (EHEA)

To toughen the strong but brittle Laves phase, a viable solution is to alloy Laves phase with new elements or form a ductile second phase. This idea work in connection with recent novel EHEA alloy design strategy. (*Lu. Y. et al. 2014*)

- Methodology

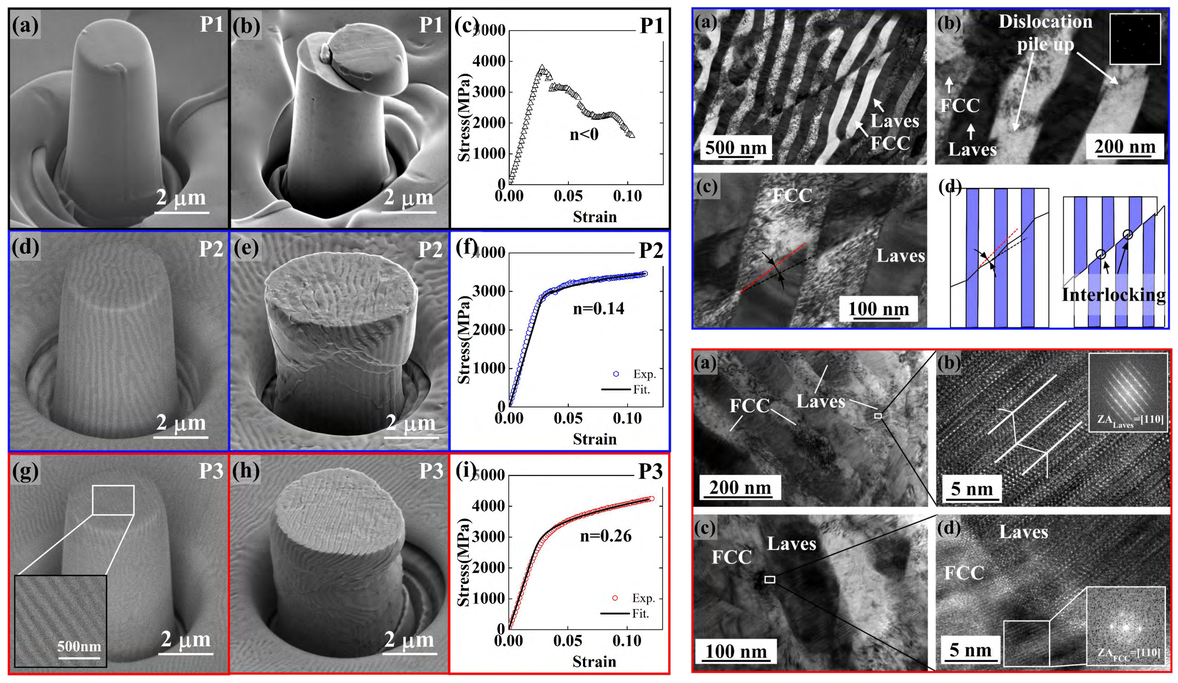
To design a multicomponent Laves contained eutectic alloy, we follow the entropy design strategy and below formula:

$$FeCoNiNb_{0.5} \approx (CoNb_{0.15}) + (FeNb_{0.14}) + (NiNb_{0.19})$$

(*Ding. Z. et al. 2017*)

Hardening Mechanism

- Size-dependent hardening behaviors

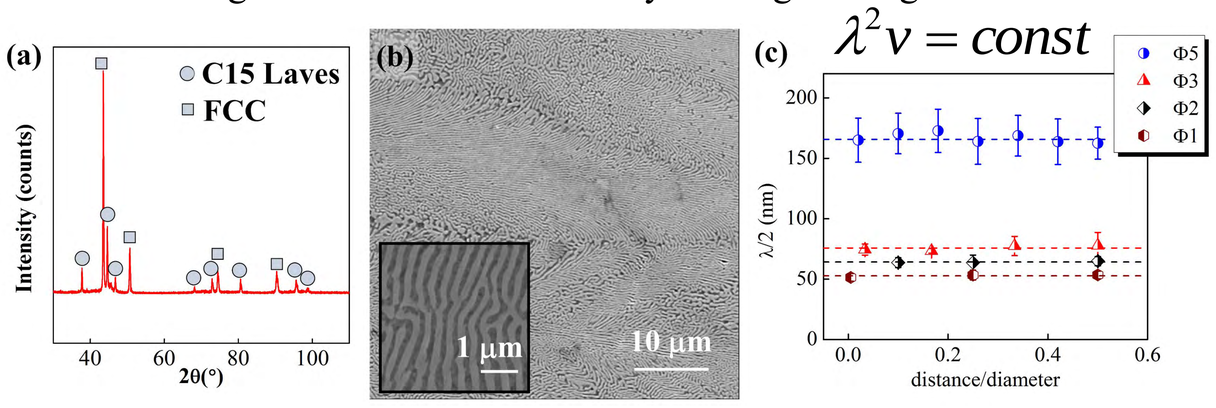


- Dislocation model

$$\tau_N = \frac{2\alpha G b_N}{L} \qquad \tau_P = \frac{2\alpha G b_p}{L} + \frac{\gamma}{b_p} \qquad L^* = \frac{2\alpha G (b_N - b_p) b_p}{\gamma}$$

