The Consortium for Enabling Technologies and Innovation

Virtual Summer Meeting for Young Researchers

High-Throughput Process Mapping for Additively Manufactured 316L Stainless Steel and FeCoNiCrMn High Entropy Alloy

Alec Sample Mangan

Ankur Kumar Agrawal

University of Wisconsin-Madison

July 8, 2020

ETI

NNSA
National Nuclear Security Administration

Biography

Alec Sample Mangan is a first year graduate student at the University of Wisconsin-Madison Alloy Design and Development Lab run by Dan Thoma. He studies additive manufacturing of high entropy alloys and in-situ monitoring of the additive manufacturing process.

Ankur Kumar Agrawal is a second-year graduate student at the University of Wisconsin-Madison. His research interest includes additive manufacturing, electron microscopy, and high strength steels. He is currently working on high-throughput process mapping and microstructural control of metal additive manufacturing.

Additive Manufacturing

Additive Manufacturing: the process of building a part by adding layers of material

Advantages:
- Complex geometries
- Reduced part number

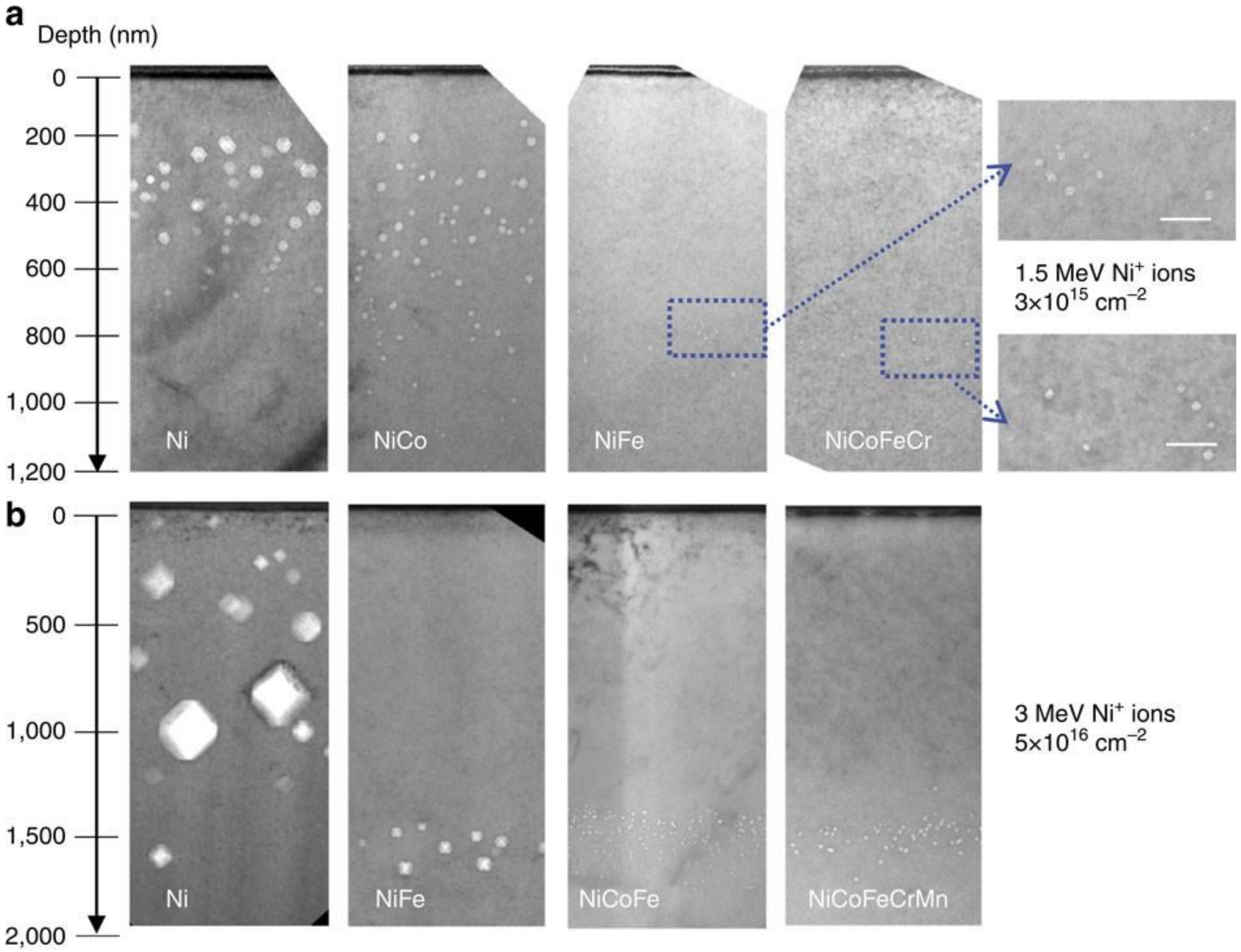
Disadvantages:
- Prone to defects and build failures
- Little control over physical properties

