Fabrication and Performance of NiCuCoFeMn High Entropy Alloy Nanopastes for Brazing Inconel 718

Denzel Bridges[1], Samantha Lang[2], Curtis Hill[3], Anming Hu[1]

[1] Department of Mechanical, Aerospace, and Biomedical Engineering, University of Tennessee

[2] Department of Materials Science and Engineering, University of Tennessee

[3] Marshall Space Flight Center, NASA, Huntsville

Overview

- High entropy alloys (HEAs) are a class of metallic alloys consisting of 5+ elemental components and have four core effects:
  1. High mixing entropy
  2. Sluggish diffusion kinetics
  3. High lattice distortion
  4. Cocktail effect
- Boron-free, silicon-free brazing materials for nickel superalloys to avoid brittle intermetallic and eutectic phase formation
- Size-dependent melting point depression can eliminate the need for boron, silicon and other melting point depressants
- A Ni-Mn-Fe-Co-Cu HEA with low solidus and liquidus temperatures (1080 °C and 1150 °C) was developed
- Low solidus and liquidus temperatures of the HEA combined with the nanoscale melting point depression in this study
- Bulk HEA fabricated by induction melting of elemental powders
- HEA nanoparticles (NPs) fabricated by ball milling of the HEA micropowder
- Inconel 718 was laser brazed in air using the HEA and bulk and NP performances are compared

