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Field assisted sintering: Challenges in scale–up from buttons to body armor

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U.S. Army Research, Development and Engineering Command

Field Assisted Sintering: Challenges in scale-up from "buttons" to body armor

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Electric Field Assisted Sintering and Related Phenomena Far from Equilibrium – Tomar, Portugal 5-11 March 2016

Outline of the Talk

- ARDEC Overview
- Motivation for FAST
- FAST Trends
- Applications in DoD
- Scalability Challenges
- Overheating Phenomenon
- Conclusions/Lessons Learned
- Acknowledgements

Armament Research, Development & Engineering Center

Research

Development

Production

Field Support

Demilitarization

Vision:

Innovative Armaments Solutions for Today and Tomorrow

Mission:

To develop and maintain a world-class workforce to execute and manage integrated life-cycle engineering processes required for the research, development, production, field support and demilitarization of munitions, weapons, fire control and associated items

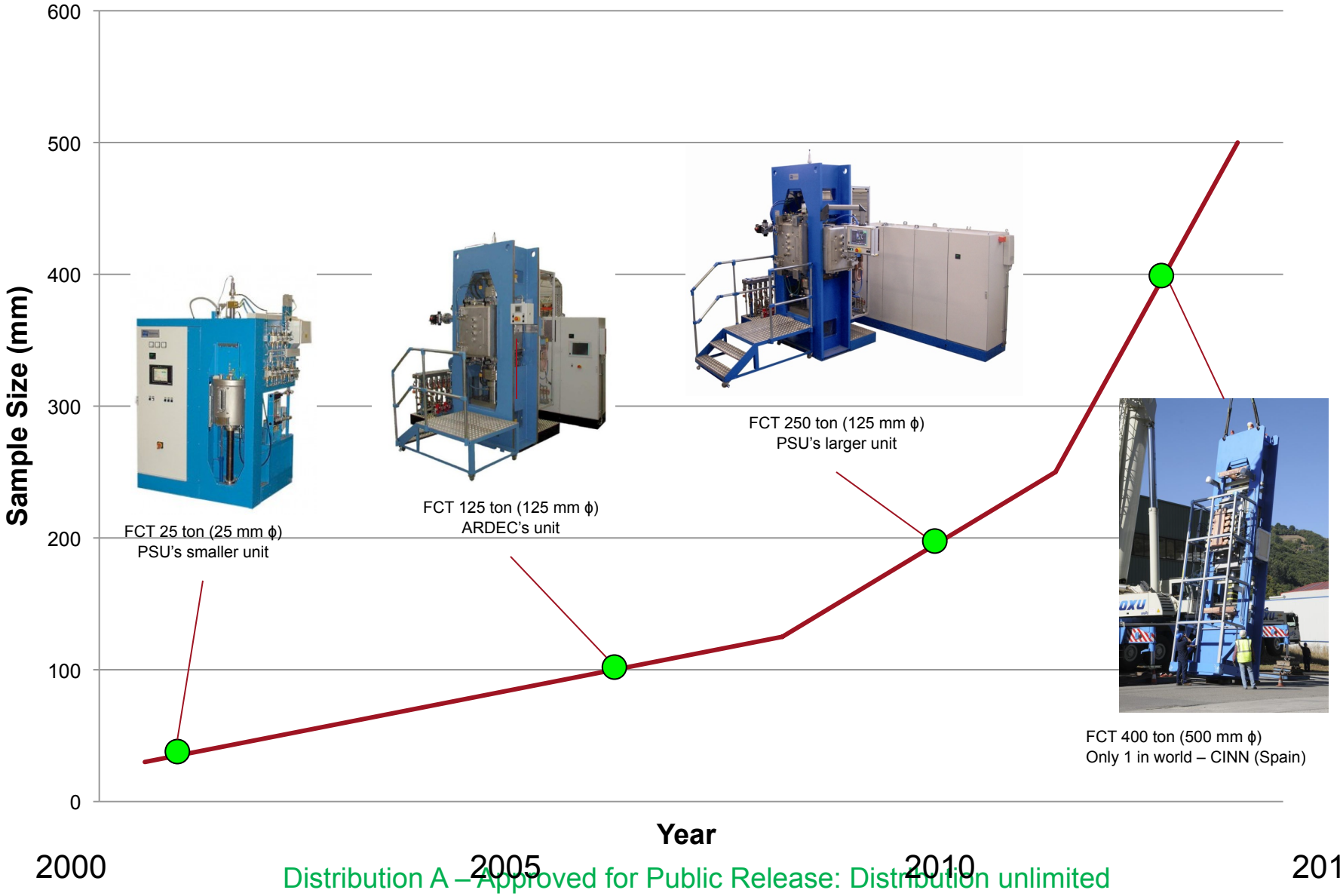
Advanced Weapons – line of sight/beyond line of sight fire; non line of sight fire; scalable effects; non-lethal; directed energy; autonomous weapons

Ammunition – small, medium, large caliber; propellants; explosives; pyrotechnics; warheads; insensitive munitions; logistics; packaging; fuzes; environmental technologies and explosive ordnance disposal

Fire Control – battlefield digitization; embedded system software; aero ballistics and telemetry

ARDEC Provides the Technology for Over 90% of the Army's Lethality; Significant support to other Services Lethality

Increase in Size Capacity

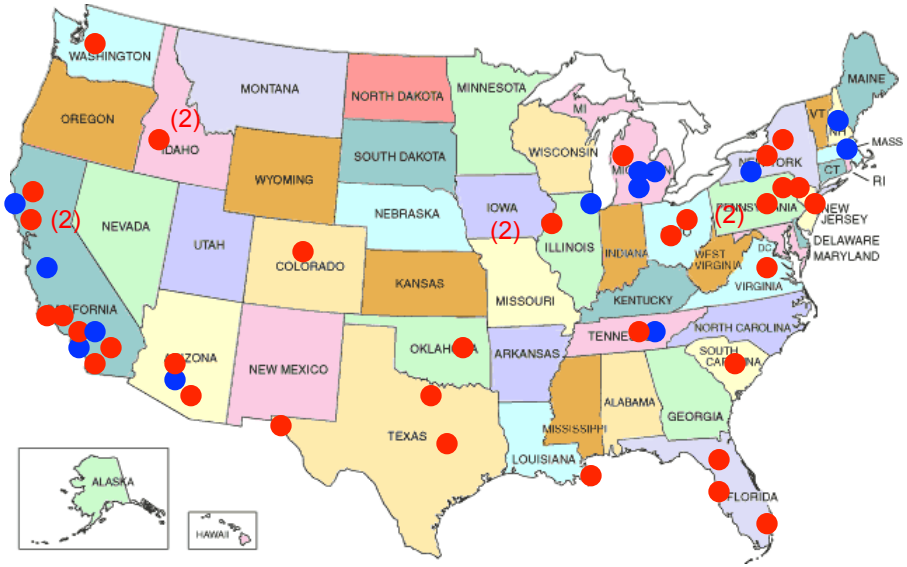


Emergence of FAST in US

2000

1

2015



60+

Academia or Gov't Lab
Industry

*Actual locations are not precise due to proprietary agreements between vendors and equipment purchasers.

