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SiC Armor Tiles via Magnetic Compaction and Pressureless Sintering

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Successfully Processed High Density SiC using Dynamic Pressing and Pressureless Sintering

- High Green Densities
  - Lower Shrinkage- Net Shape
- Fine Microstructure
- Initial data suggests good material quality
- Three tiles pressed in <1 millisecond

- Ballistic tests still to be done

Outline

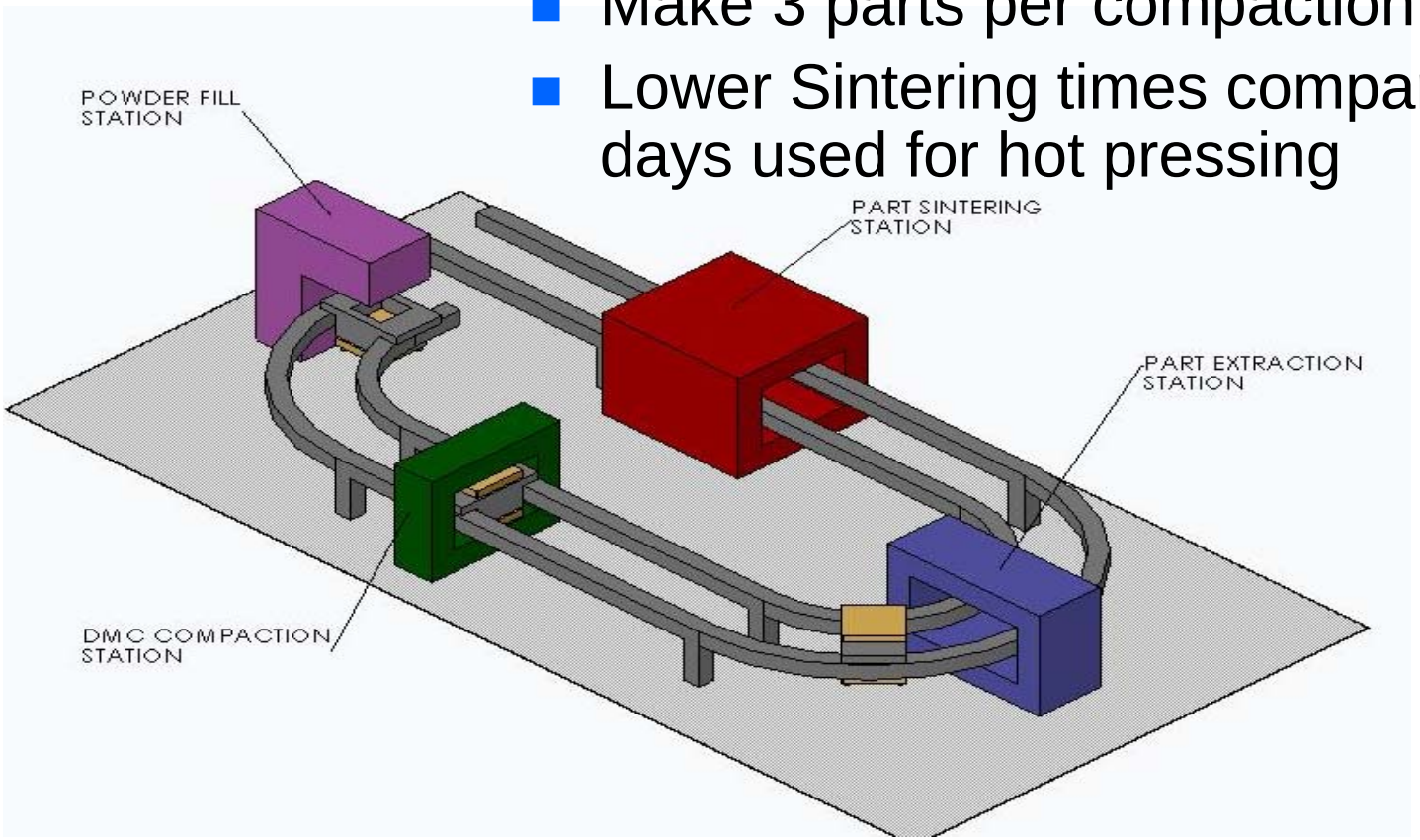
- Review Project Goals and Team
- What is the DMC process?
- Summary of work on sub-scale 1”x1”x1/2” and 1.25”x0.75”x0.75 “system
- Material optimization effort with DMC-PS process with 490 NDP (Superior Graphite) Powder
- Work in progress under SBIR Phase II effort