HEA Nanopaste Synthesis and Brazing

Table 1: HEA bulk concentration

Element	Concentration (at%)
Ni	20
Mn	35
Fe	5
Co	20
Cu	20

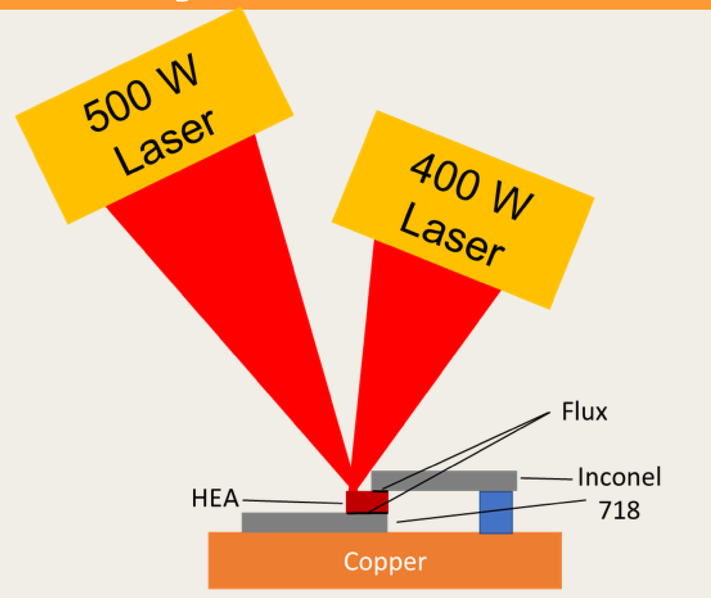

Figure 1: Laser Brazing schematic

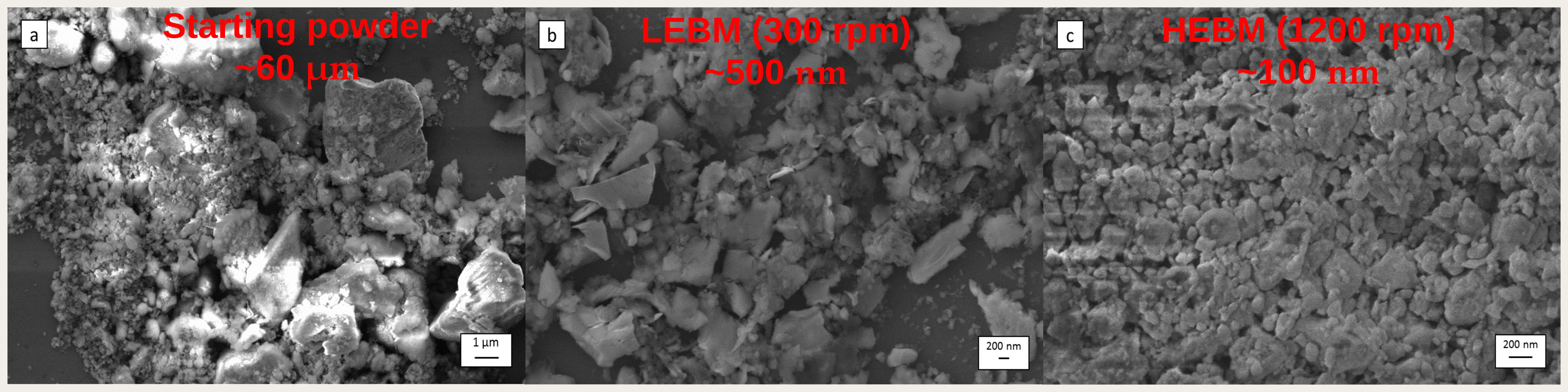

Figure 2: SEM of starting HEA micropowder and after 12 hours of low energy ball milling (LEBM) and 6 hours of high energy ball milling (HEBM). NPs were dispersed in terpineol for fabricating nanopaste