FeCoNiCrMn High Entropy Alloy

B. Cantor et. al. discovered the unique high entropy alloy (HEA) $Fe_{20}Co_{20}Ni_{20}Cr_{20}Mn_{20}$ in 2004.

- "High Entropy" due to high entropy of mixing[1]

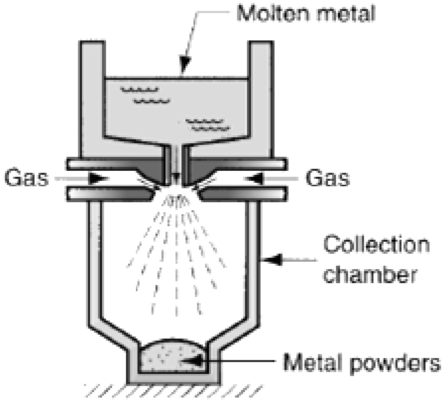
HEA's have good radiation resistance by mitigating void swelling[2]



1. B. Cantor, et. al., Microstrutural development in equiatomic multicomponent alloys, Materials Science and Engineering A, 2004
2. C. Liu, et. al., Enhancing radiation tolerance by controlling defect mobility and migration pathways in multicomponent single-phase alloys, Nature Communications, 2016

Select Laser Melting

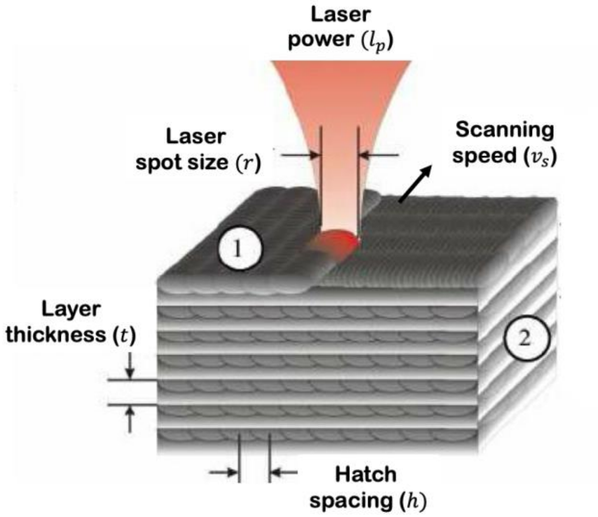
Gas atomization



Composition
Size & shape distribution

CAD (3D models)

