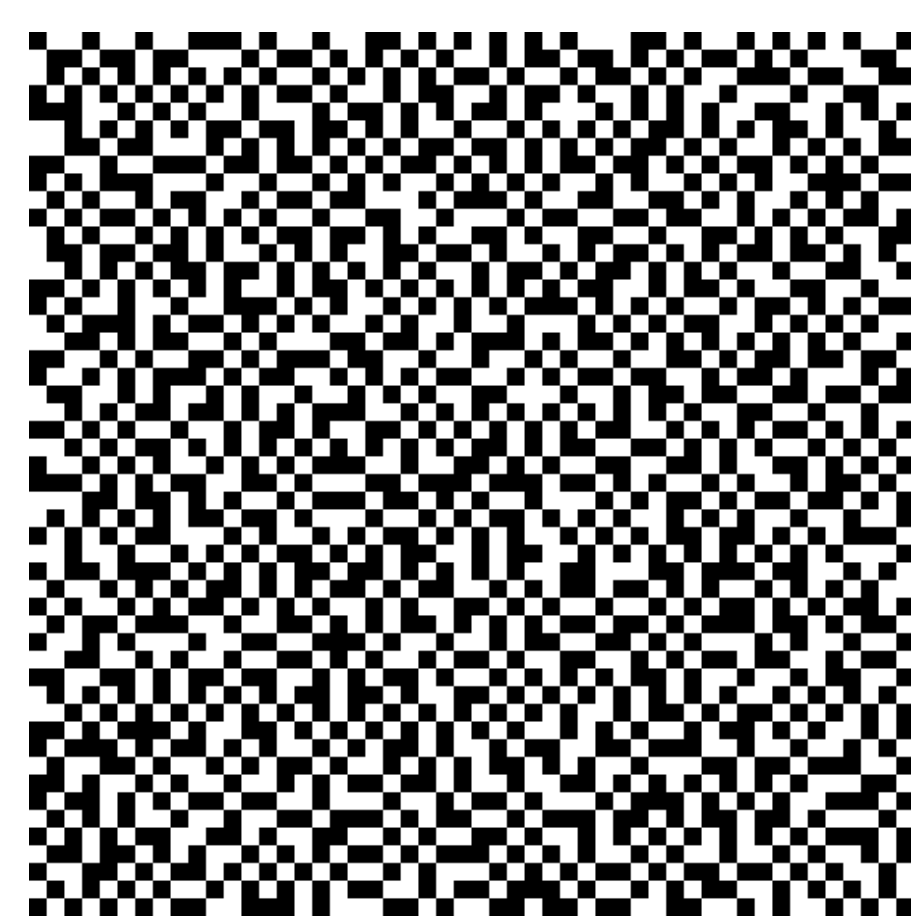


## Abstract

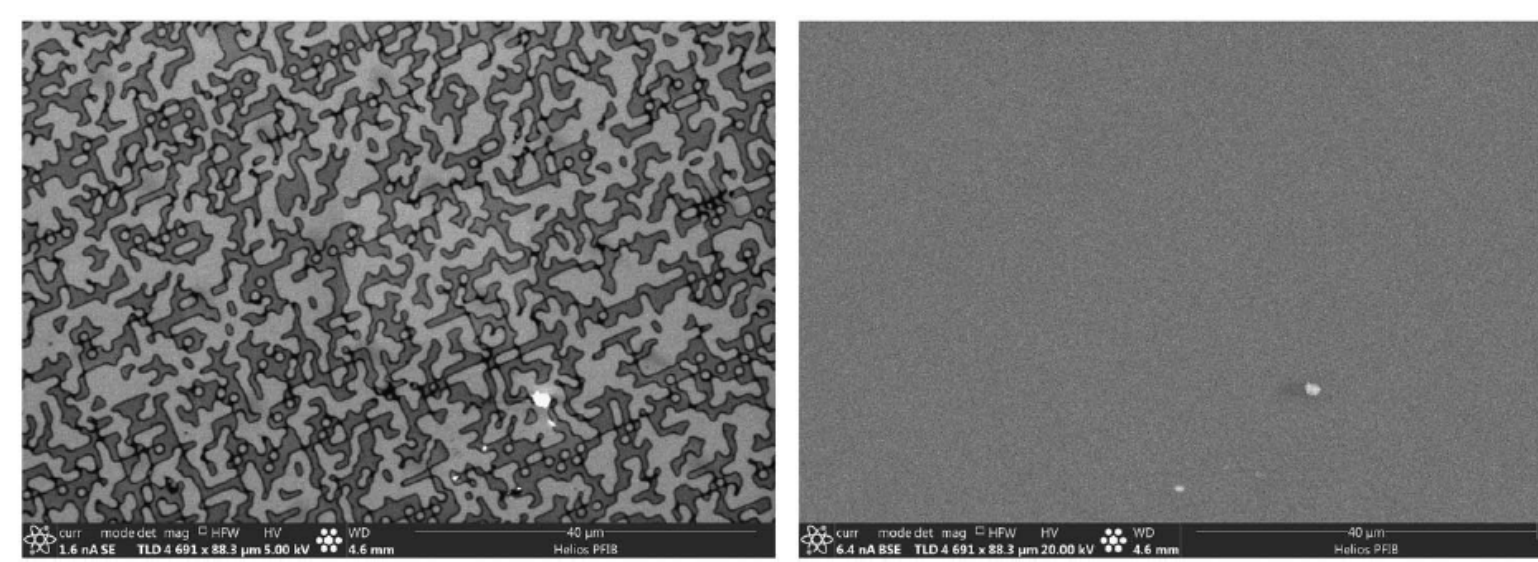
For this project, an inked rubber stamp was applied to a small Inconel 625 specimen. The stamp transferred a thin pattern with microscale features for digital image correlation (DIC). The pattern is easily visible at lower voltages and thin enough to not obstruct backscattered electrons. The unique characteristics of the pattern enabled the concurrent acquisition of DIC and high-resolution electron backscatter diffraction (HR-EBSD) data while the specimen was loaded in-situ. The challenges of in-situ testing and combining EBSD with DIC measurements are discussed. By combining the elastic strains (from HR-EBSD) and total strains (from DIC) the result of this approach is an estimate of stress-strain behavior at points across the specimen surface. This combined dataset can then be used as higher-fidelity data in the calibration of crystal plasticity models.

## Background

- This project continues the methods of coupling digital image correlation (DIC) and high angular resolution electron backscatter diffraction (HR-EBSD) methods to characterize the role of microstructure on the deformation of polycrystalline materials by uncoupling contributions by elastic deformation gradients, slip, and rigid body rotations from the total deformation gradient [1,2]
- Typical methods of applying DIC patterns to a material are unsuitable for this method to be applied over a coincident domain for several reasons
  - Cover up important details, i.e., fatigue crack initiation
  - Prevent accurate collection of diffraction patterns via EBSD
- Micro speckle stamps can be created using urethane rubber, which exhibits the selectively electron-transparent behavior desired [3,4]
- The proposed methods allow for the design of speckle patterns for use as master patterns, removing the randomness of typical methods and allowing important characteristics of DIC patterns to now become design parameters while optimizing for accuracy and precision [5]



