Effect of High Velocity Impact On Grain Structure of A36 Steel

by

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Background

- A-36 Steel is one of the standard steel alloys that has many global applications, there is little known about the effect of high velocity impact on the crystalline structure and material phase.
- The physical characteristics and molecular structure under static conditions of A-36 steel are well known.

Objectives

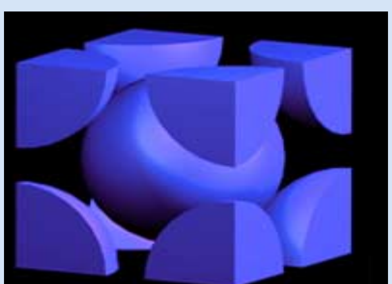
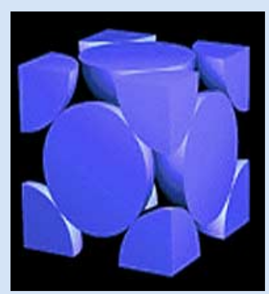
- Effect of high velocity impact on grain structure and properties on A-36 Steel is being studied in this research.
- The primary measure of the impact effect is the comparative metallic crystalline structure composition in a variety of locations relative to the impact crater.
- Another measure is surface hardness change due to impact at near and far locations relative to impact crater.
- The objective of this work is to:
  - investigate the permanent phase change on a standardized size A-36 steel plate due to several high velocity impacts.
  - measure and quantify observations at different relative locations from impact crater.

Outline

- INTRODUCTION
- DESIGN OF EXPERIMENT
- MEASUREMENT AND INSPECTION DEVICES
- INSPECTION OF TEST RESULTS
- CONCLUSION
- RECOMMENDATIONS AND FUTURE WORK

Metallic Crystalline Structures (BCC, FCC, HCP)

- Out of the 14 different types of crystal unit cell structures lattices that exist in nature, metals and many solids have unit cell structures described as in 3 categories:

Body Center Cubic (BCC)	**Face Centered Cubic (FCC)**	**Hexagonal Close Packed (HCP)**
		

Material Characteristics

Chemical Composition

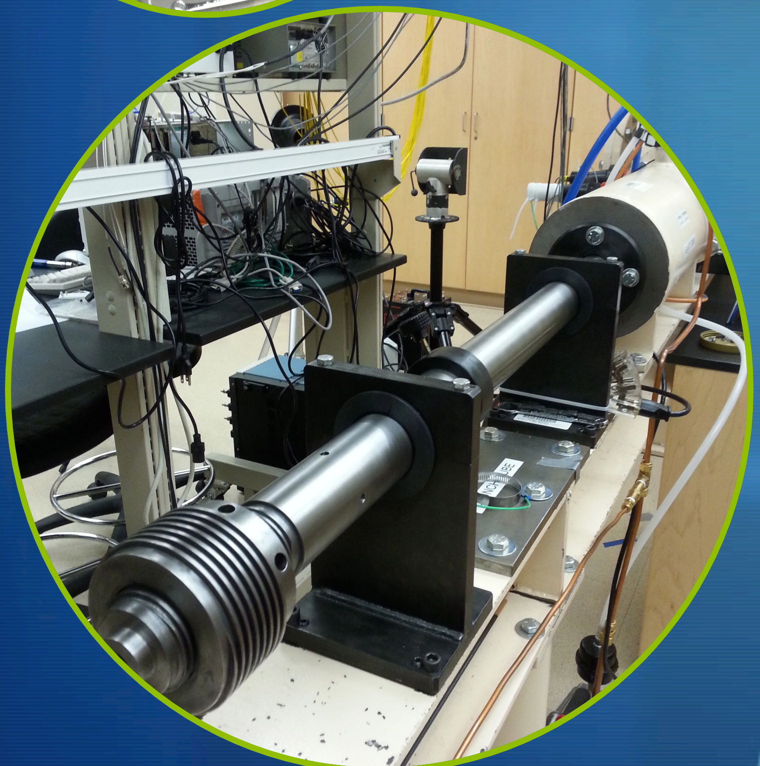
Element	Content
Carbon, C	0.25 - 0.290 %
Copper, Cu	0.20 %
Iron, Fe	98.0 %
Manganese, Mn	1.03 %
Phosphorous, P	0.040 %
Silicon, Si	0.280 %
Sulfur, S	0.050 %

Physical Properties

Physical Properties	Metric	Imperial
Density	7.85 g/cm^3	0.284 lb/in^3

Mechanical Properties

Mechanical Properties	Metric	Imperial
Tensile Strength, Ultimate	400 - 550 MPa	58000 - 79800 psi
Tensile Strength, Yield	250 MPa	36300 psi
Elongation at Break (in 200 mm)	20.0 %	20.0 %
Elongation at Break (in 50 mm)	23.0 %	23.0 %
Modulus of Elasticity	200 GPa	29000 ksi
Bulk Modulus (typical for steel)	140 GPa	20300 ksi
Poissons Ratio	0.260	0.260
Shear Modulus	79.3 GPa	11500 ksi



Design of Experiment

- Damage caused by projectile impact is simulated, in order to design a better protective structures.
- Computational analysis tools are used for accurate simulations.
- A phase change in steel during the impact will cause a change in the material properties.
- Conclusive evidence is needed to determine if this phase change occurs for A-36 steel so that correct material properties can be used in simulations.