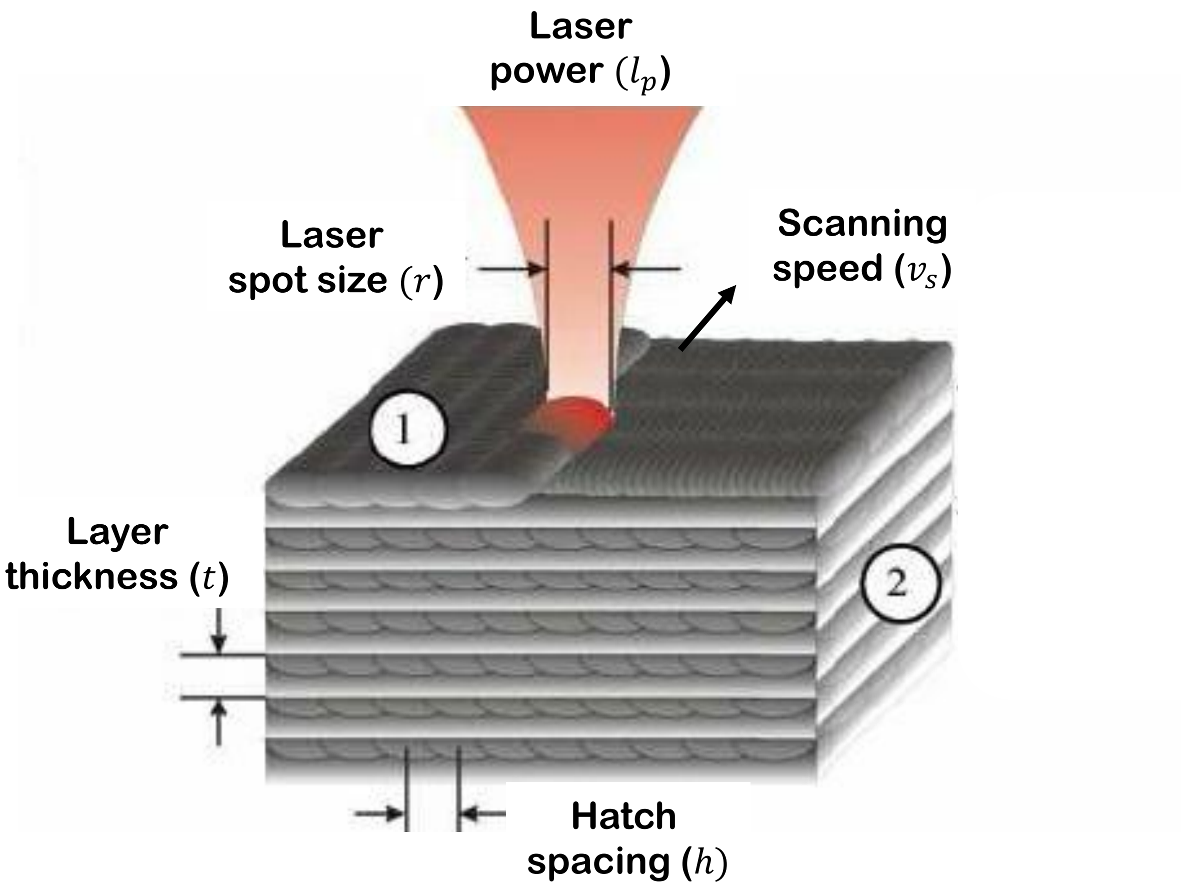
Powder Bed Fusion

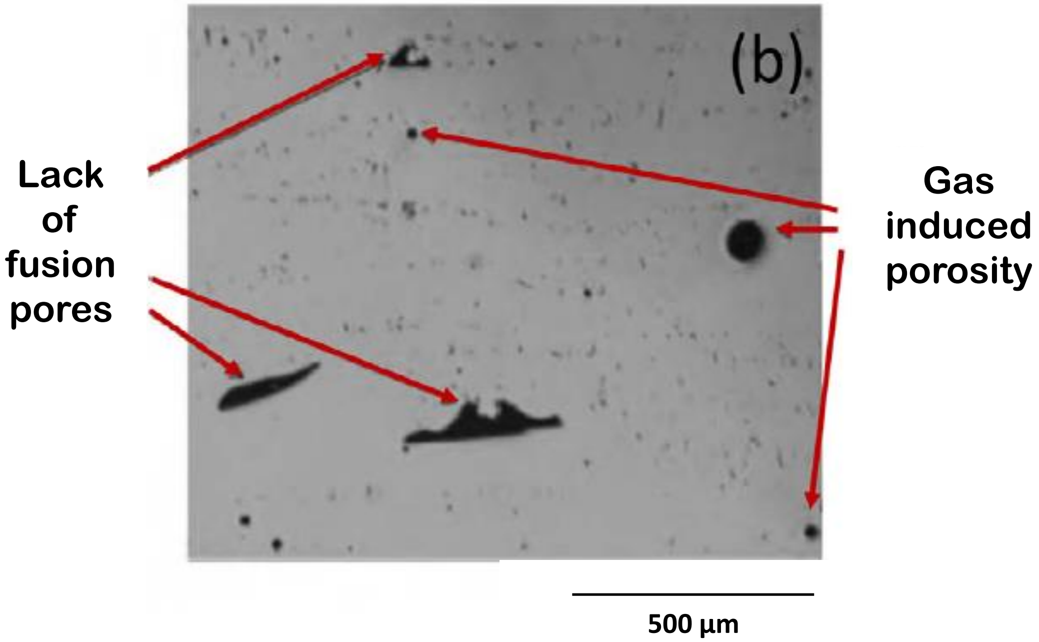


Processing Parameter Optimization
Solidification Conditions
In-situ Monitoring

As-printed components

Challenges in metal additive manufacturing





Volumetric Energy Density:

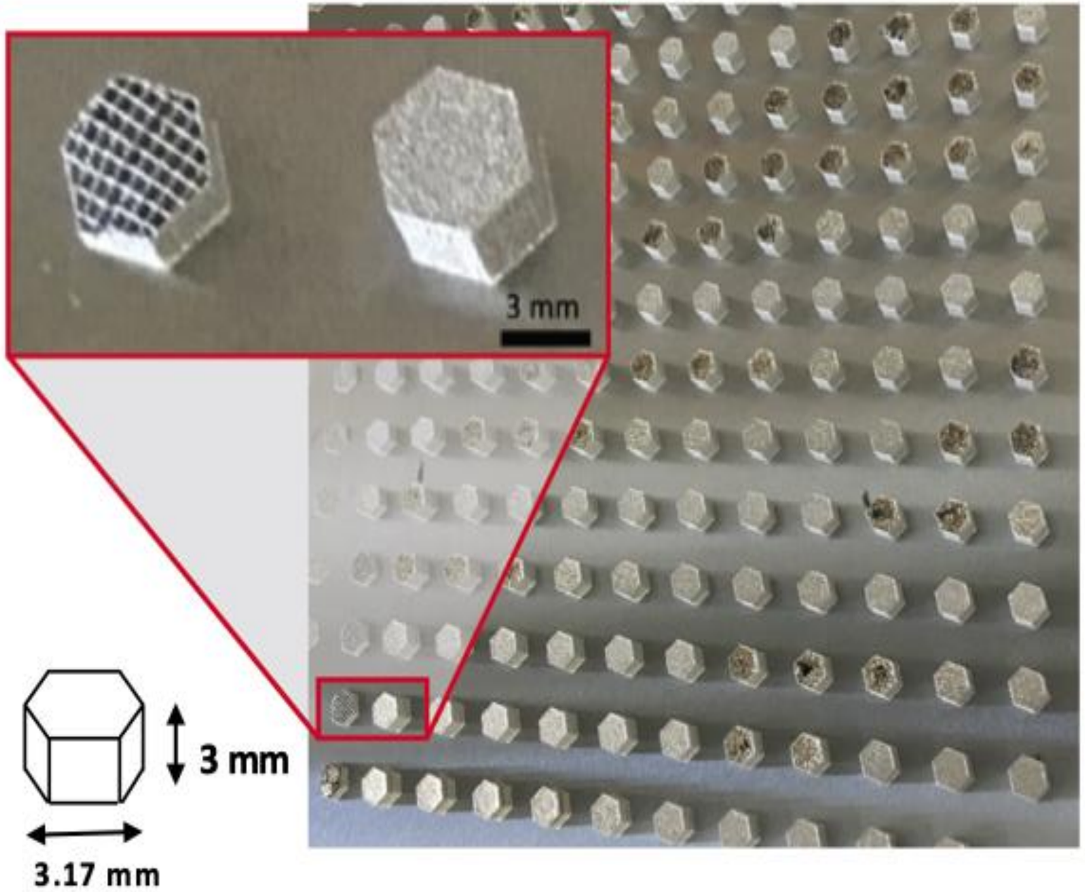
$$\mathrm{VED} = \frac{l_p}{v_s . h . t}$$