Project Goals

- Designed and built a sub-scale DMC systems to produce a near net shape flat (1x1x1/2”) and 1.25”x0.75”x0.75” armor tiles
- Pressureless Sinter (PS) SiC tiles to full density-on going
- Characterize test samples
- Populate 3’x3’ Array for Ballistic test

SiC Processing via Semi-Continuous Dynamic Magnetic Compaction

- DMC Compaction Time < 1 millisecond
- Make 3 parts per compaction cycle
- Lower Sintering times compared to days used for hot pressing



Phase II Project Team

Powders

- Superior Graphite powders (made for Pressureless sinter (PS) with B and C additives)
- Ceramatec (special powder chemistry for PS)

Sintering

- MicroCeramics (not operational) and Ceramatec Inc

Testing

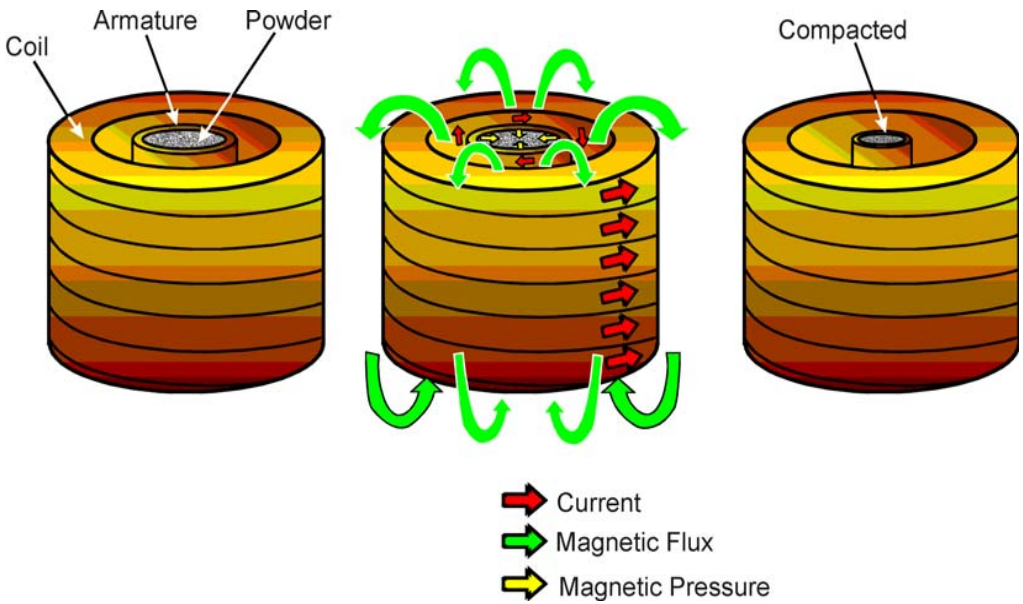
- Ceramatec, ORNL ,ARMY and UDRI

What is Dynamic Magnetic Compaction?

- Dynamic
  - Kinetic process
  - High compaction pressure for sub-millisecond
- Magnetic
  - Pulsed magnetics provide compaction energy
- Compaction
  - DMC delivers high density compacts
  - Fine microstructures