Gas Gun Experimental Procedure

The 2-stage light gas gun uses a powder breech to fire a plastic piston into a pump tube filled with helium or hydrogen. The light gas is compressed as the piston moves through the pump tube. A petal valve separates the light gas from the launch tube, which is under vacuum. The petal valve ruptures from the compressed gas causing the projectile to rapidly accelerate down the launch tube and into the containment tank where it will impact the target. These experiments are designed so that the projectile causes severe damage to the target but does not penetrate all the way through. A successful experiment will leave the target plate with a large crater in the front and a smooth bump in the back.

Test Equipment, Preparation, and Logistics

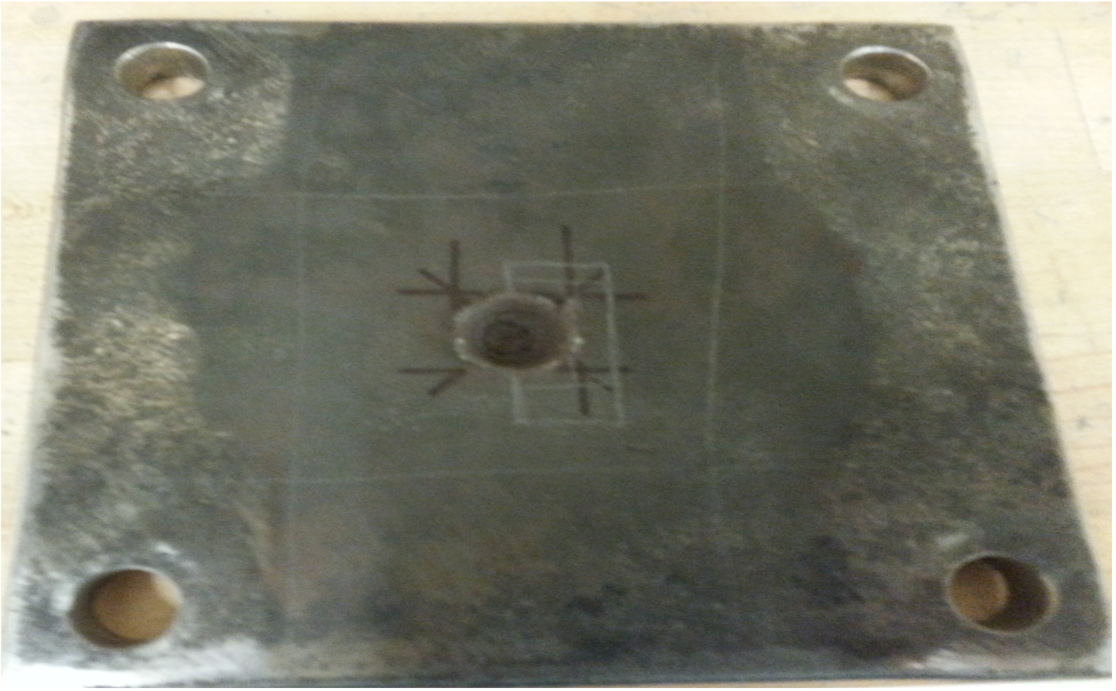
- Test Sample Description
  - 15.4 x 15.4 cm A36 steel plates of 1.27 cm thickness are impacted
- Test Preparation
- Preparing Impacted Sample For Inspection

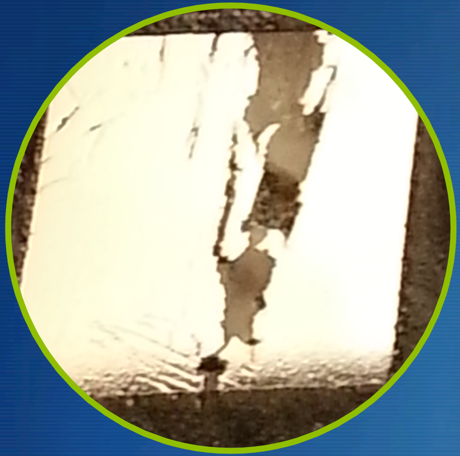
Test Preparation

- The target material is subject to high pressure and temperature over a very short period of time.
- The impacting momentum range is at velocities between 3 km/sec and 6 km/sec.
- The damage zone develops in the target within 5 microseconds. Some steel materials go through a reversible phase change when subject to elevated temperature and high quasi-static pressure. It is unknown whether A-36 steel experiences this phase change during high velocity impact.