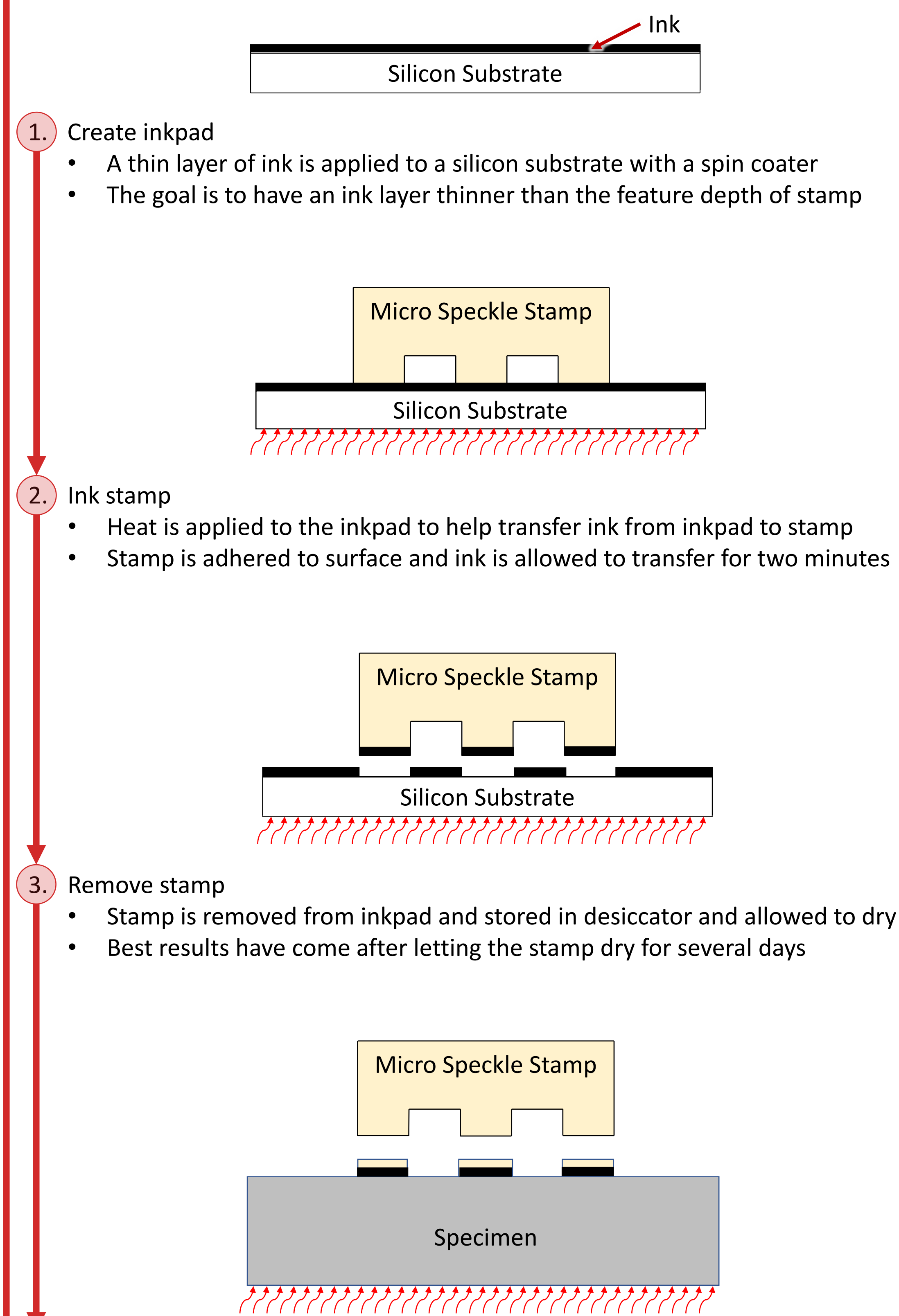
Example image of optimized DIC pattern used to create micro speckle stamps [5]



Comparison of ROI imaged a) using a secondary electron detector at 5 kV and 1.6 nA and b) backscatter electron detector at 20 kV and 6.4 nA [3]