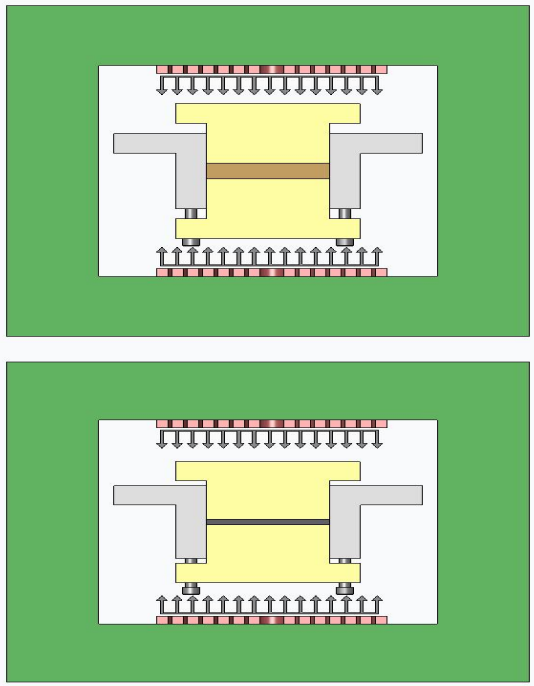
Fundamentals of DMC Pressing

Radial Compaction



- Net shaped cylindrical parts
- High L/D part shapes

Axial Compaction



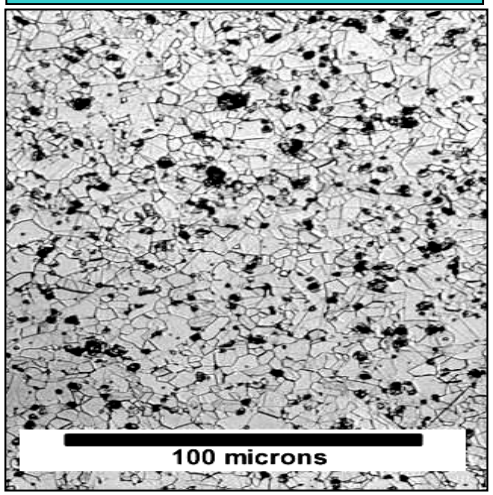
- Net shaped flat tiles

Sub-Scale Compaction System For 1”x1”x0.5” and 1.25x0.75”x0.75” SiC Tiles

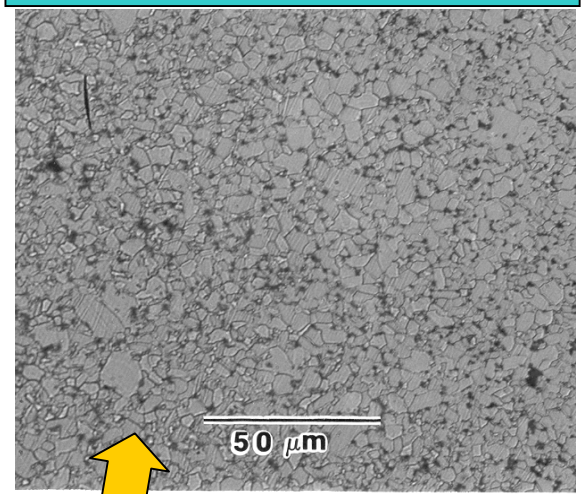
- ✓ FE Modeling
  - Magnetic Modeling
  - Dynamic Modeling
- ✓ Completed Final Design and Built Two Sub-Scale Flat Compactors
- ✓ Laboratory Testing of Flat Compactor in Progress
- Sample Fabrication and Process Optimization - In Progress

Phase I Results Summary
Microstructure of DMC/PS VS Conventionally Processed Samples