Impacted Test Sample

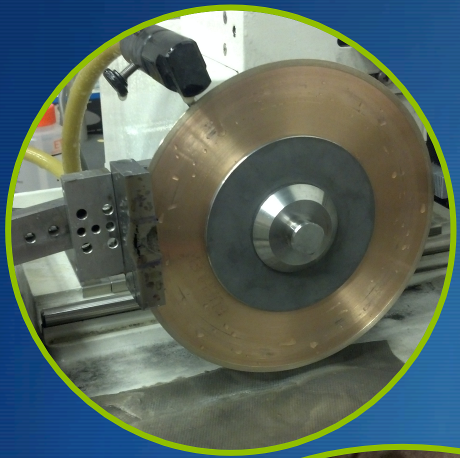
Impacted Plate at 4.509 km/sec





Impacted Sample Preparation Procedure for Electron Back Scatter Diffraction (EBSD)

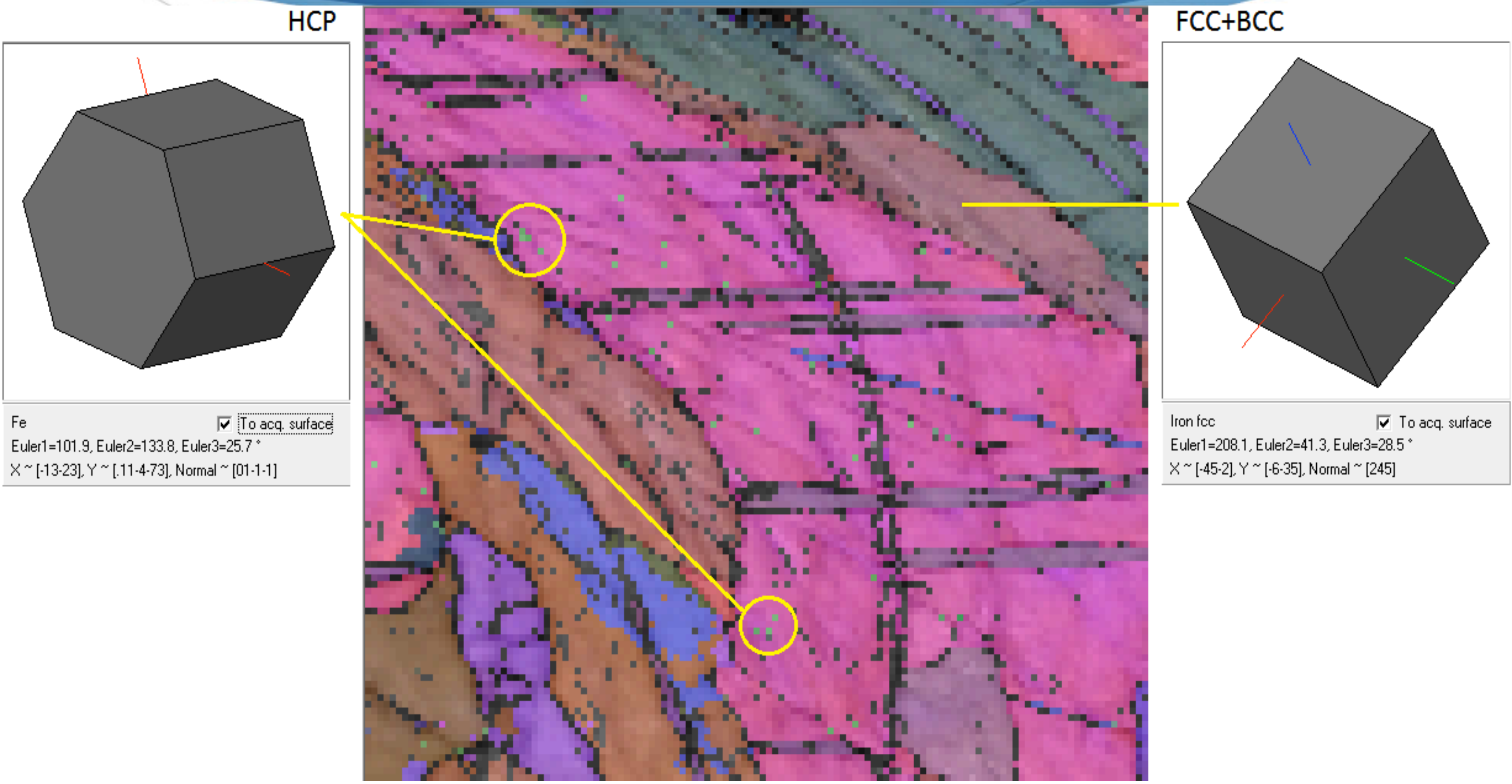
- The surface of the impacted plates are prepared for inspection by Electron Back Scatter Diffraction (EBSD) microscope. Ten regions on each impacted plate area are examined.
- Each region is approximately 90x90 square microns. These regions are distributed from the area immediately under impact crater to locations that are not physically affected by the impact.