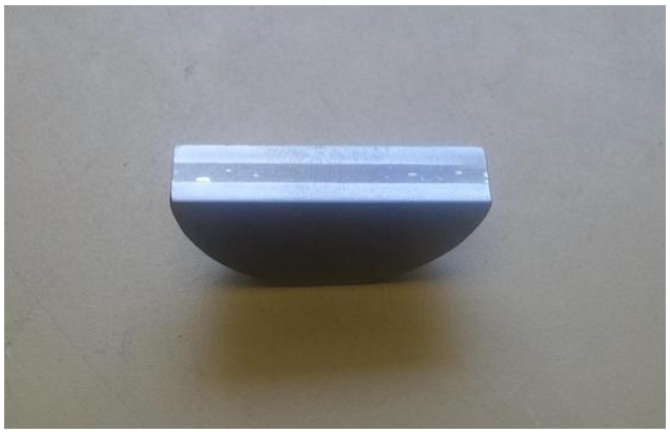
Applications in DoD

Soldier Protection

Lethality

Functional Components

Layered Structures

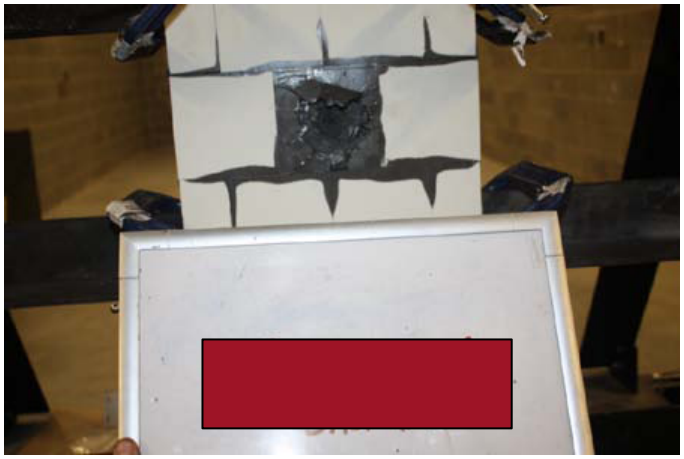


Soldier Protection

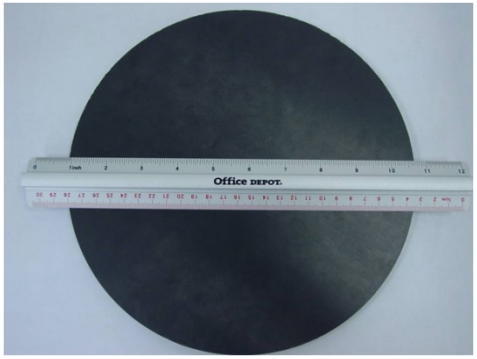
Soldier Protection

Initial Small (3” Dia.) Samples

Scaled up 4” x 4” Plates



Conducted Ballistic Testing



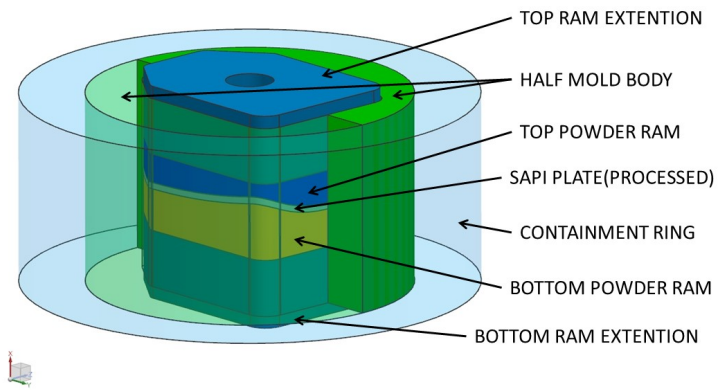
250 mm Dia. Plates

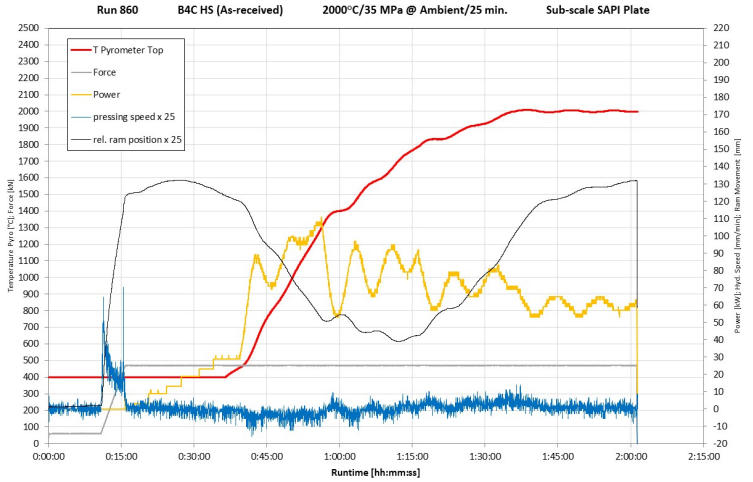
Sub-scale SAPI

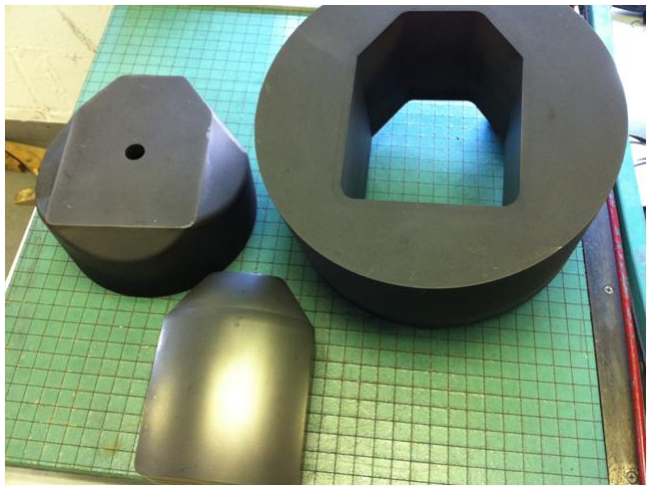
We Are Here

Full Scale SAPI Plates

Subscale SAPI



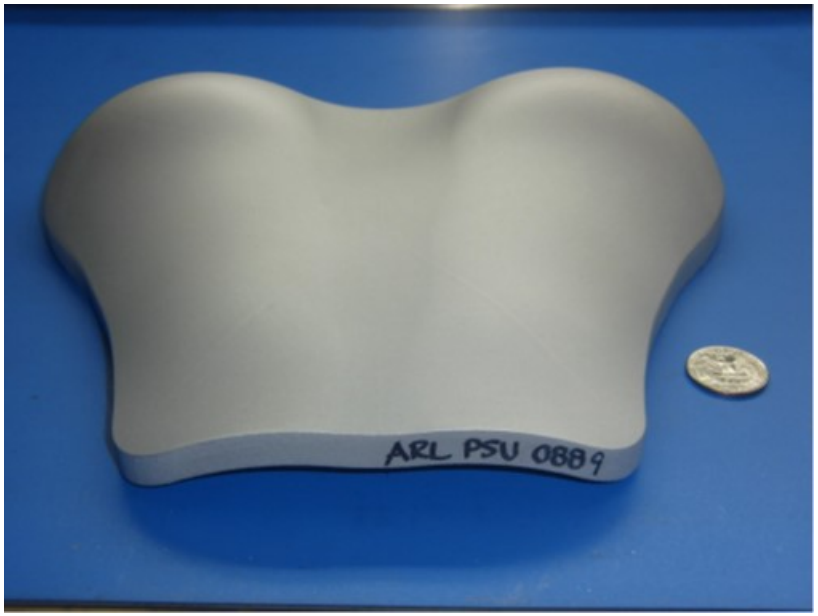


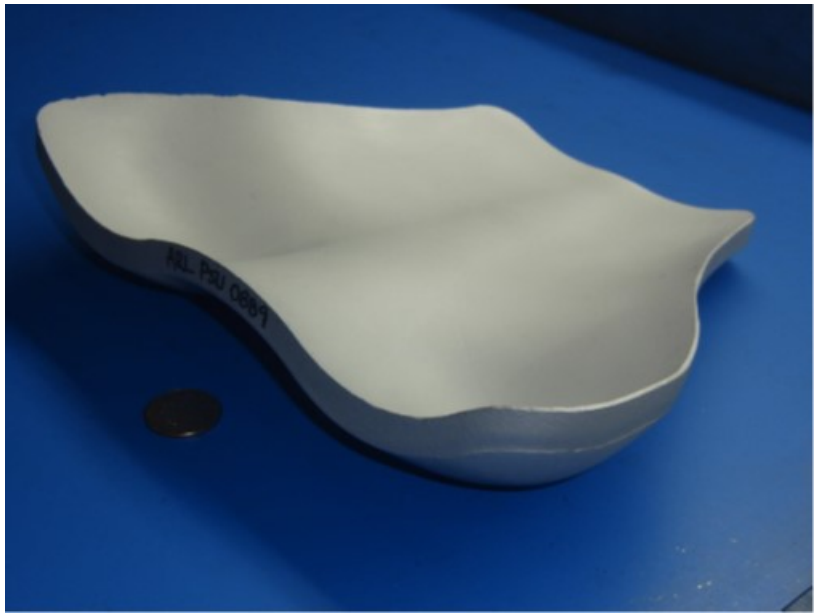


95% Dense, Cracked Tooling

99% Dense, Tooling Intact

Body Armor – Future Concepts





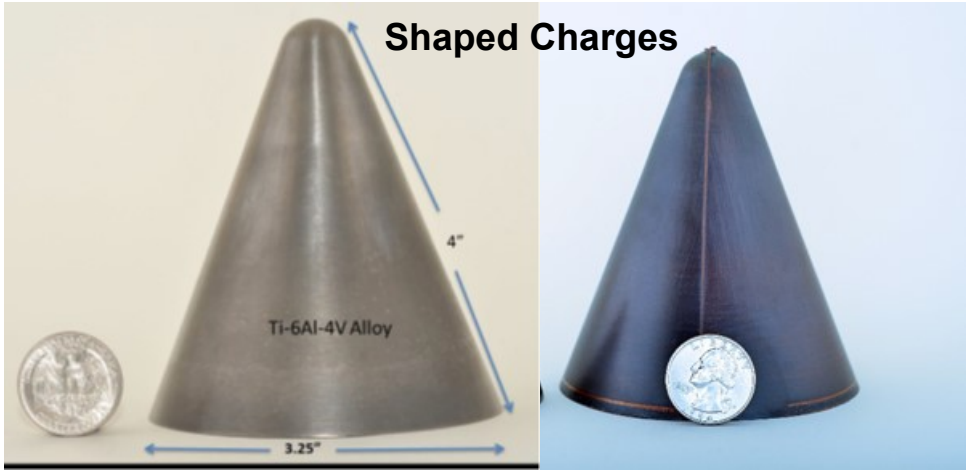
Proof of Concept Female SAPI plates made via FAST