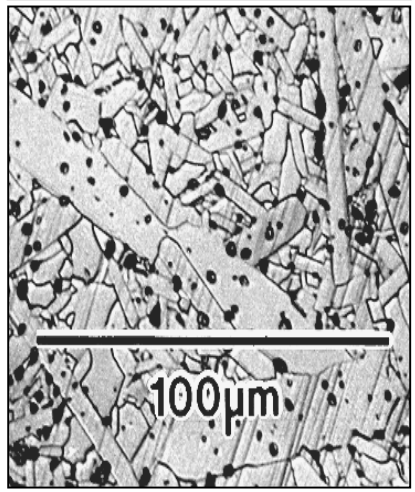
Hot Pressed SiC



DMC & PS SiC

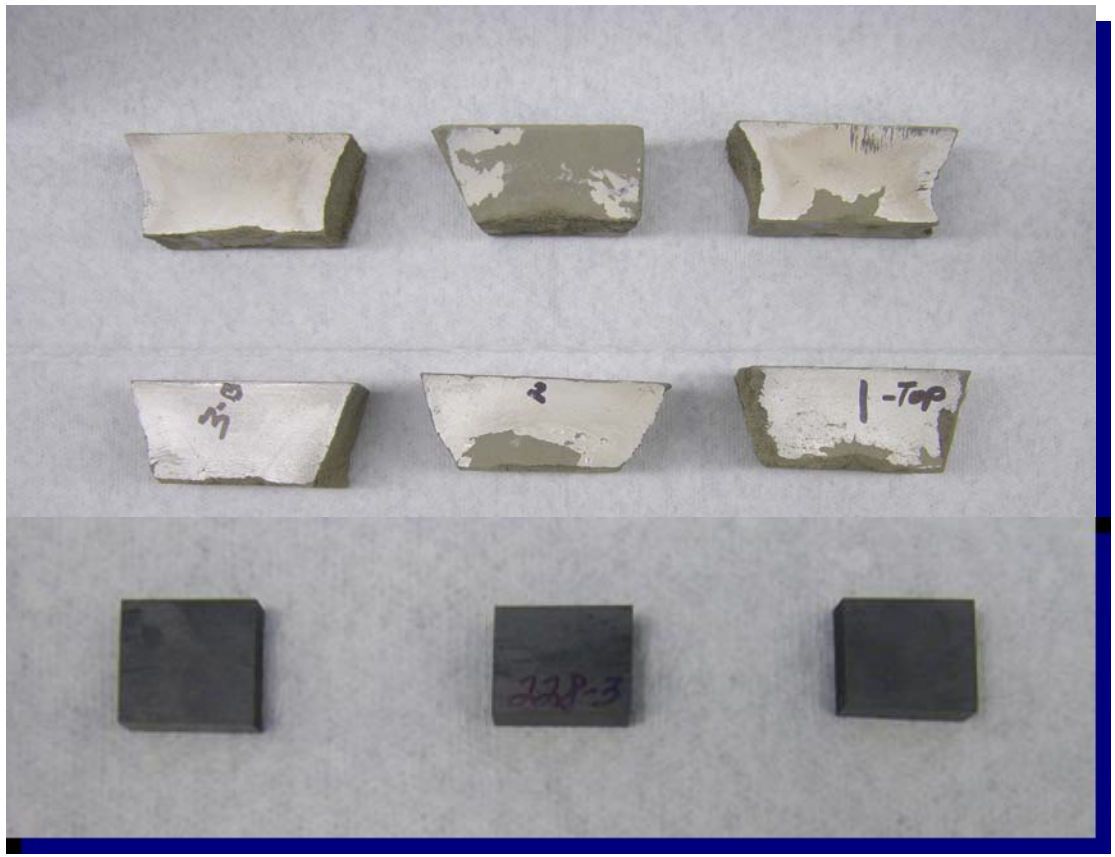


PS-SiC

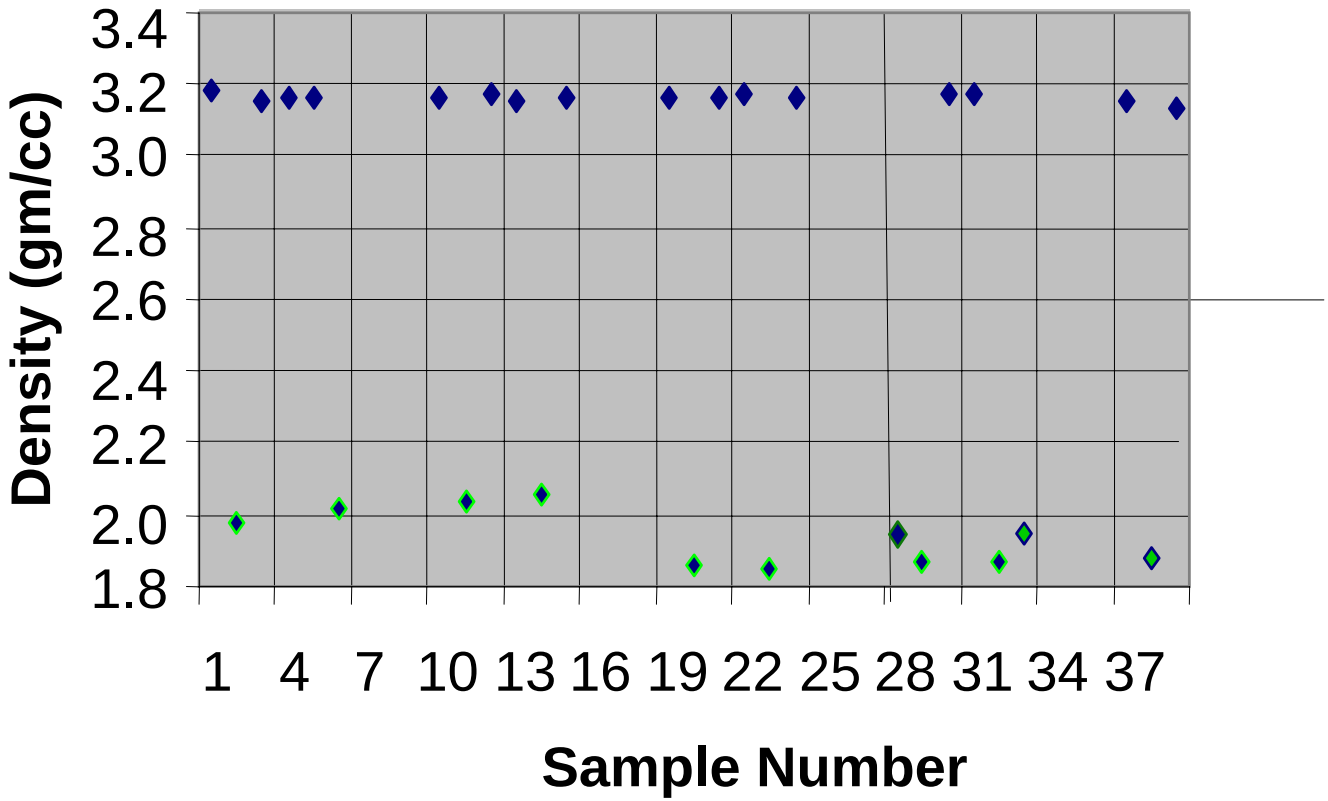


Uniform, Fine Grained Microstructure
Minimal Grain Growth

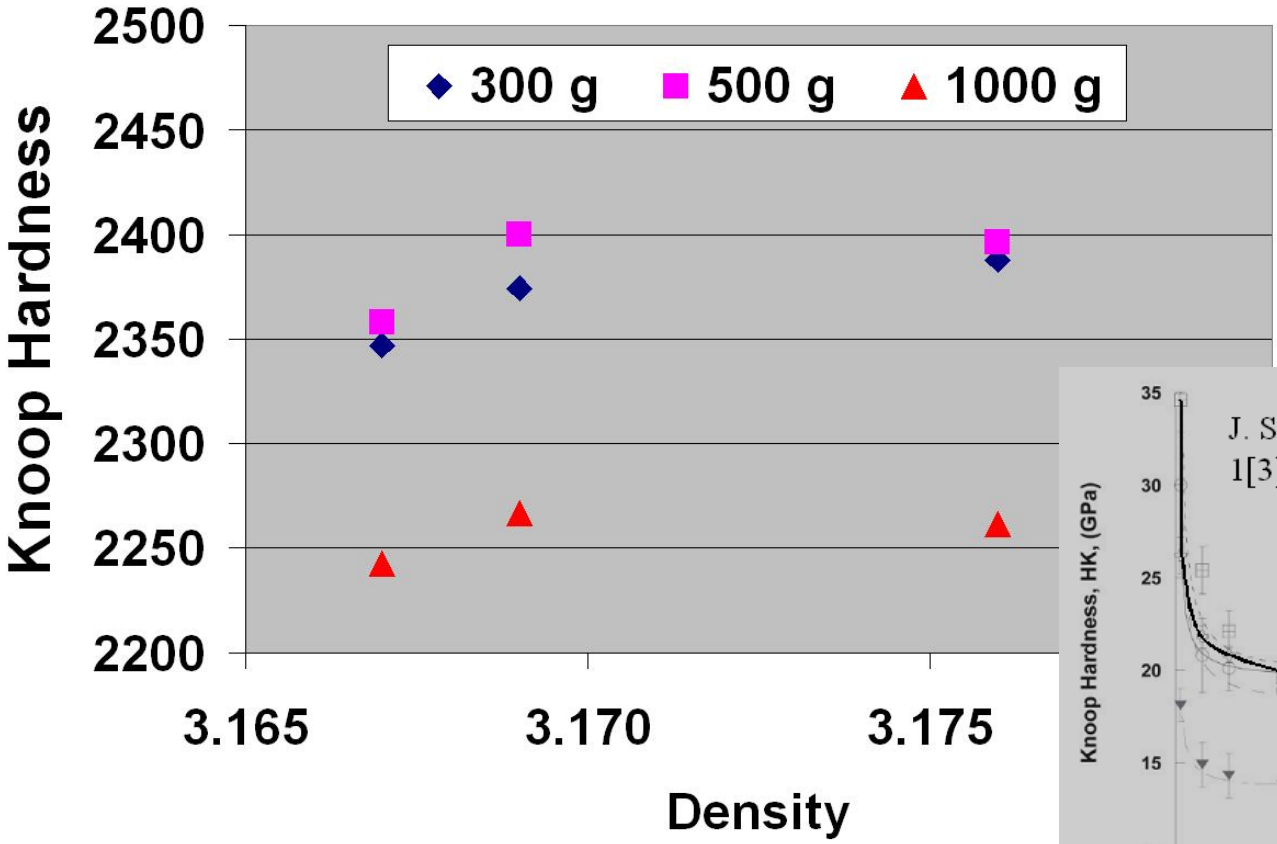
Green and Sintered Samples