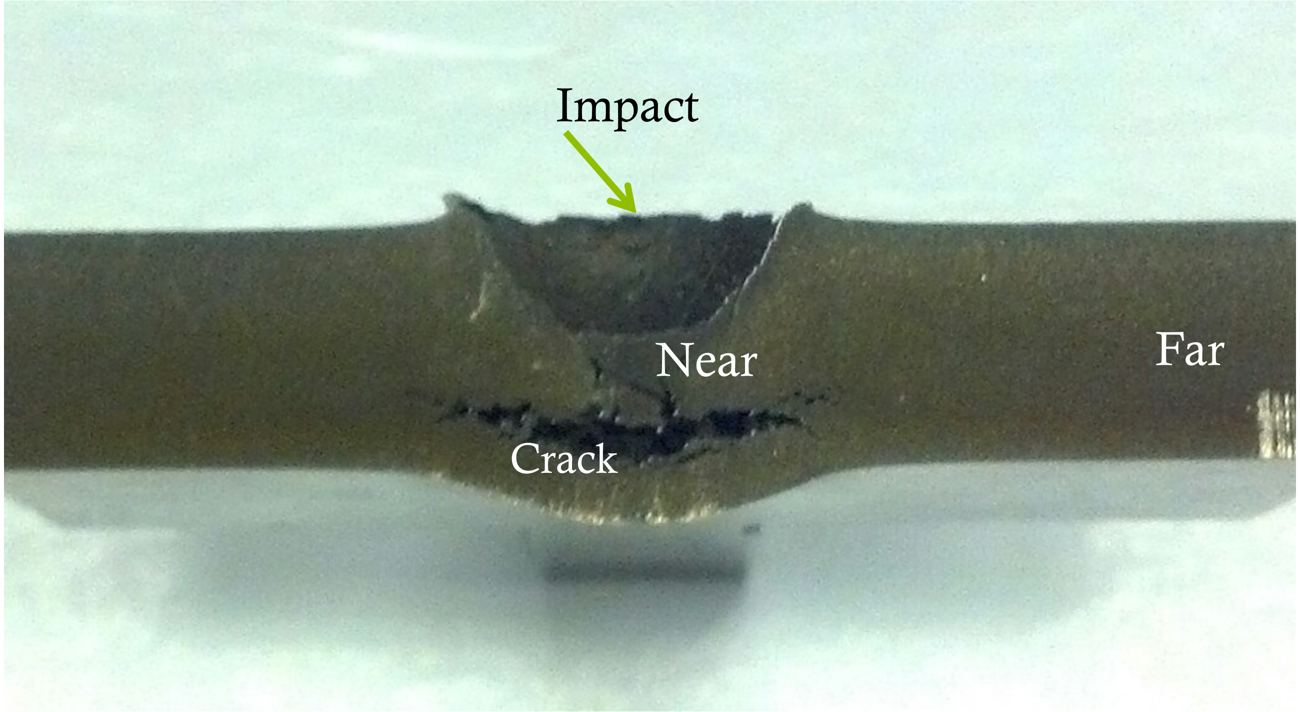
Sample Preparation Procedure for Electron Back Scatter Diffraction (EBSD)

- Cut sections from target plate
- Mechanical polishing
- Electro-polishing
- Chemical etching
- Ion beam milling / Ion etching
- Coating
- Sample storage

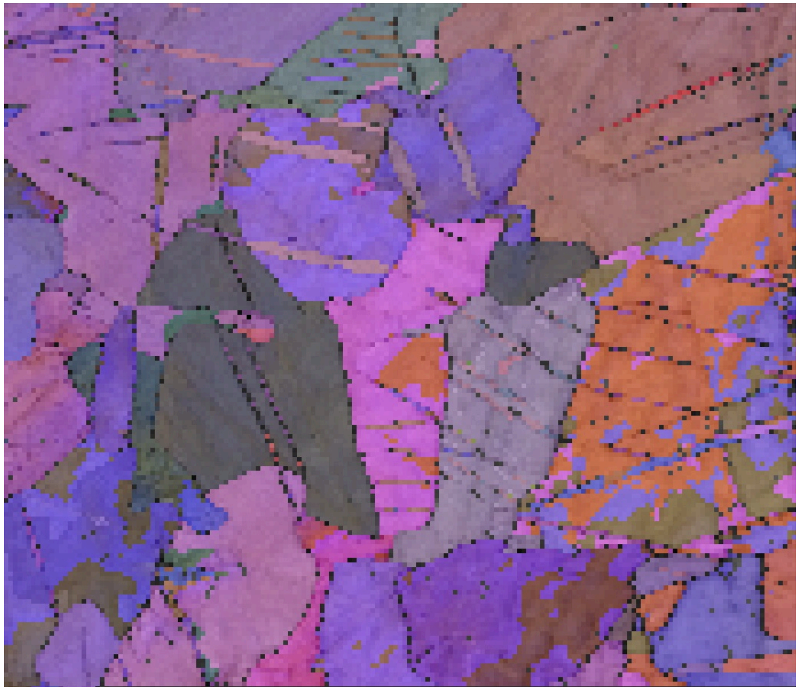
Results


HCP
Fe
To acq. surface
Euler1=101.9, Euler2=133.8, Euler3=25.7 °
X ~ [-13-23], Y ~ [.11-4-73], Normal ~ [01-1-1]
FCC+BCC
Iron fcc
To acq. surface
Euler1=208.1, Euler2=41.3, Euler3=28.5 °
X ~ [-45-2], Y ~ [-6-35], Normal ~ [245]