Lethality

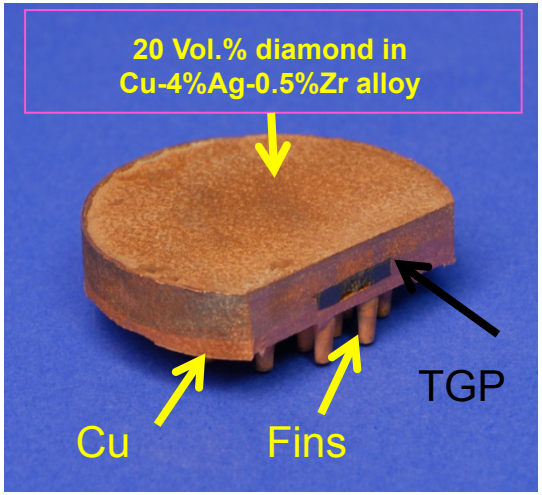
Lethality

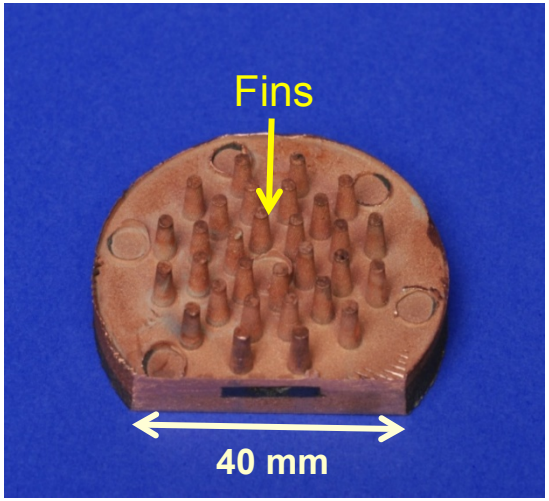
There exists a *major* cost benefit for NNS warheads due to minimization of scrap. Conventional CNC machining or forging yields very high % of scrap with raw materials in the $100's/lb range

