Serration Statistics in High Entropy Alloys and the Portevin Le Chatelier Effect

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Overall Objective of this new 3 year program

(1) Provide the fundamental understanding of the serration behavior for high-entropy alloys (HEAs) through mechanical experiments, theoretical analyses, and slip-avalanche modeling.

(2) Reveal the deformation mechanism of HEAs and develop and test new serration-based models to predict the mechanical performance for HEAs' long-term fossil-energy applications

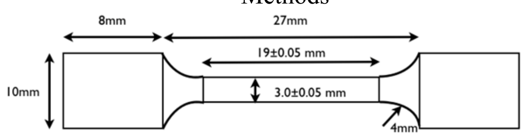
Avalanche Statistics: Background

- Under compression, the stress builds up until a weak spot slips, triggering other weak spots to also slip in a **slip avalanche** visible as a stress drop or serration.
- **Broad avalanche size distribution** – predicted by a simple mean field model to be **scale invariant [1,2]**.

High Entropy Alloys (HEAs)

- New materials that **contain five or more elements** in the alloy, with 5%-35% atomic percents, hence the name "high entropy".
- These alloys have **great tensile strengths** at **high temperatures.**
- Applications in materials science, mechanical engineering, and medicine.

Methods



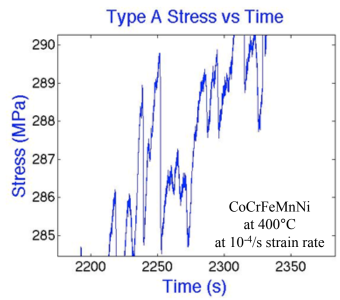
- **Cut** into tensile specimens with dimensions shown (quasi 2-dimensional)
- **Pulled** by an Instron 4505 at a constant strain rate and at temperatures ranging from **300˚C to 700˚C.**
- Data analysis: Extract complementary cumulative distribution function (CCDF) of stress drop sizes.
- Stress-time behavior resembled **Portevin-Le Chatelier (PLC) Effect**

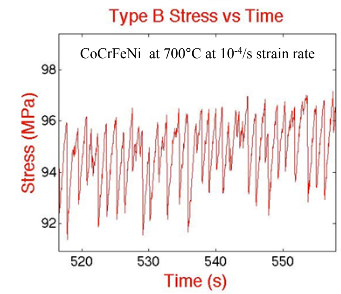
Portevin Le Chatelier (PLC) Effect

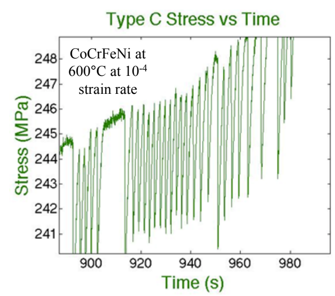
In the PLC effect stress drops are manifested in three types of **slip bands**:

1. Type A bands: continuously propagating with **no spatial pattern** of stress drops.
2. Type B bands have intermittent propagation with larger stress drops but with **irregular amplitudes**.
3. Type C bands are defined as static bands that have large stress drops of **equal amplitude** through the plastic deformation.

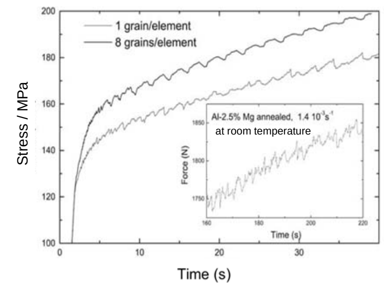
Our data on High Entropy Alloys







Published data on other systems [3,4]



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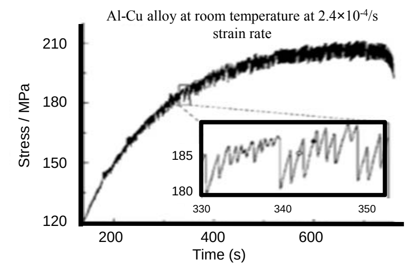

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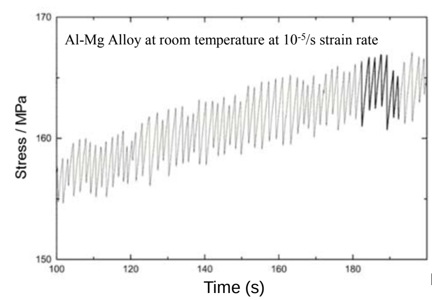
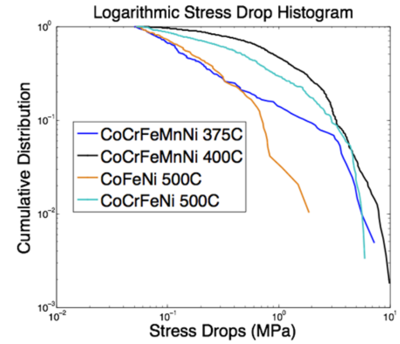


[3]

Complementary Cumulative Distribution Function with Fitted Power Law



Fitted power-law dependence $C(S) \sim S^{-(\kappa-1)}$, with $\kappa = 1.6 \pm 0.2$ agrees with our mean field model prediction ($\kappa = 1.5$) [1].
Power-law dependences are consistent with Type A band behavior.

Conclusions

Slowly deformed High Entropy Alloys at 300°C-700°C reflect the PCL effect with band types A,B, and C. The serration statistics for type A behavior follows a power law predicted by a simple model.

Next steps: (1) Examine if similar PLC behavior is observed in other high entropy alloys and if it occurs at particular strain rates and temperatures. (2) Model development.

Acknowledgments

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References

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