A-36 Steel at 5.8 km/sec Impact Speed

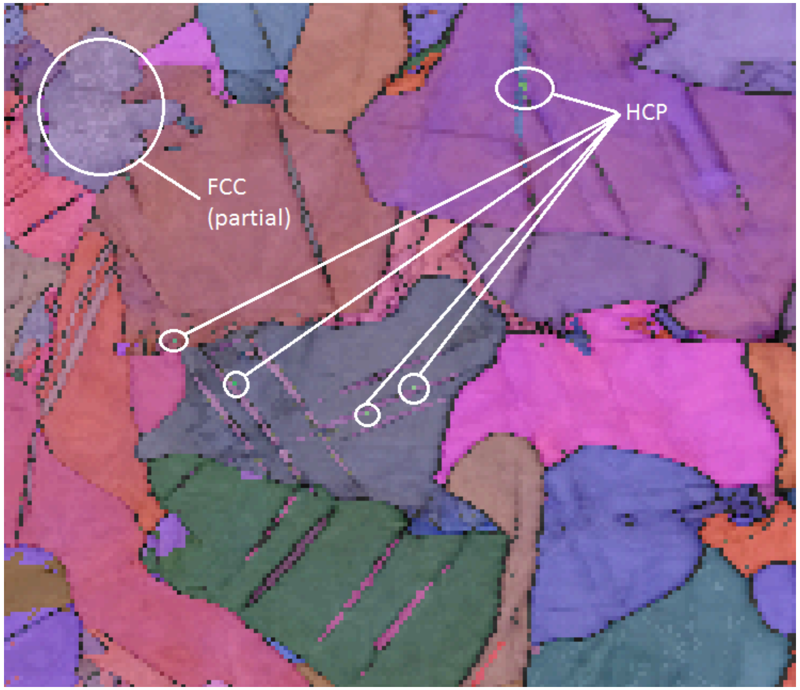


Phase of Impact Area at 4.509 km/sec far from Impact



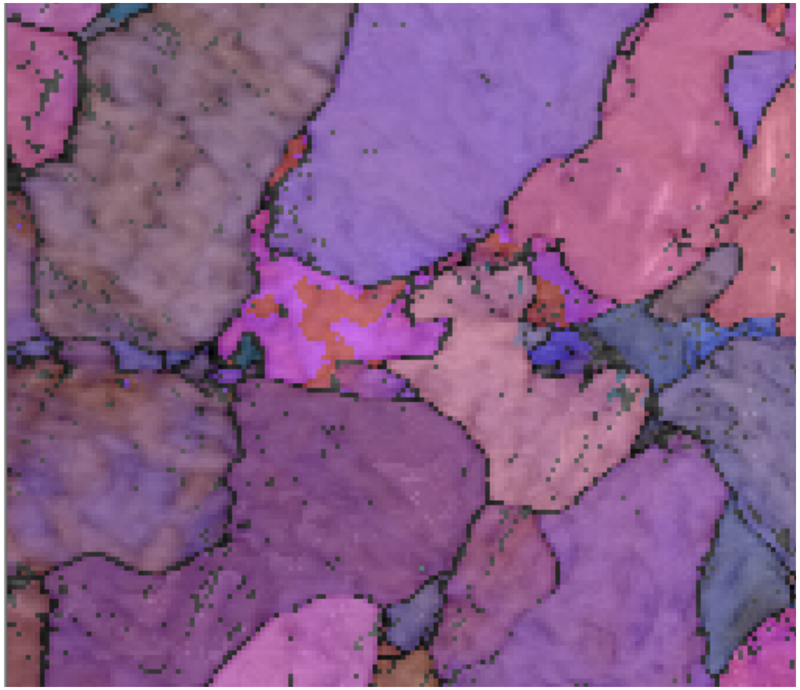
Phase	Impact (far) At 4.509Km/sec
BCC	99.22%
FCC	0.7120%
HCP	0.07152%