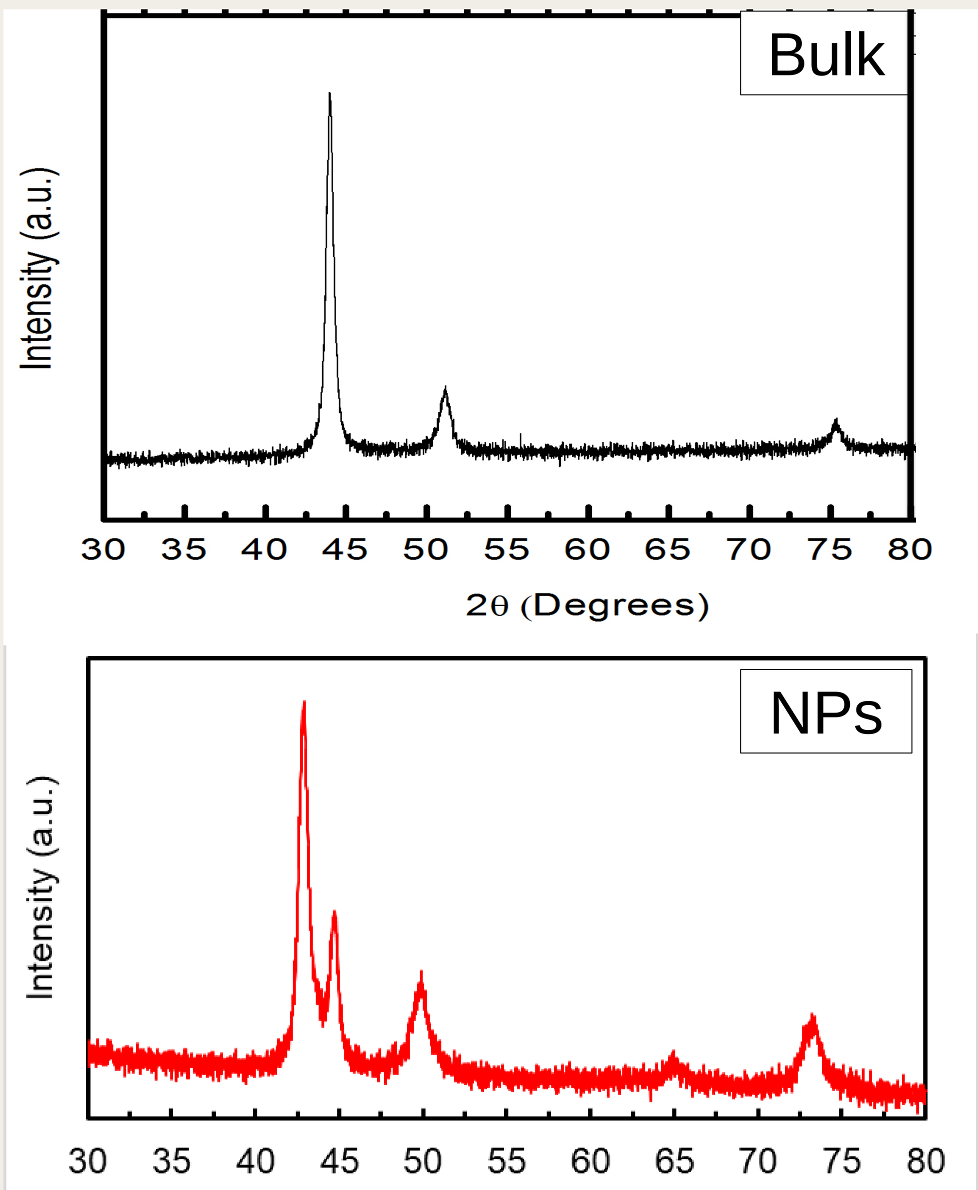

Figure 3: XRD of as-fabricated bulk HEA and HEA NPs

Elemental distribution