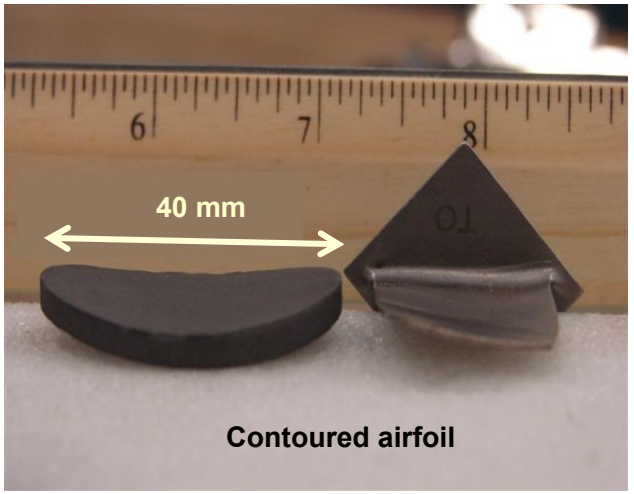
Lethality

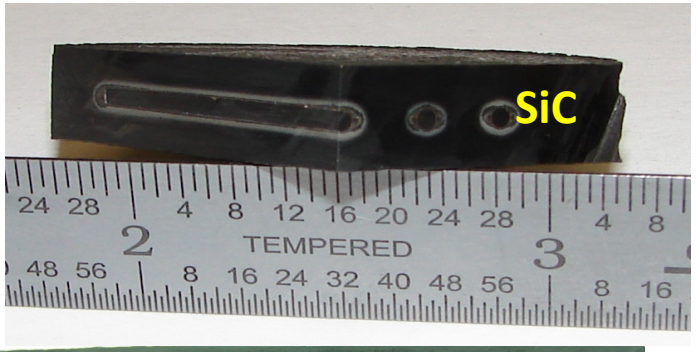


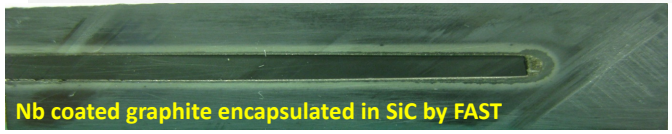
Functional Components

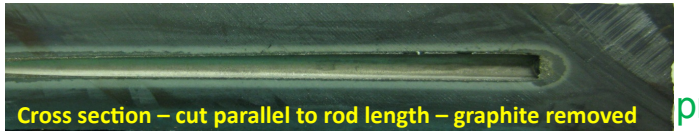


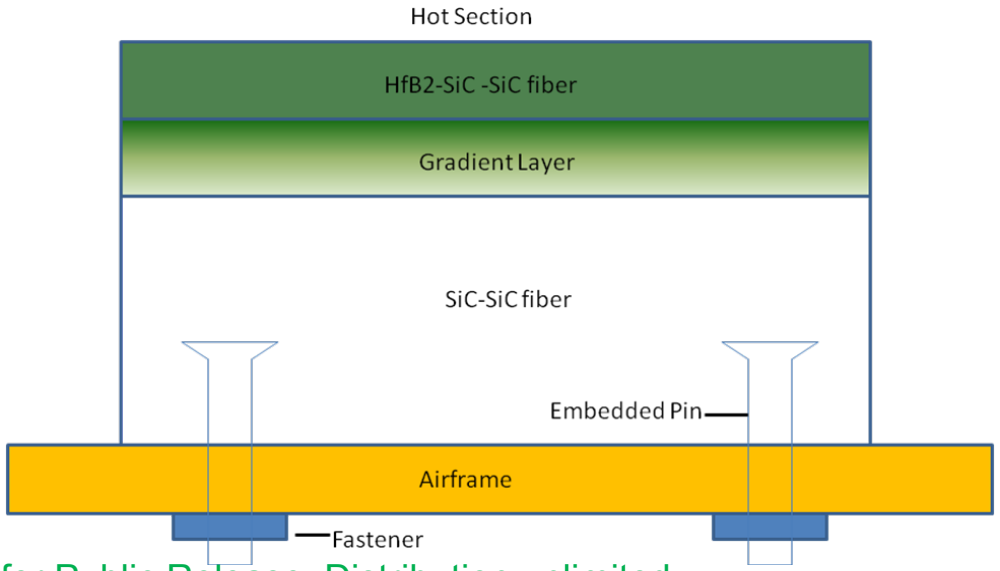