Impact Area at 4.509 km/sec Near Impact



Phase	Impact (center) At 4.509Km/sec
BCC	96.68%
FCC	2.874%
HCP	0.439%

Non-Impact Area

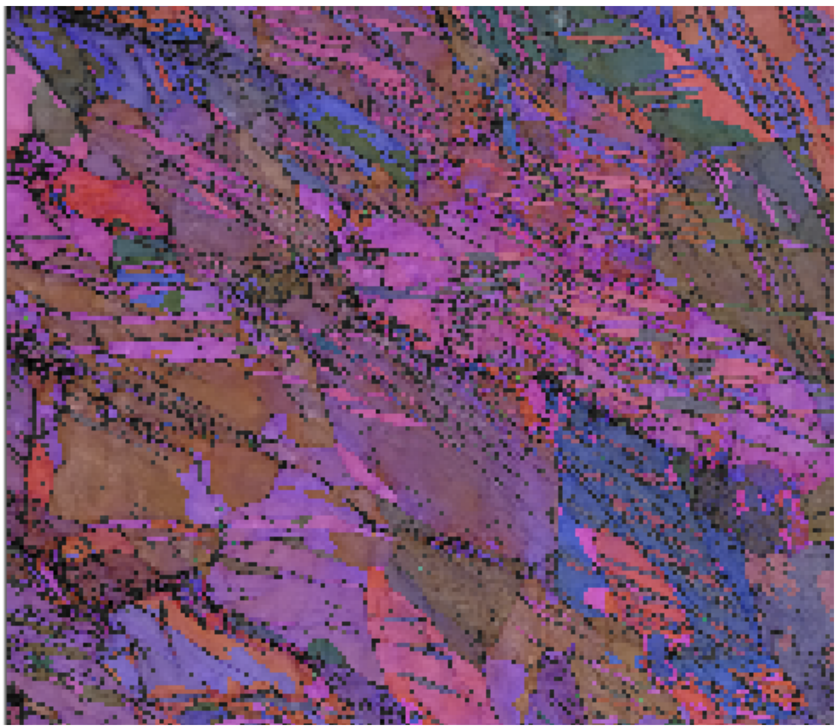


Phase	Non-Impact
BCC	99.96%
FCC	0.09%
HCP	0%

Table of Results at 4.509 km/sec Speed of Impact

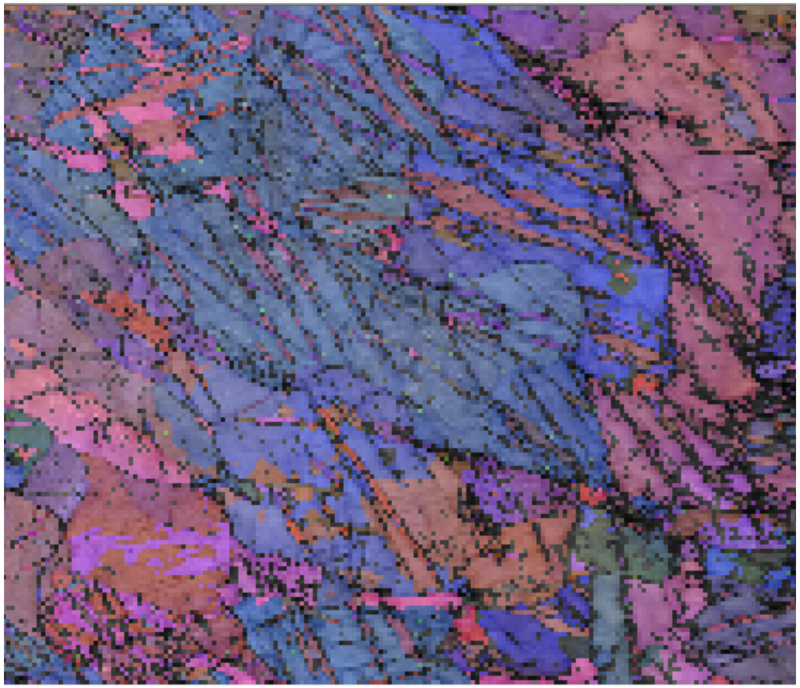
Phase	Impact (far) At 4.509Km/sec	Impact (near) At 4.509Km/sec	Clear (non -impact)
BCC	99.22%	96.68%	99.96%
FCC	0.7120%	2.874%	0.09%
HCP	0.07152%	0.439%	0%

Impact area at 5.80 km/sec far from Impact



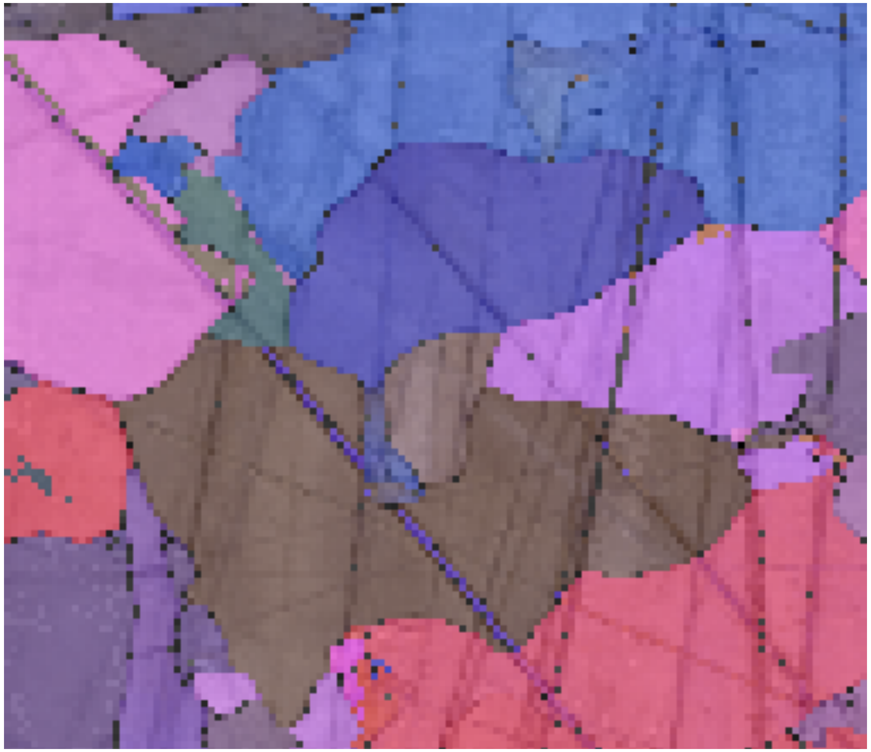
Phase	Impact (far) at 5.80 Km/sec
BCC	98.45%
FCC	1.44%
HCP	0.12%