High Throughput Experiment

Day 1:
Print Samples

Day 2:
Remove support
Density measurement

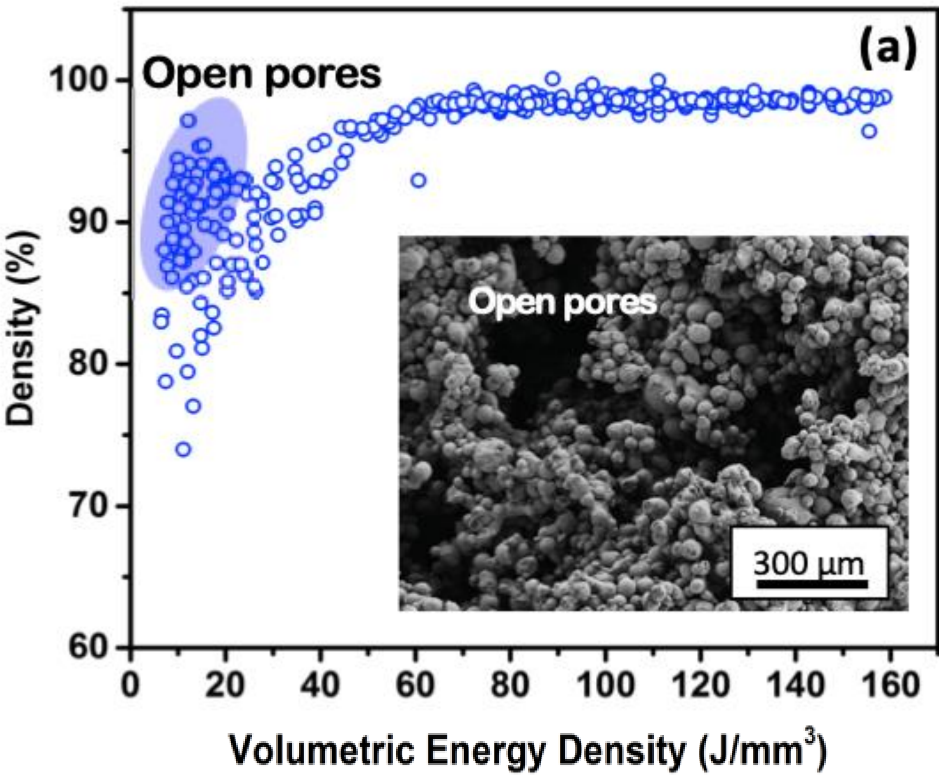
Day 3:
Hardness measurement

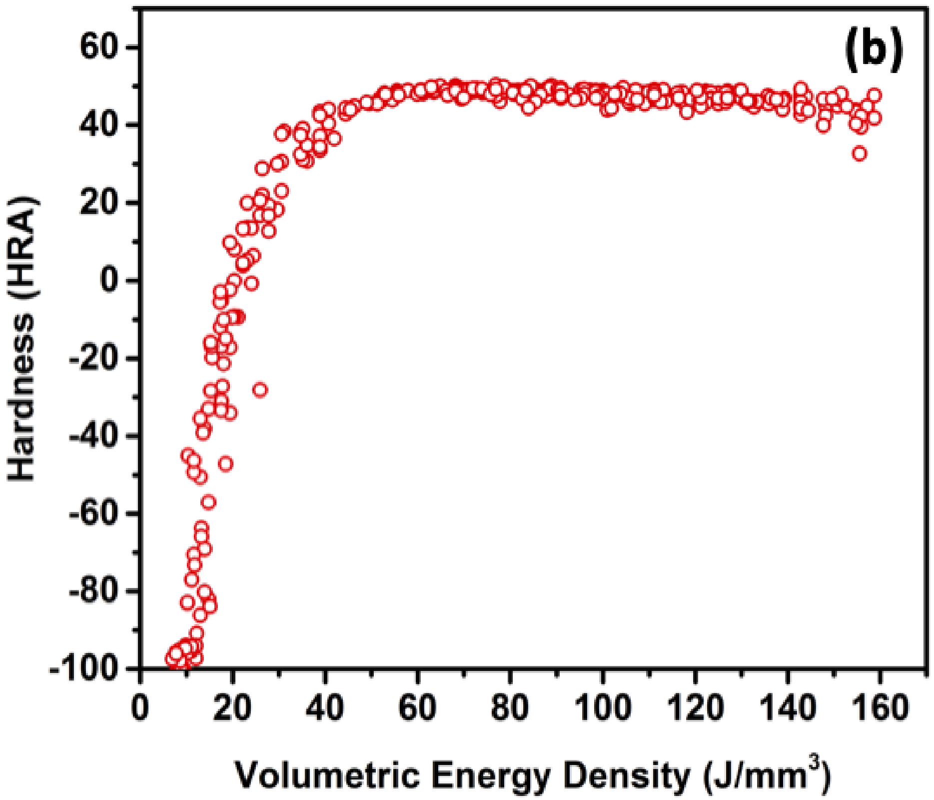


A.K. Agrawal, et. al., High throughput experimentation to produce processing maps and microstructural design in additively manufactured 316L stainless steel, Materials Science and Engineering A, 2020