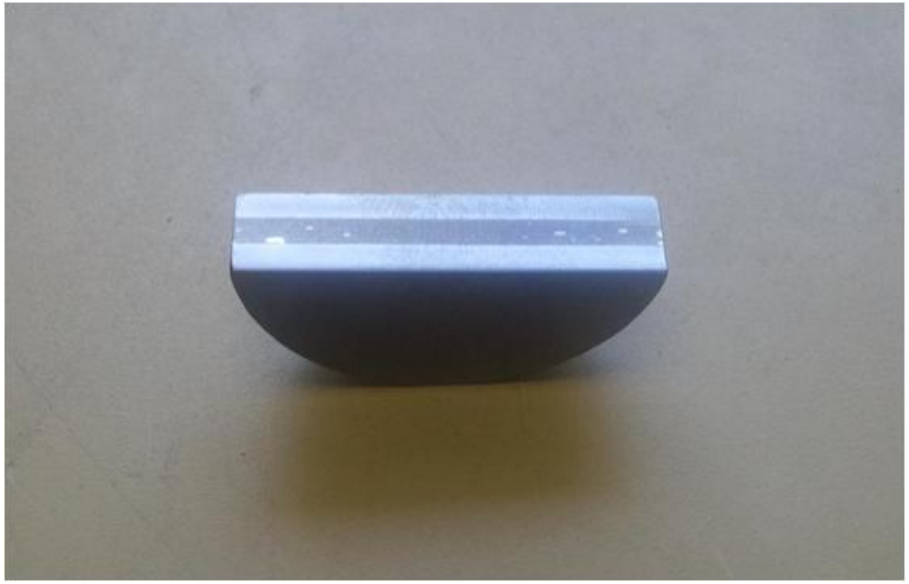


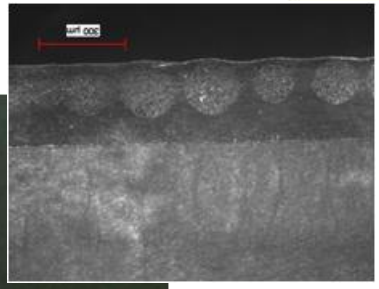


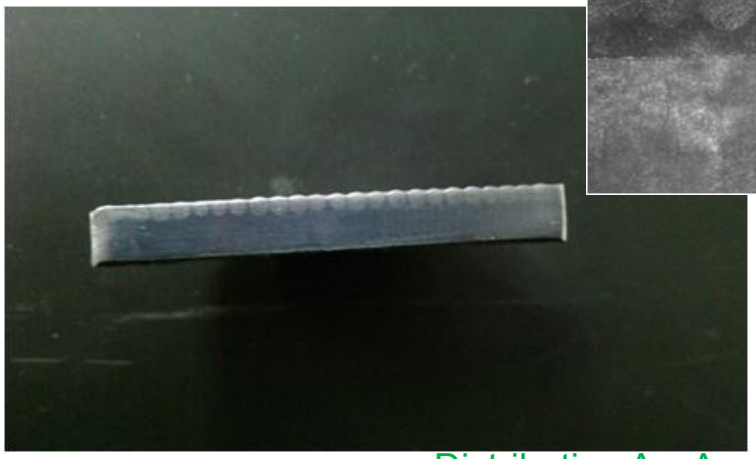


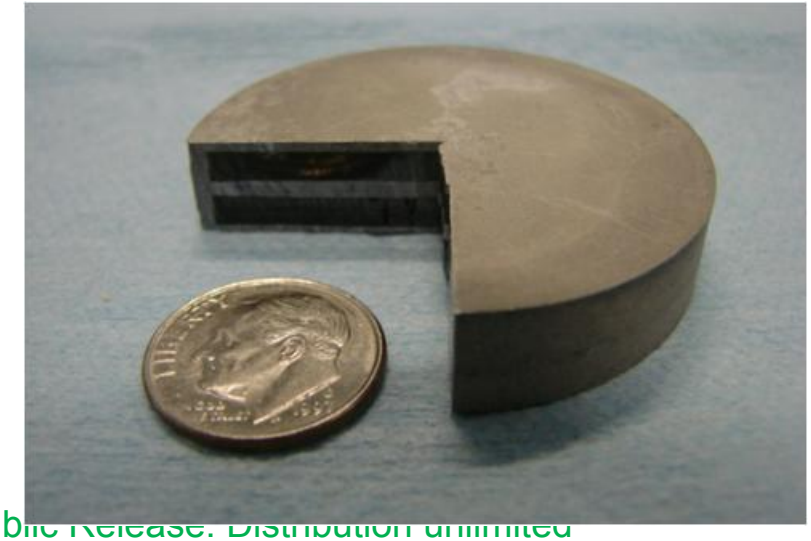


Layered/Composite Materials



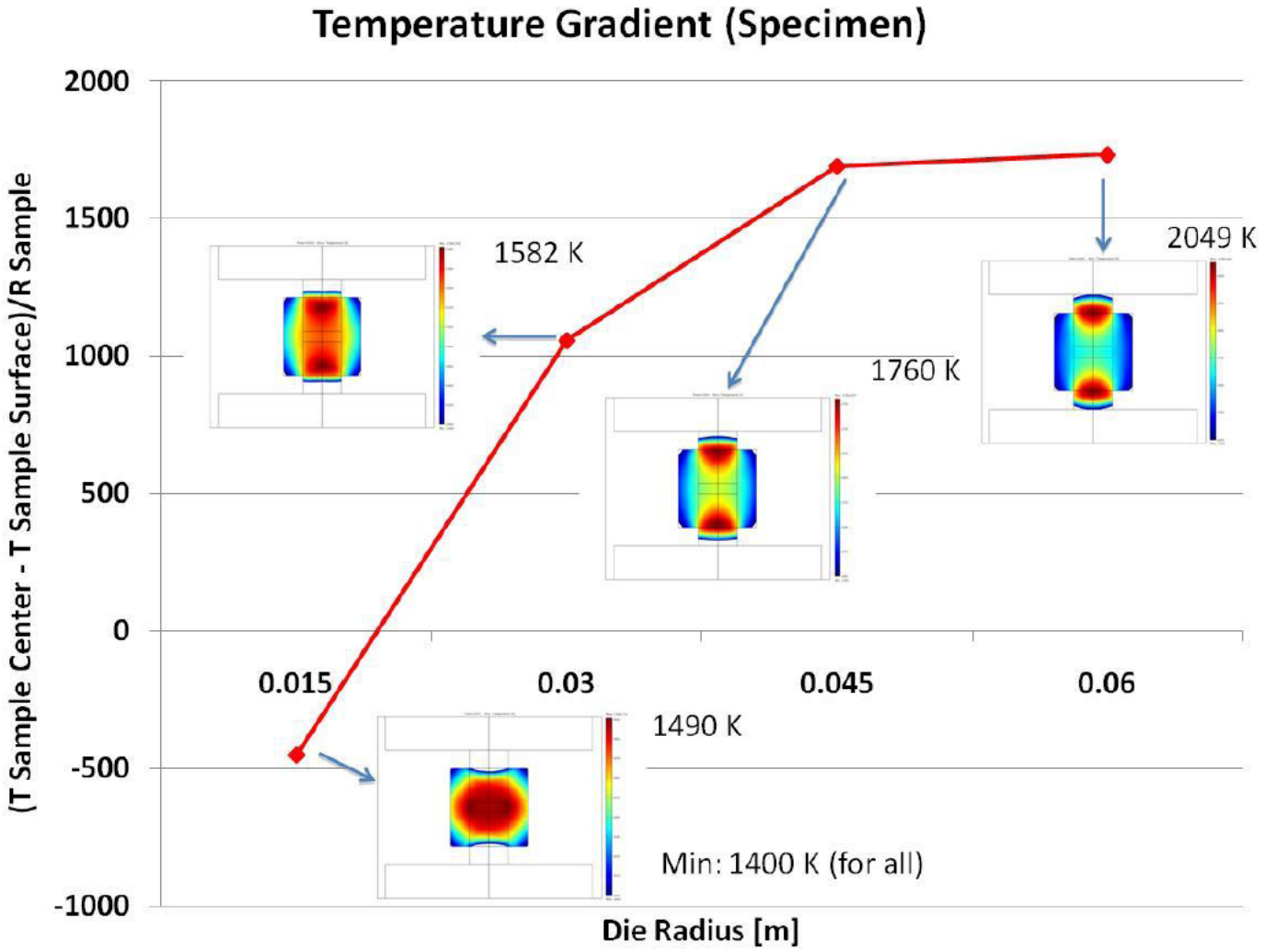




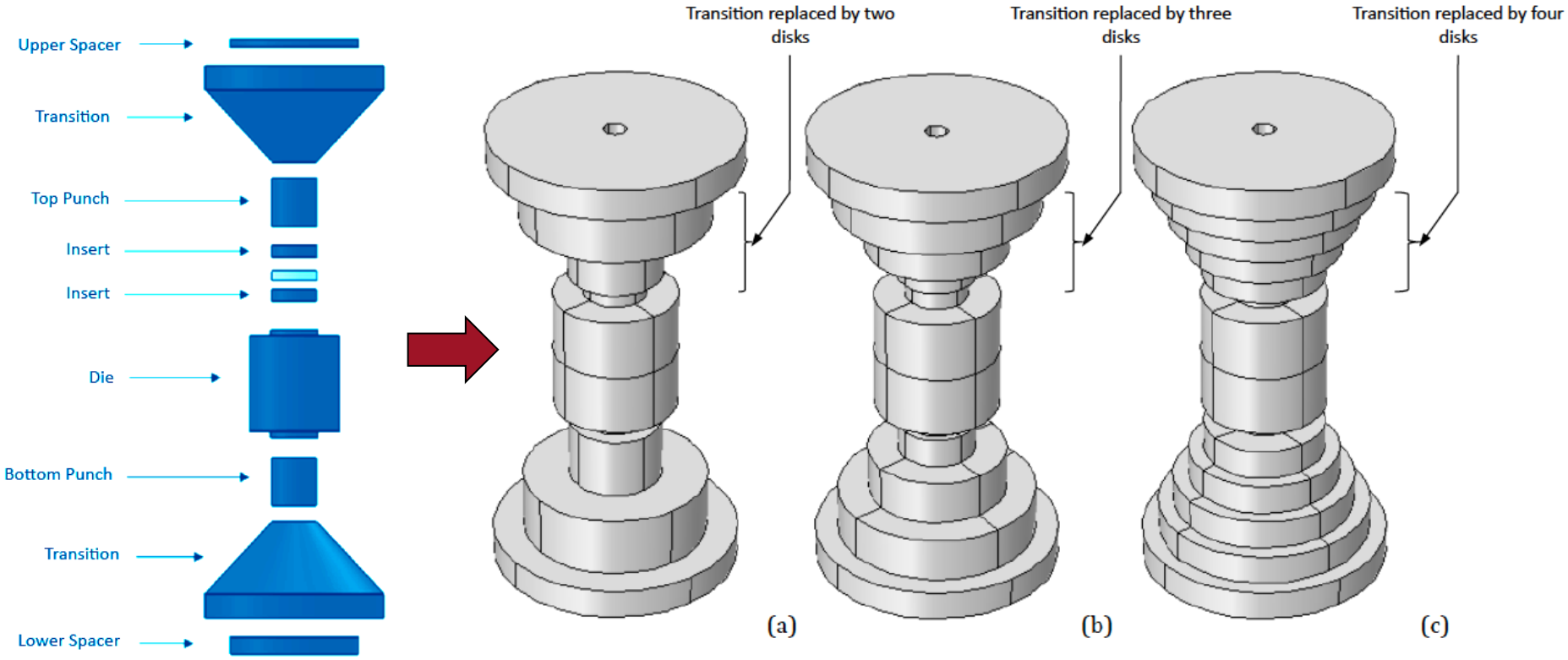