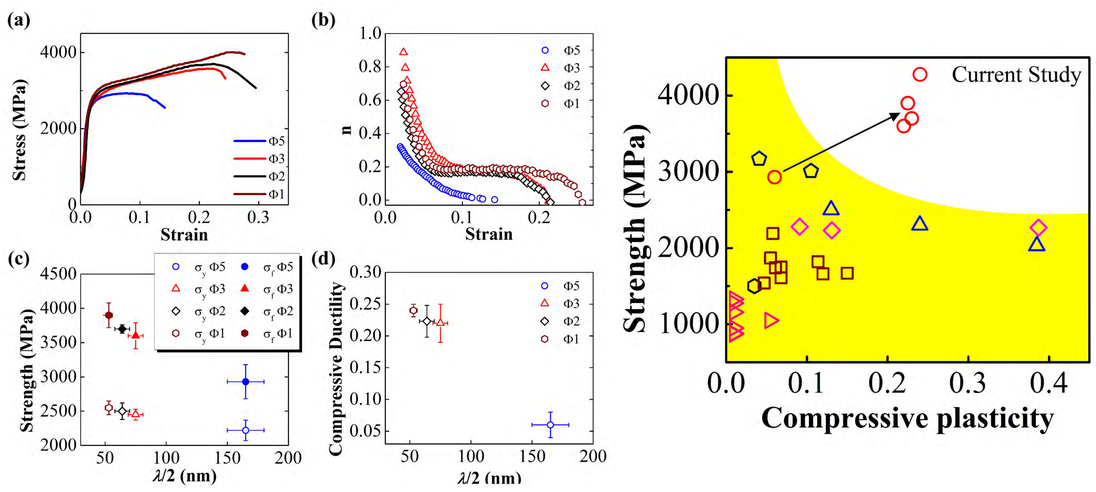
Alloy Processing & Performance

- Controlling eutectic microstructure by altering cooling condition

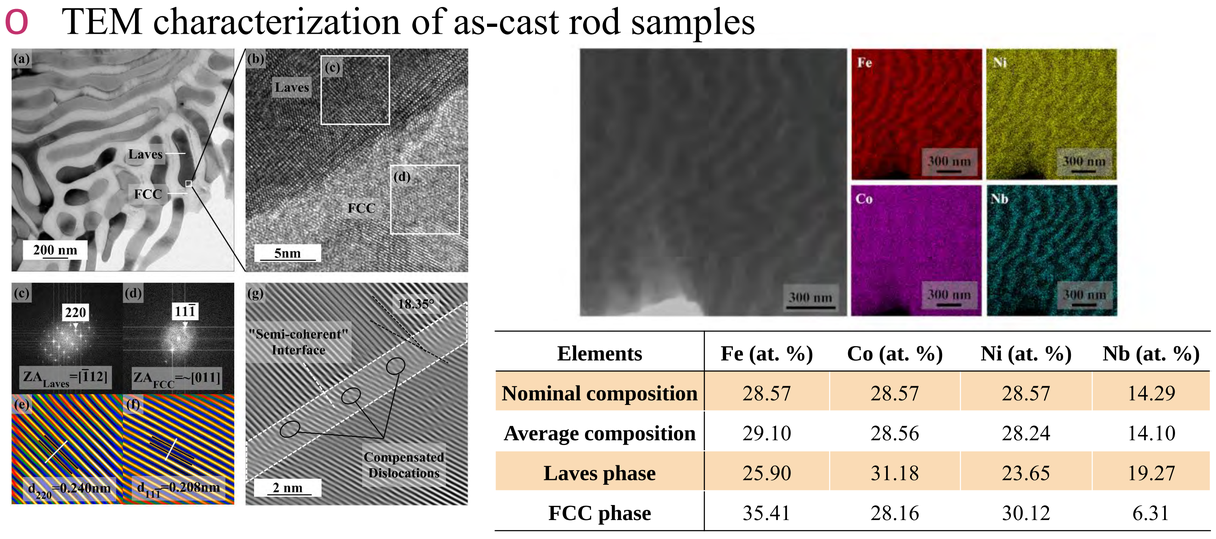


- $FeCoNiNb_{0.5}$ alloy exhibit two phase nature and bimodal size distribution.
- Eutectic inter-lamellar size λ decrease with decrease casting sample size, qualitatively agree with Jackson-Hunt theory.

- Improved mechanical properties with smaller lamellar size



- TEM characterization of as-cast rod samples



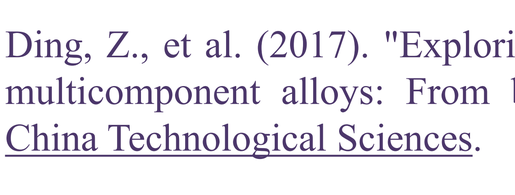
Elements	Fe (at. %)	Co (at. %)	Ni (at. %)	Nb (at. %)
Nominal composition	28.57	28.57	28.57	14.29
Average composition	29.10	28.56	28.24	14.10
Laves phase	25.90	31.18	23.65	19.27
FCC phase	35.41	28.16	30.12	6.31

- HRTEM unveils a semi-coherent interface and EDX mapping demonstrate elements distribution between FCC and Laves phase.

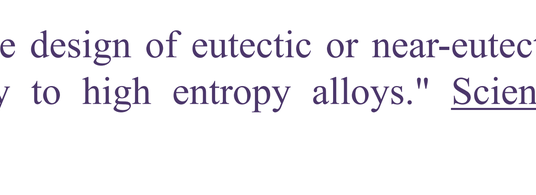
Potential Applications

- Strong and ductile tool materials

- High temperature materials



- Wear resistance alloy



- Hydrogen storage alloy

Summaries

- Two phase Laves rich eutectic composite are successfully synthesized.
- With smaller microstructure size, composites exhibit higher strain hardening rate, leading to both higher strength and malleability.
- Among other hardening mechanisms such as slip induced interlocking, the size-affected nanotwinning is most effective to sustain overall strain hardening.
- Current study implies that at ambient condition, Laves phase brittleness can be evaded.

References

- Ding, Z., et al. (2017). "Exploring the design of eutectic or near-eutectic multicomponent alloys: From binary to high entropy alloys." Science China Technological Sciences.