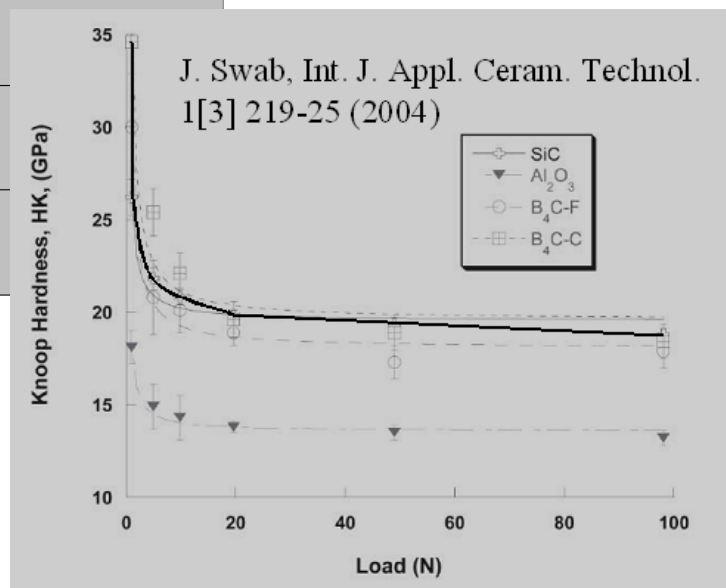


Consistent Density in Each Batch and Batch to Batch

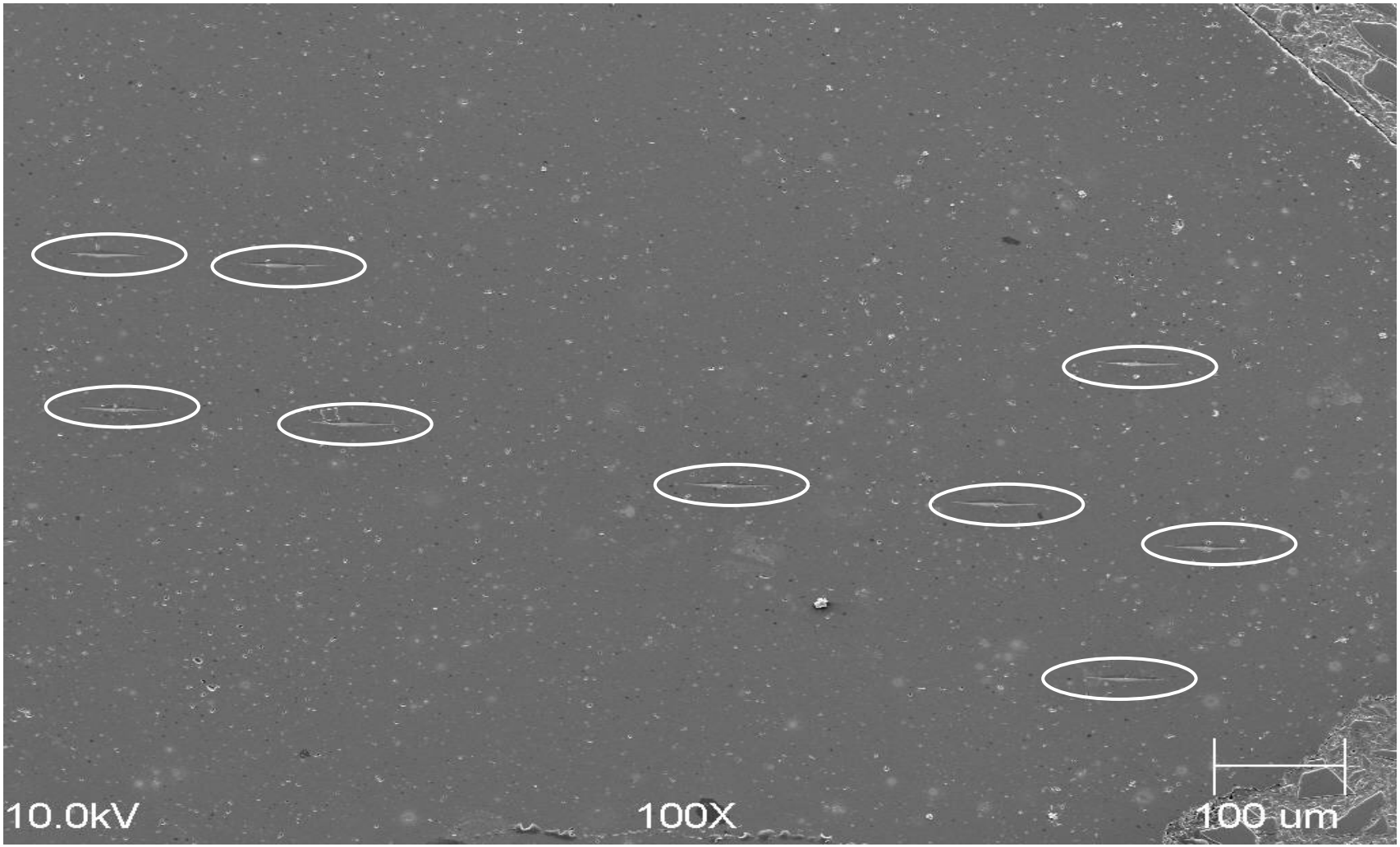


Knoop Hardness

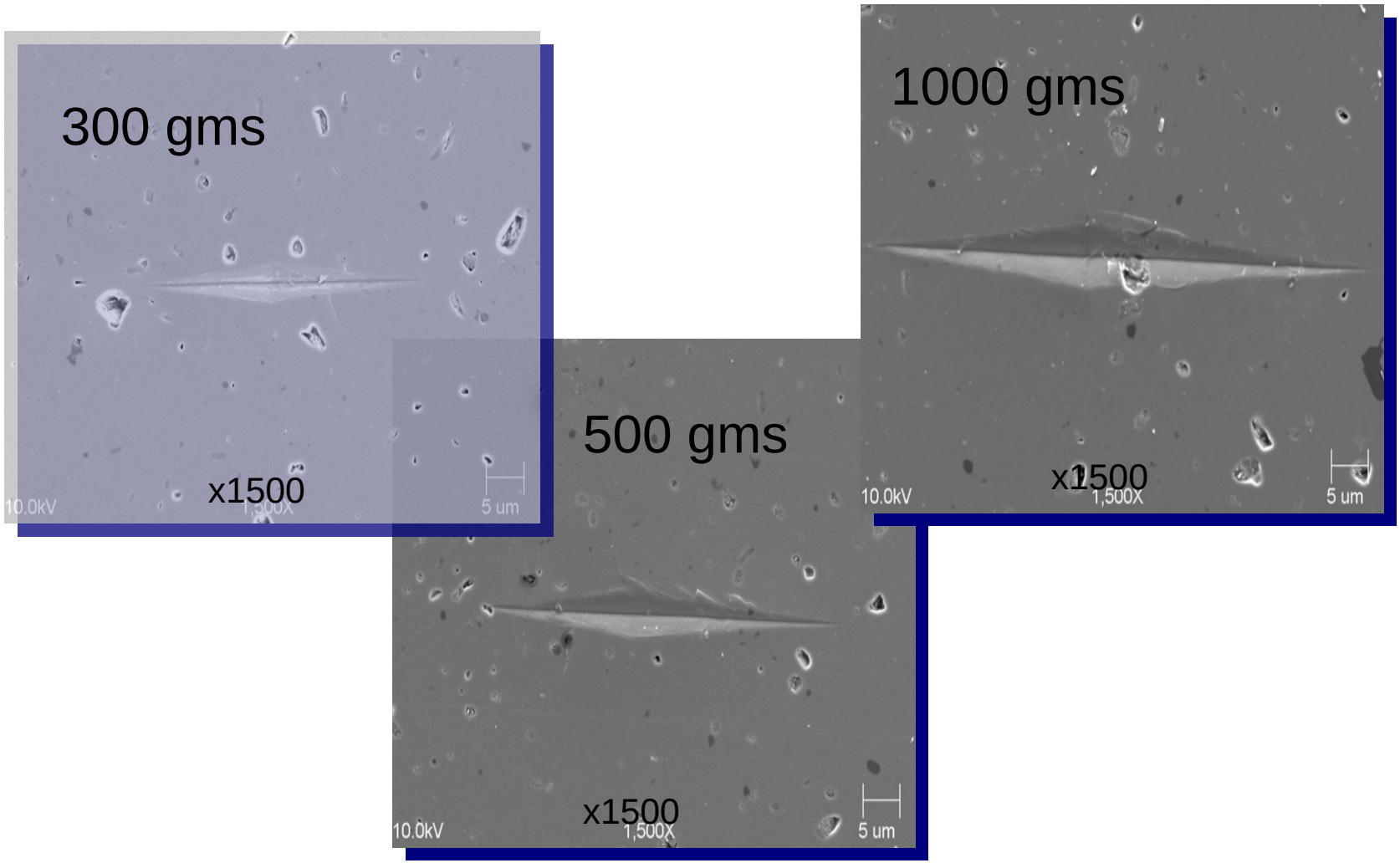




Knoop Indentations



Knoop Indentations at 300,500,1000gm load



*Elastic Modulus Using Resonant Ultrasound Spectroscopy (RUS)