Scalability Challenges

Scalability Issues



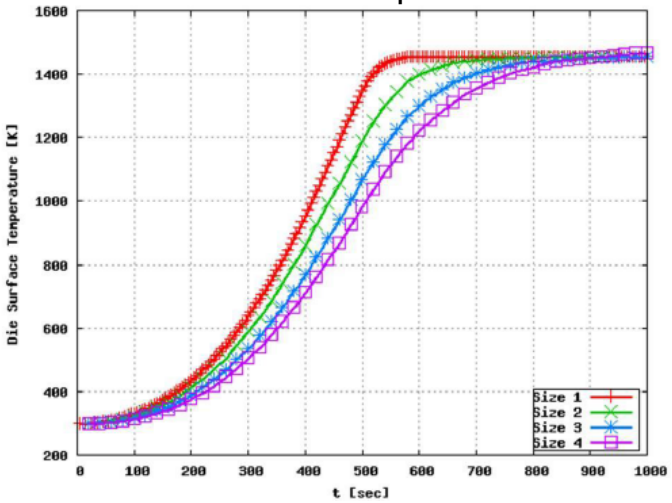
Scalability Issues



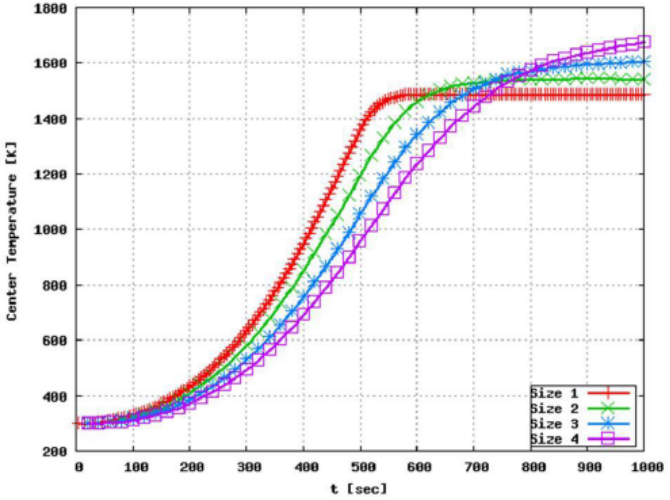
D Giuntini, EA Olevsky, C Garcia-Cardona, AL Maximenko, MS Yurlova, CD Haines...Materials 6 (7), 2612-2632