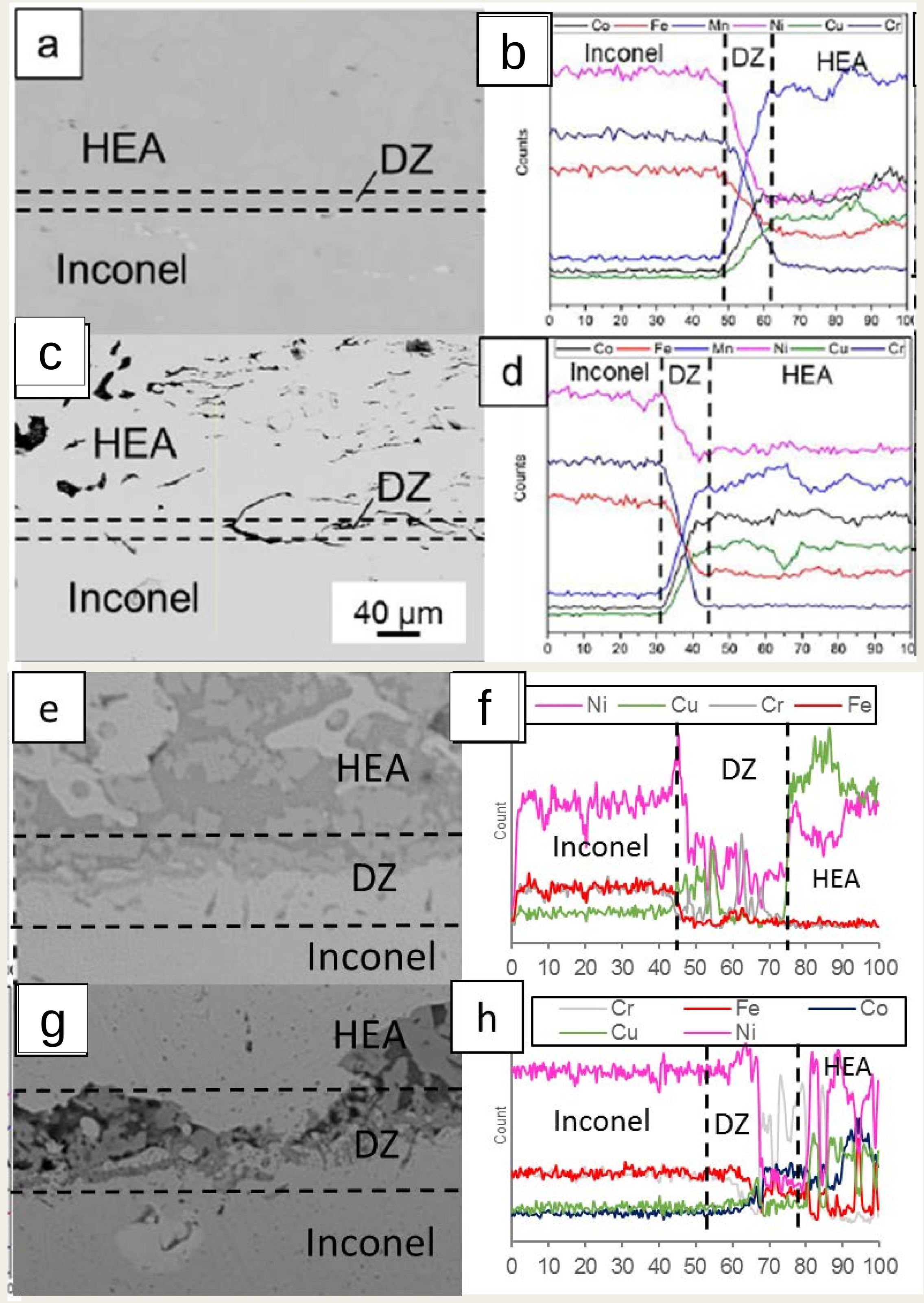

Figure 4: EDX line scan of HEA bulk (a-d) and NP (e-h) material at (a-b, e-f) 350 W and (c-d, g-h) 400 W laser power