Impact area at 5.80 Km/sec Near-Impact



Phase	Impact (center) At 5.80Km/sec
BCC	97.52%
FCC	1.1566%
HCP	1.322%

Non-Impact



phase	Non-Impact
BCC	99.11%
FCC	0.89%
HCP	0%

Table of Results
At 5.8km/sec Speed of Impact

Phase	Impact (far) at 5.8Km/sec	Impact (near)	Clear (non-impact)
BCC	98.45%	97.52%	99.11%
FCC	1.44%	1.1566%	0.89%
HCP	0.12%	1.322%	0%

Conclusion

- Conclusion
  - Non-Impacted zone does not have any HCP nor significant amount of FCC.
  - Increasing impact momentum increased the HCP Percentage.
  - Near crater, the HCP is higher percentile than in far region.
  - Grain size near impact is compacted near impact site.

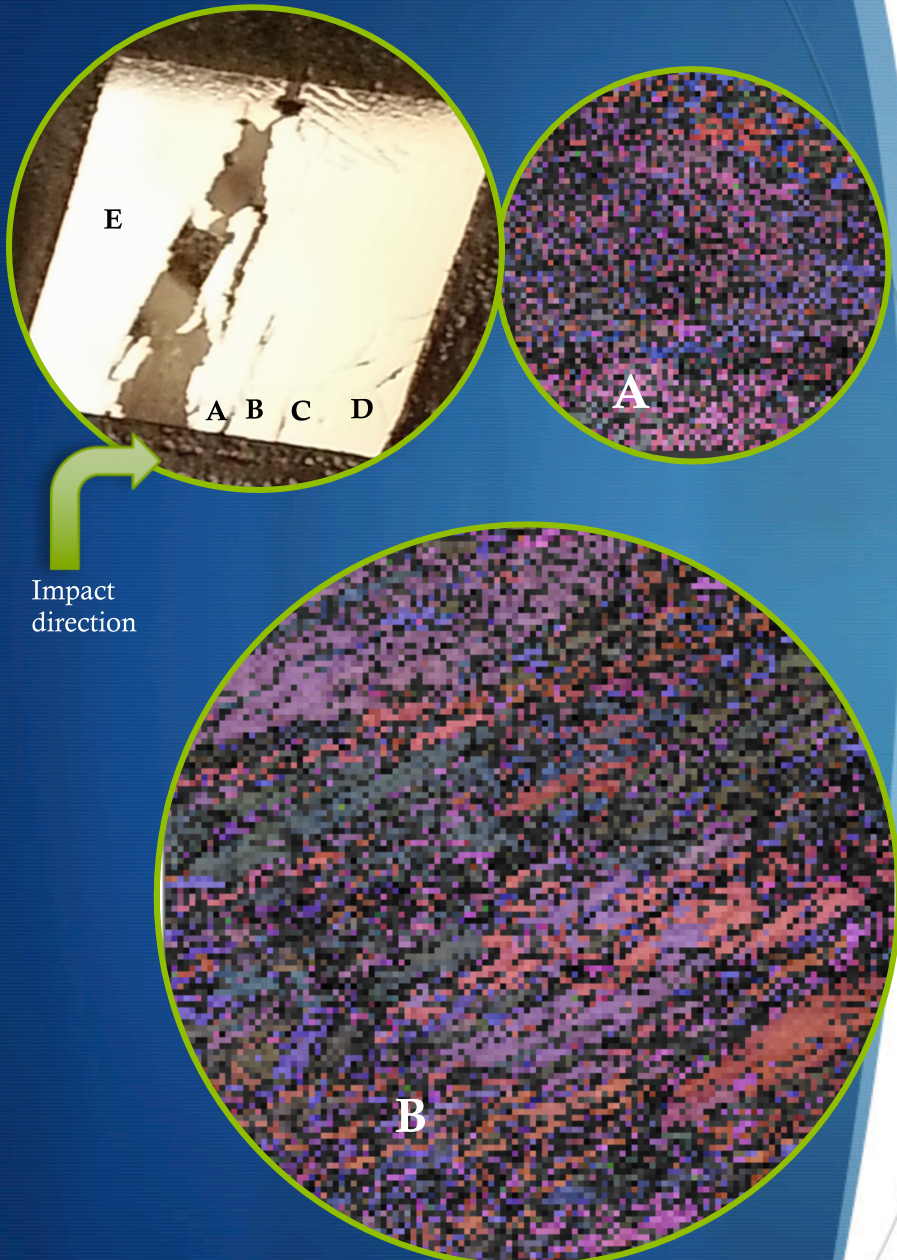
Recommendations and Future Work

- Iron may be transformed into a stable and metastable non-BCC phases by manipulation of thermodynamic parameters.
- More accurate viewing is needed to recover details of the view near the crater.
- The low percentage of HCP is possibly in the noise level of the system. Additional statistical analysis is needed to determine the confidence intervals of the calculated percentages.