Scalability Issues

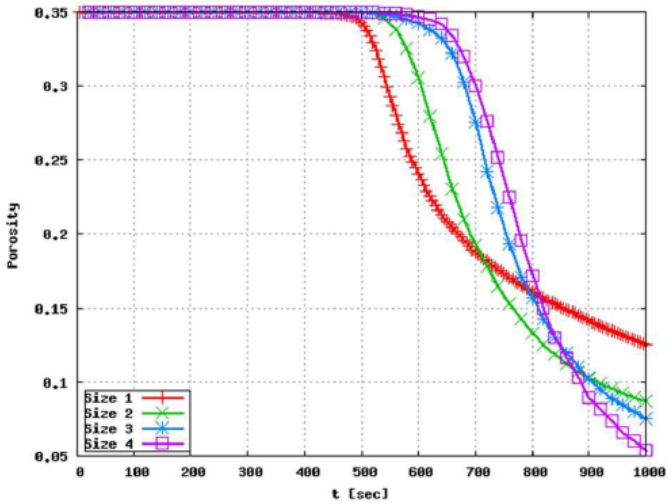
Die Surface Temperature



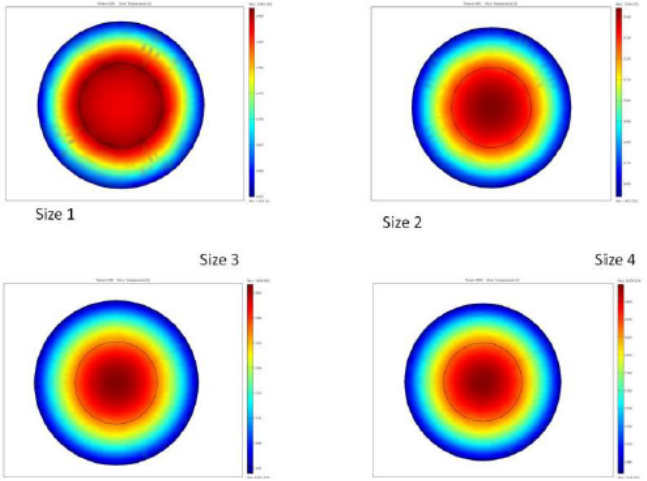
Specimen's Center Temperature



Specimen's Center Porosity

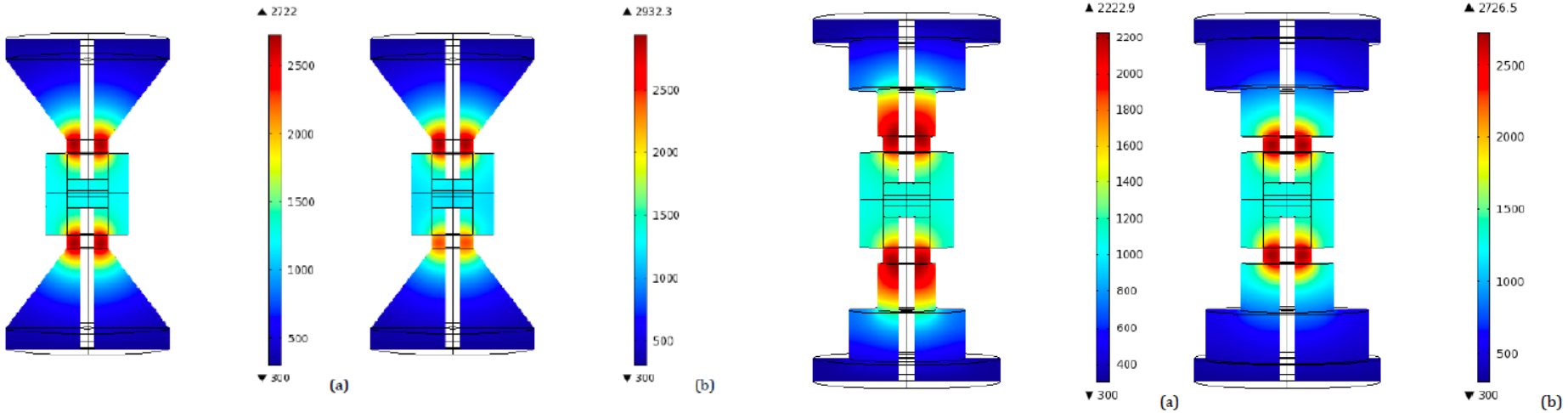


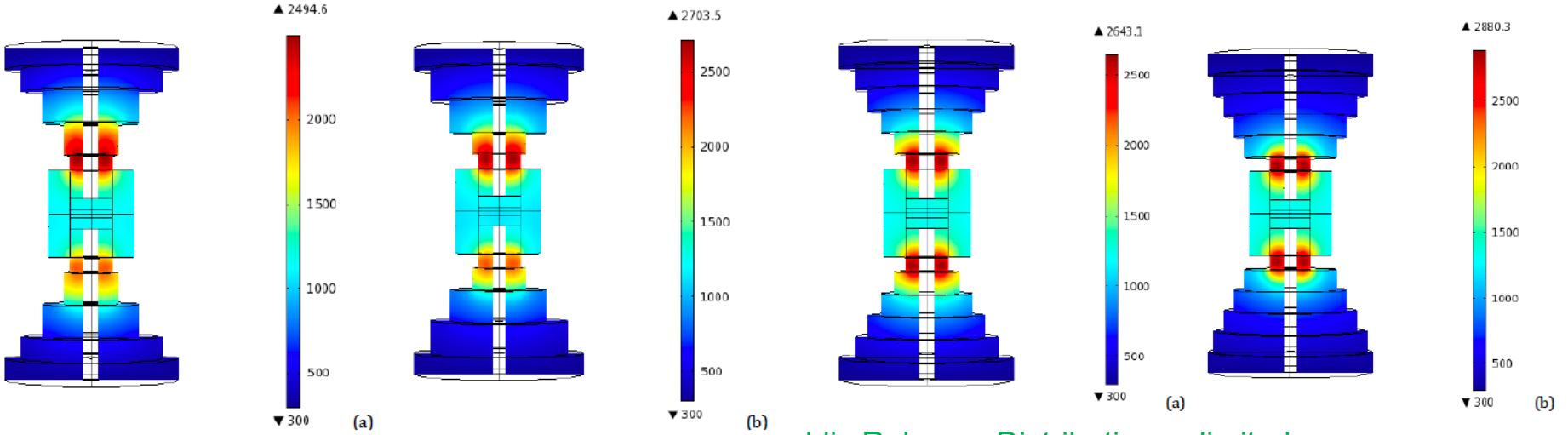
Specimen Temperature Profile