Material	Youngs Modulus-Gpa	Poisson ratio
(DMC&PS) 98.4% Dense Phase I	430	0.19
DMC&PS 99.2% Dense Current	437	0.16
Cercom (Hot Press)-SiC-N 100% Dense	460	0.16

*Oak Ridge National Labs

Comparison of DMC and SiC-N

Property	Material (DMC & PS)	Hexalloy Direct sintered	SiC-N (Hot pressed)
Density (g/cc)	3.18	3.10	3.2
Knoop Hardness (GPa)	23.88 (Load 300gms)	28(Load 100gms)	24 (Load 300 gms)
Young's Modulus (GPa)	437	410	460
Poisson's ratio	0.16	0.14	0.16

Future Work

- Density, Powder and Process Optimization
- Ballistic Testing
- Alternate Tile Shapes

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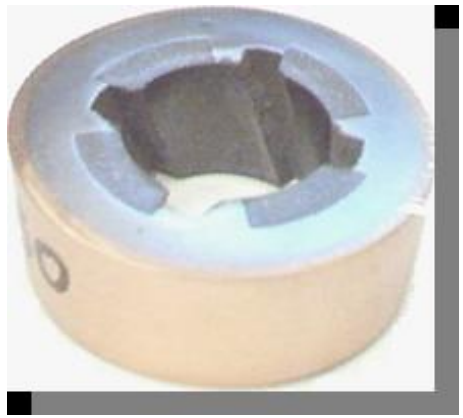
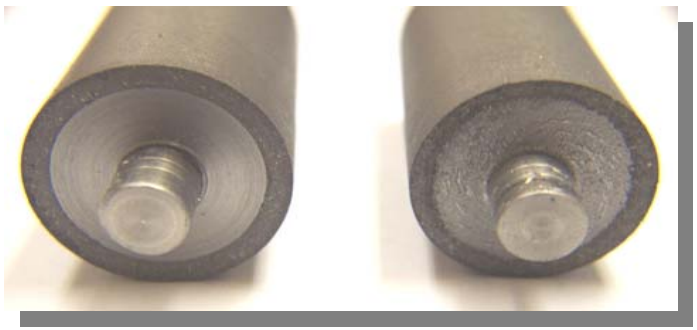
P/M Applications – Power Train Gear

- Conventional process is machining forged blanks

Motor Components via Co-Filling Powders

- Stators





Solid Core Powder Core

- Rotors