## Methods

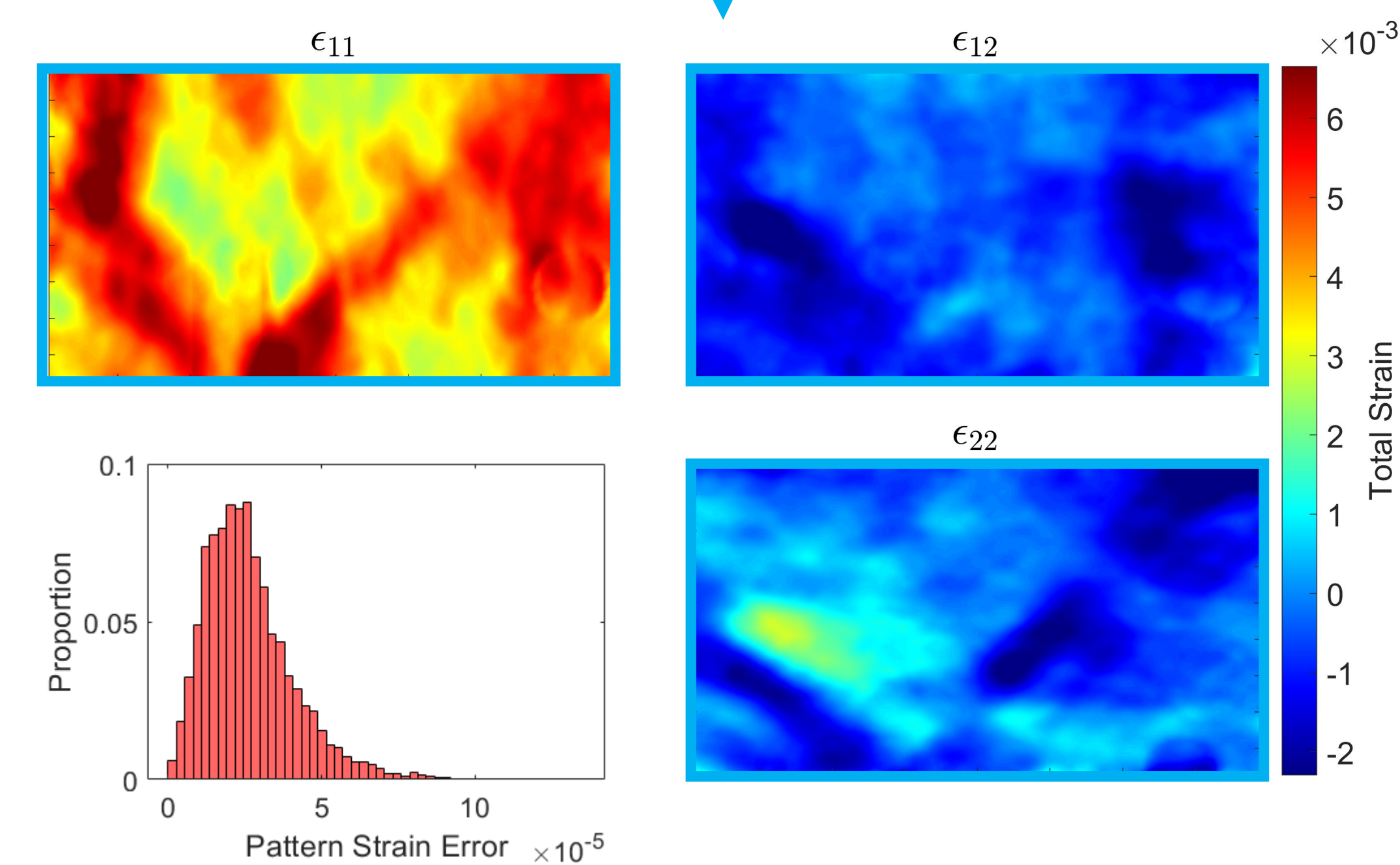
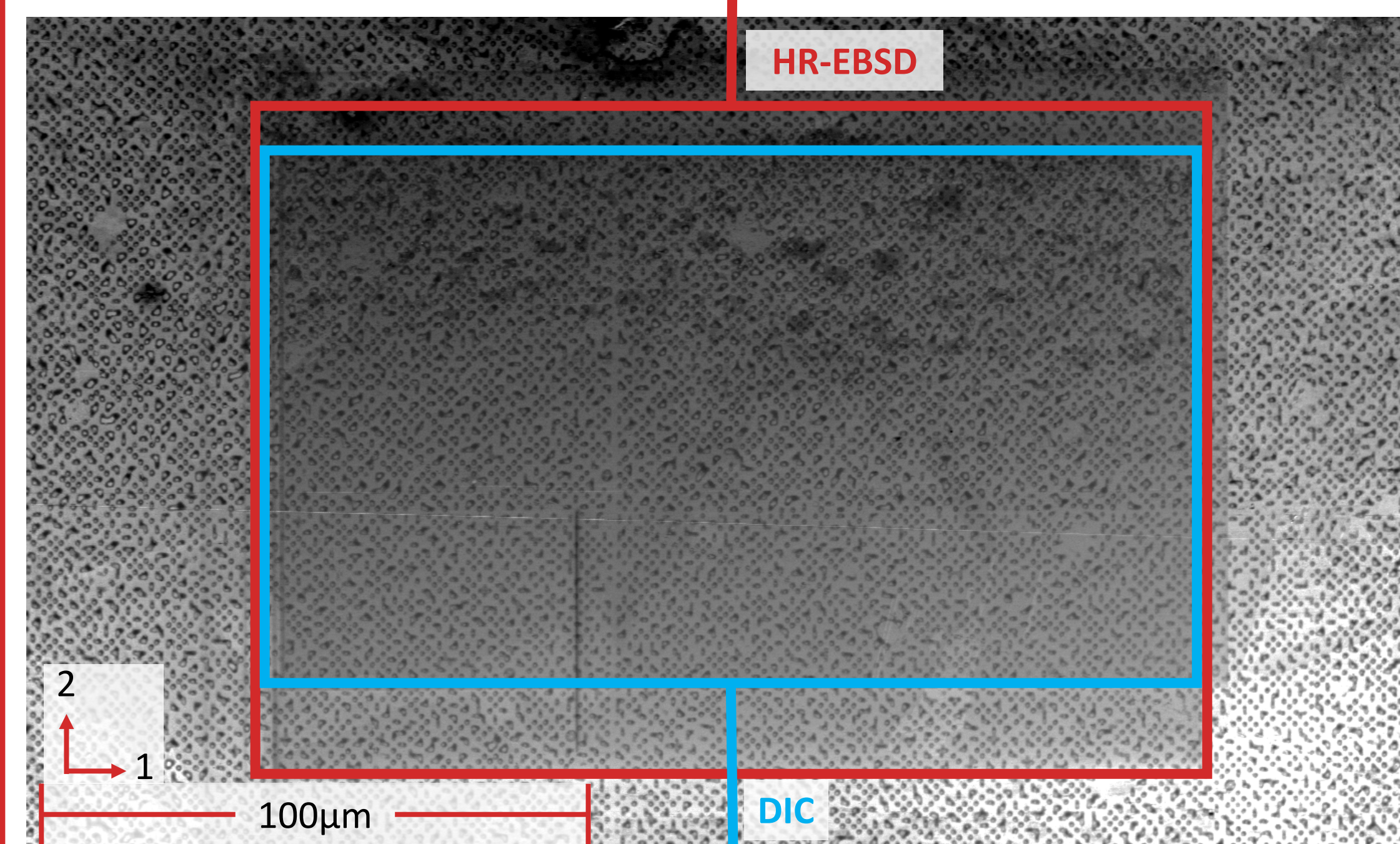
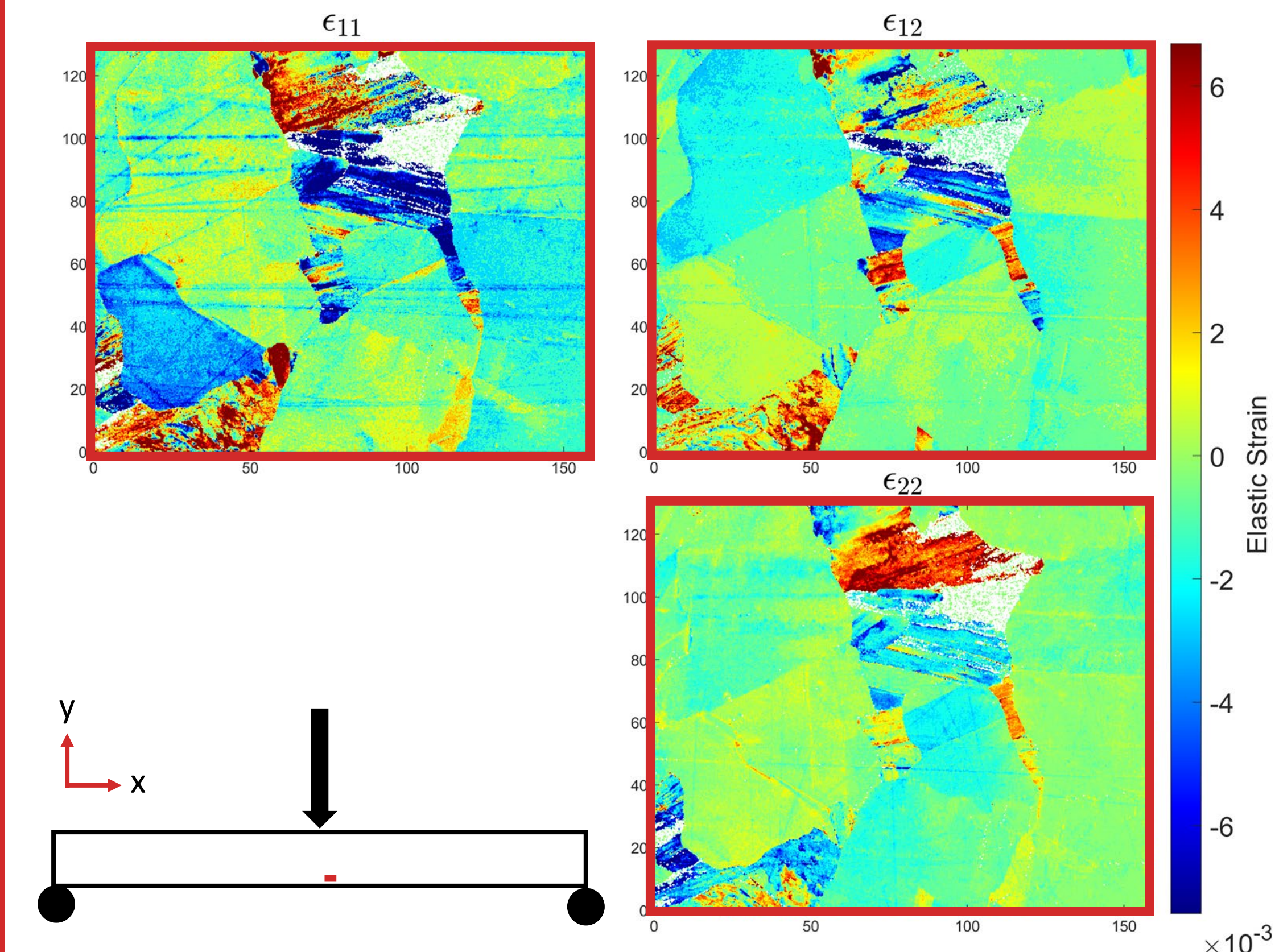
- Addition of ink to the residual layer method allowing for easier reproduction of DIC pattern and enabling the use of optical techniques [3]
- Master pattern designed to have even split of light and dark features, average speckle size of  $1\mu\text{m}$ , and rounded features to prevent the joining of features