asmangan@wisc.edu

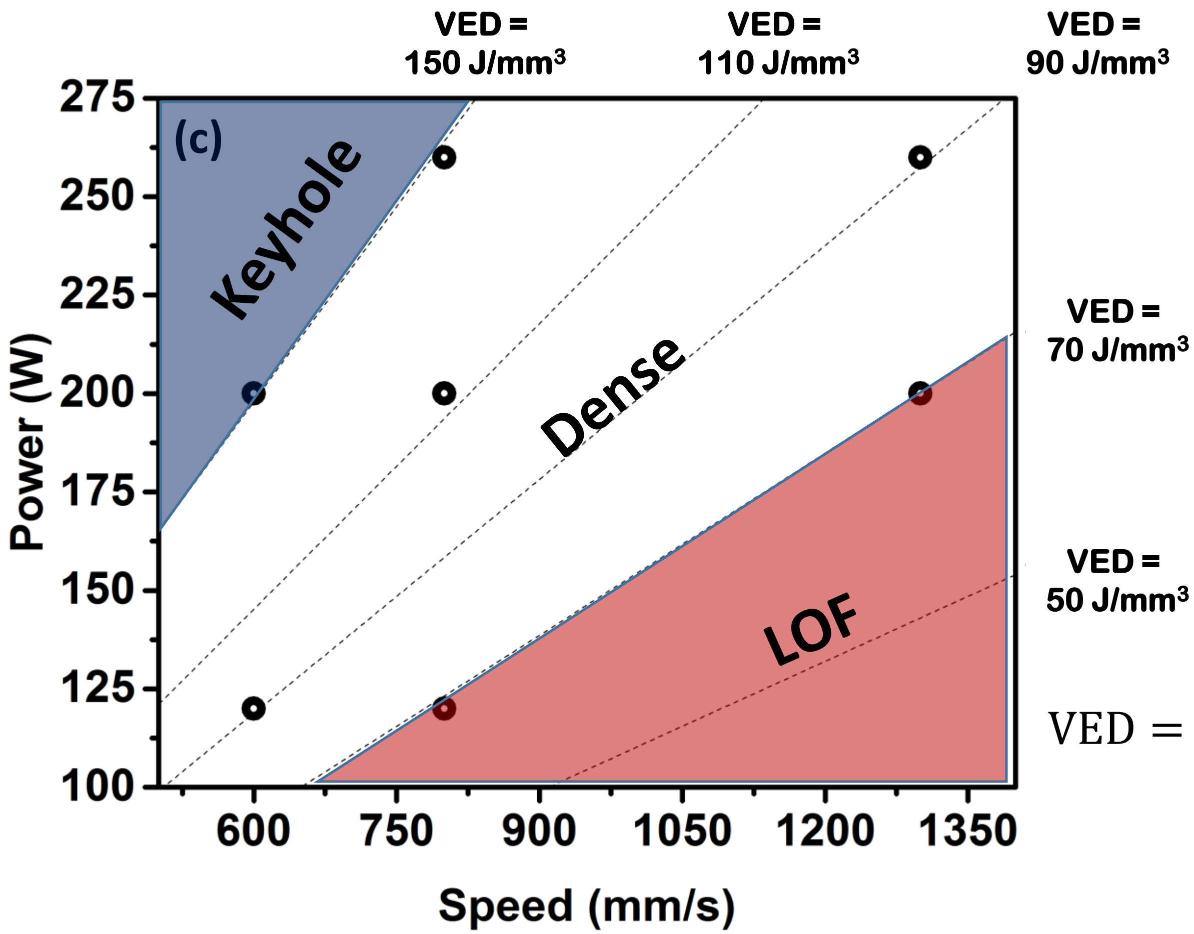
316L Stainless Steel Results



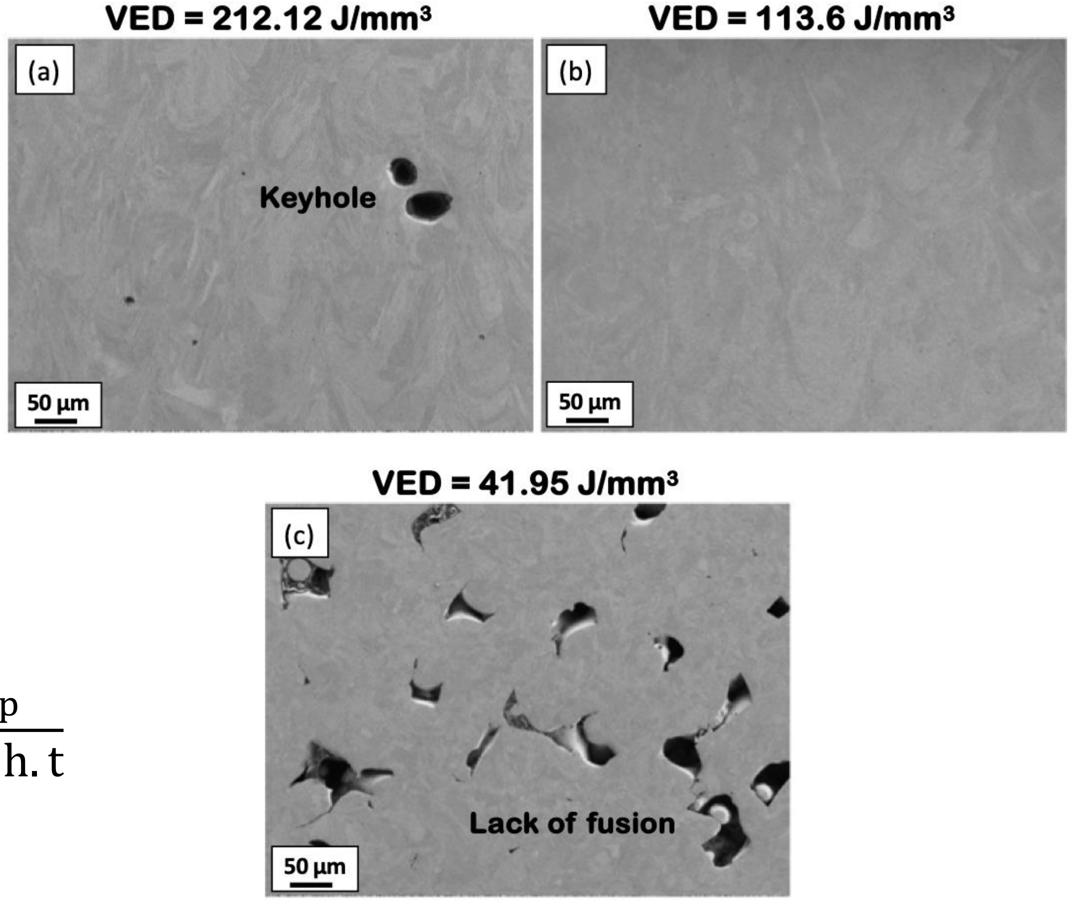


A.K. Agrawal, et. al., High throughput experimentation to produce processing maps and microstructural design in additively manufactured 316L stainless steel, Materials Science and Engineering A, 2020

316L Stainless Steel



$$VED = \frac{l_p}{v_s.h.t}$$



A.K. Agrawal, et. al., High throughput experimentation to produce processing maps and microstructural design in additively manufactured 316L stainless steel, Materials Science and Engineering A, 2020

FeCoNiCrMn HEA Results

This data has not been published.
Please contact Alec Mangan or Dan Thoma if you'd like to discuss the data.
asmangan@wisc.edu
dthoma@wisc.edu

Conclusion

High throughput experiments allow for quick identification of process maps for new materials