Recommendations and Future Work

- Furthermore, it is of interest to determine whether increasing the velocity of the projectile, thereby increasing the pressure, will increase the amount of non-BCC phases.
- Future samples will include A36 steel that has been impacted at higher and lower velocities as well as samples from the starting (non-impacted) steel.

Test Points Relative Locations



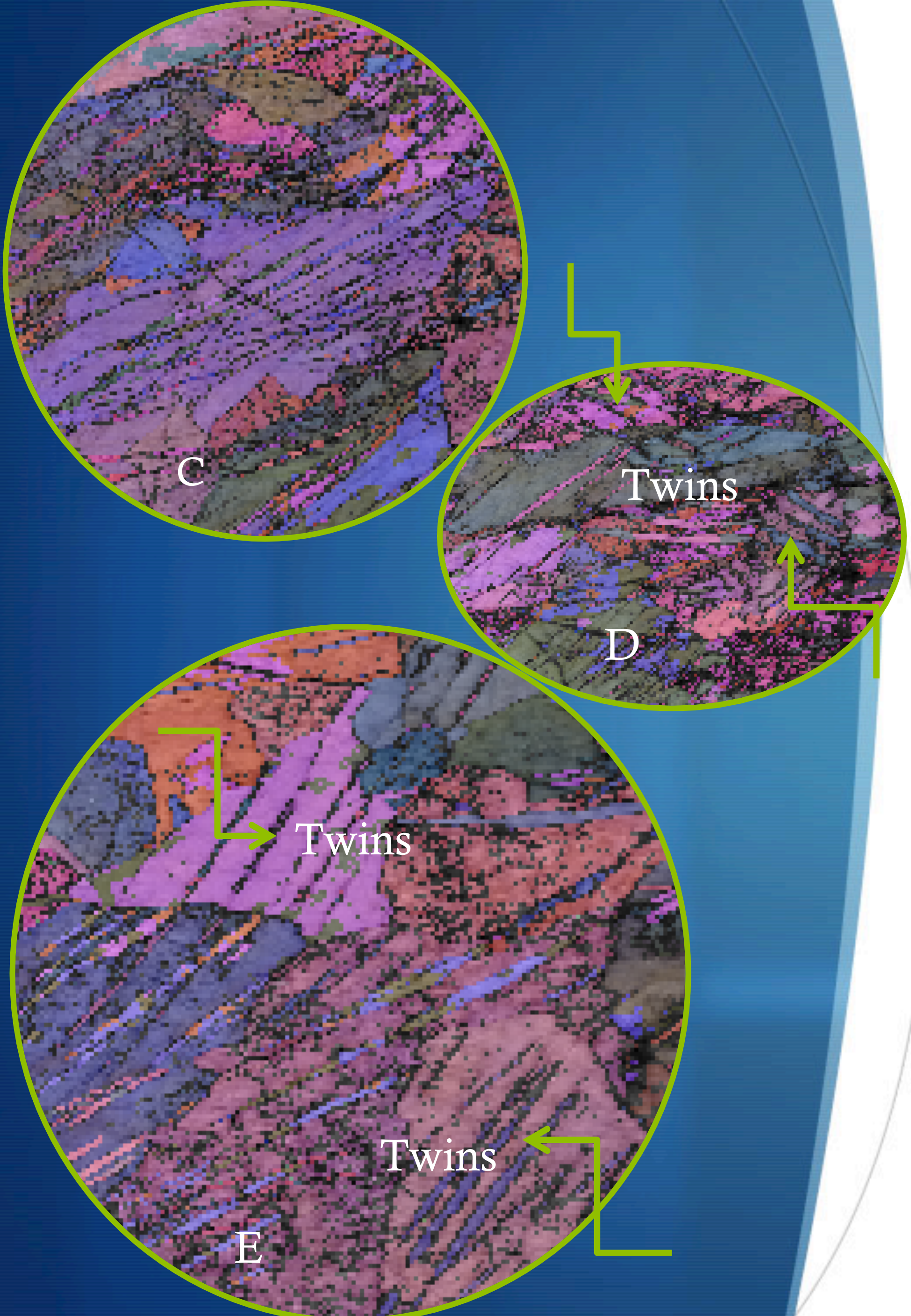
- Relative locations for each point of test as indicated in the actual picture to the left

Between "A_B" is 500 micron

Between "B_C" is 500 micron

Between "C_D" is 1000 micron

E is away from the impact direction (Far position) 3mm



Future work

- More research is needed in regard to examining the presence of twin phases in some of the images, and why they appear in certain test locations. Imaging also needs to be improved, especially pertaining to grain size.
- Impact effect on surface hardness could be examined.
- Ion-polishing could also be used to improve the image quality of the 'near zone' post impact, especially for 5.80 km/per second speed impact samples.
- Different projectile material and shape could also be used.

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THANK YOU