Mechanical Properties

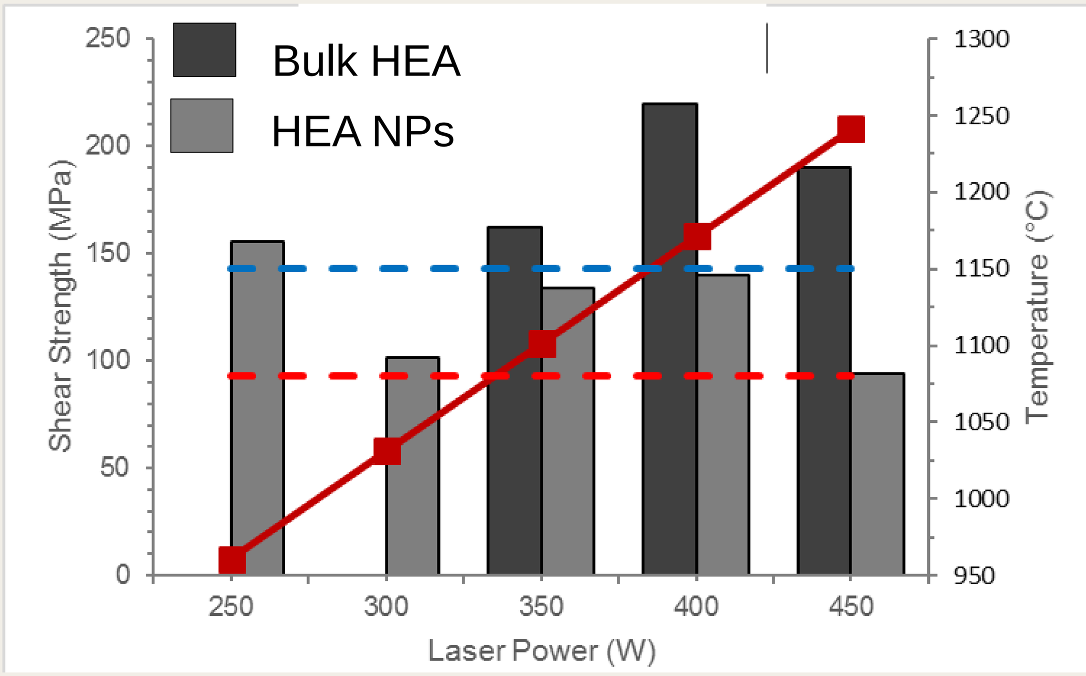

Figure 5: Shear strength of bulk HEA and NP joined Inconel 718

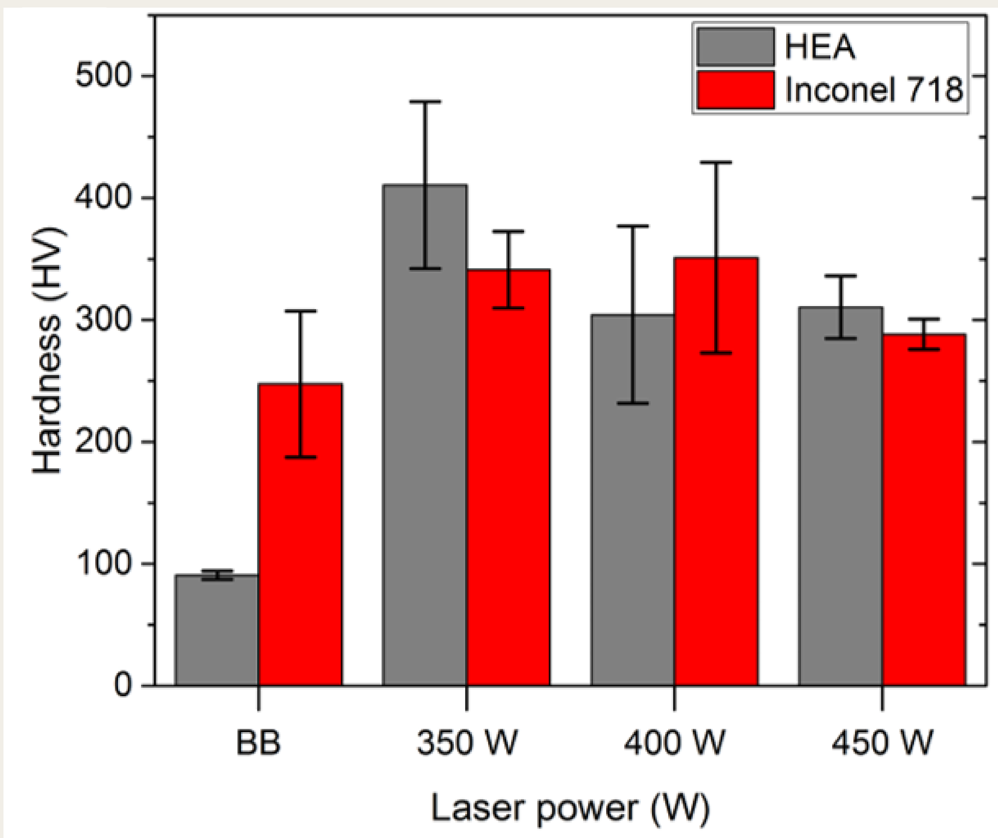

Figure 6: The average hardness of Inconel 718 and the bulk HEA before brazing (BB) and after brazing

Conclusions

- Phase separation observed in NP brazing material as-fabricated and post-brazing
- Brazing using bulk material up to 220 MPa
- Nanopaste brazing exhibits lower strength, but can be processed over 100 ° C lower than the bulk material
- Hardness of the bulk HEA significantly increases post-brazing
- **Future work directions**
  1. Optimize nanopaste formulation
  2. NP structure characterization
  3. HEA thermodynamic properties evaluation

References

[1] J.W. Yeh, S.K. Chen, S.J. Lin, J.Y. Gan, T.S. Chin, T.T. Shun, C.H. Tsau, S.Y. Chang, Adv. Eng. Mater., 6 (2004) 299-303.
[2] M.-H. Tsai, Entropy, 18 (2016) 252.
[3] N.P. Gurao, K. Biswas, J. Alloys Compd., 697 (2016) 434-442.
[4] M. Gao, Z. Yu, S. Liu, M. Kaufman, unpublished, 2017.
[5] D. Bridges, S. Zhang, S. Lang, M. Gao, Z. Yu, Z. Feng, A. Hu, Mater. Lett. (2017)
[6] X. Ye, X. Hua, M. Wang, S. Lou, J. Mater. Process. Technol., 222 (2015) 381-390.
[7] D. Bridges, C. Ma, Z. Palmer, S. Wang, R.-Z. Li, Z. Feng, A. Hu, J. Mater. Process. Technol. (2017).
[8] S. Wang, Entropy 2013, 15, 5536-5548.

THE UNIVERSITY OF TENNESSEE KNOXVILLE

This project is jointly supported by a seed grant from Oak Ridge National Laboratory and the Institute of Public Service, University of Tennessee through the I/UCRC project of the National Science Foundation. Thank you to John Dunlap, Maulik Patel, Zane Palmer, and Chris Wetteland for use of their electron microscopy and EDS equipment.

NASA