- Processing window for 316L and FeCoNiCrMn HEA is 70-150 J/mm3

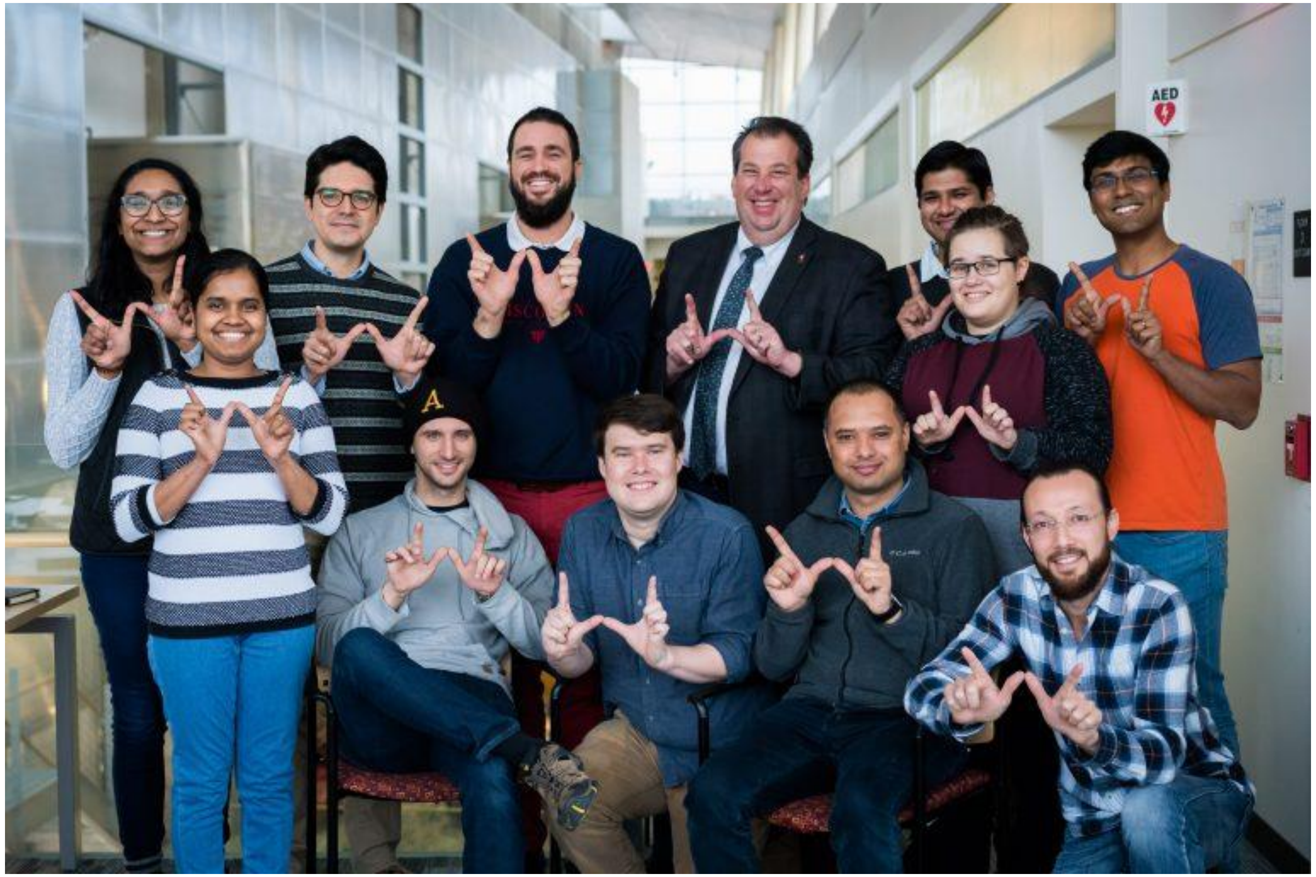
Density and Hardness of SLM parts are strongly dependent on Volumetric Energy Density

High throughput experiments can be used to test many processing parameters for a new material (as in FeCrNiCoMn high entropy alloy) at once

Alloy Design and Development Laboratory

Dan Thoma (PI)
Ankur Agrawal
Janine Erickson
Marcus Jackson
Celal Kursun
Alec Mangan
Michael Moorhead

Phalgun Nelaturu
Michael Niezgoda
Behzad Rankhoui
Brodan Richter
Subodh Subedi
Mythili Thevamaran
Tory Wendlandt



Acknowledgement

This material is based upon work supported by the Department of Energy/National Nuclear Security Administration under Award Number DE-NA0003921.

asmangan@wisc.edu