- After stamping the specimen is placed in a three-point bending fixture mounted to the stage of SEM
- DIC reference and calibration images are collected, and the specimen is deformed
- DIC images are collected for the deformed configuration
- SEM stage is rotated, EBSD camera inserted, and data is collected
- Perform data analysis

## Results

- Data collected from an additive manufacture Inconel 625 specimen using the FEI Teneo SEM and EDAX Velocity Super EBSD Camera
- DIC images processed with open-source software Ncorr [6]
- HR-EBSD data processed offline with the open-source software OpenXY [7]



## Conclusion

- Micro speckle stamps allow for easily repeatable, selectively electron-transparent DIC patterns to be applied to a surface
- Use of the stamp allows for easier replication and use of the ink, when compared to just urethane transfer, enables the method to be used with optical techniques
- Optimized, computer-generated speckle patterns enable important characteristics to become design parameters, increasing accuracy and precision while eliminating randomness of traditional DIC pattern methods
- The proposed method has the capability to collect DIC and HR-EBSD data over a coincident domain
- Results will allow further characterization and understanding of the role of microstructure on deformation of materials

## Future Work

- Work to understand and minimize possible carbon contamination resulting from the application of DIC pattern
- Register DIC and HR-EBSD data to allow each data point to be used for uncertainty quantification and calibration of crystal plasticity models [2]
- Extending mechanical testing to include fatigue testing to expand understanding of crack initiation

## Acknowledgements and References

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Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

Micro speckle stamps are created by 1900 Engineering LLC. Information is available at [researchmicrospeckle.com](http://researchmicrospeckle.com).

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