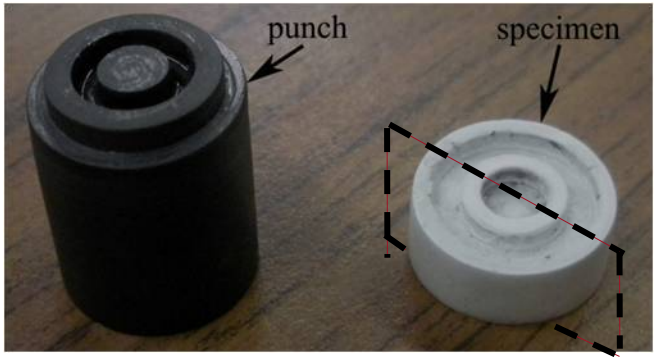
D Giuntini, EA Olevsky, C Garcia-Cardona, AL Maximenko, MS Yurlova, CD Haines...Materials 6 (7), 2612-2632

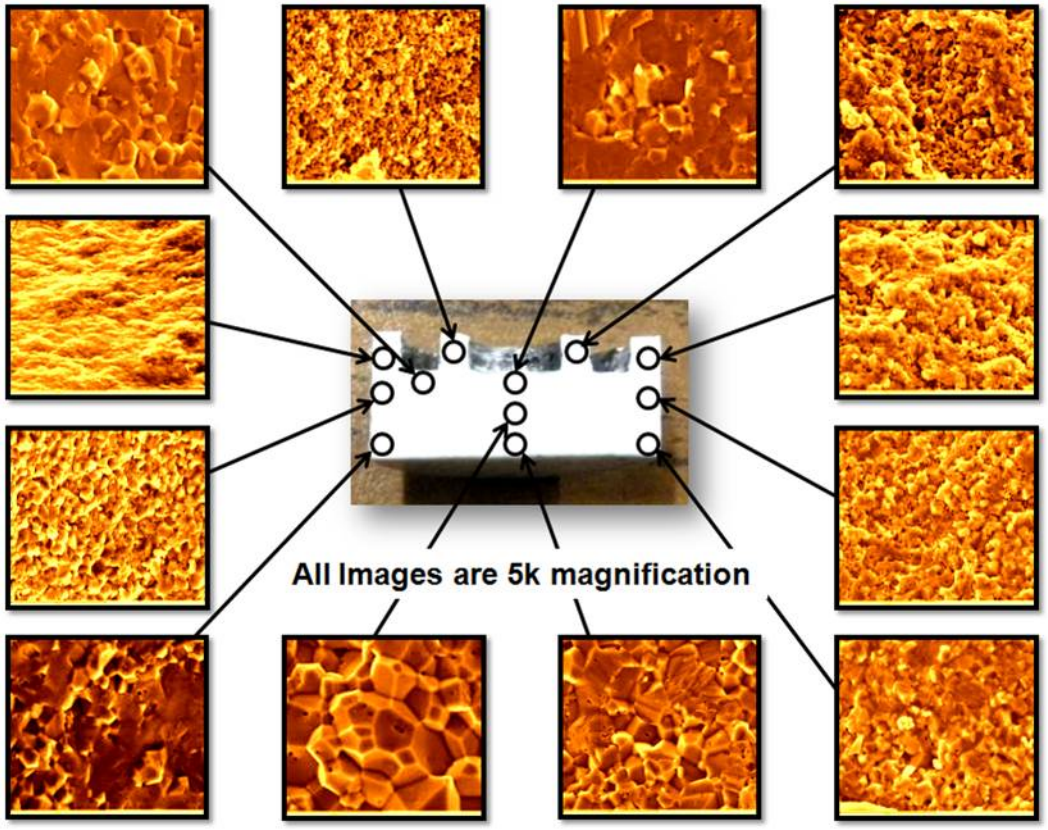
Overheating Phenomenon





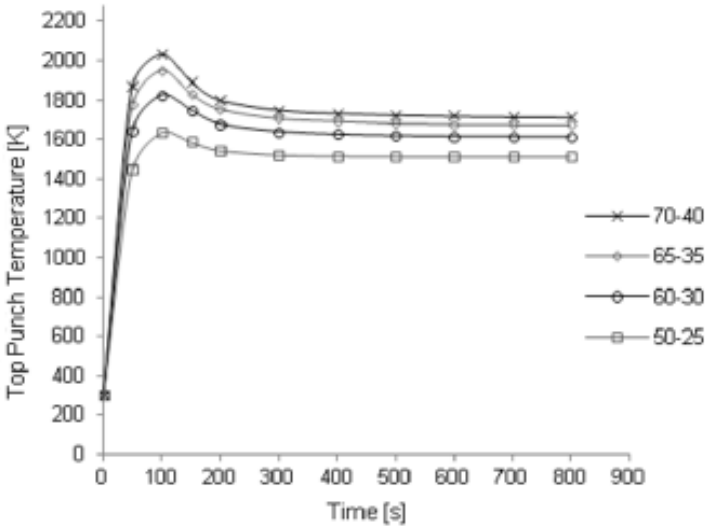
Microstructure Variation

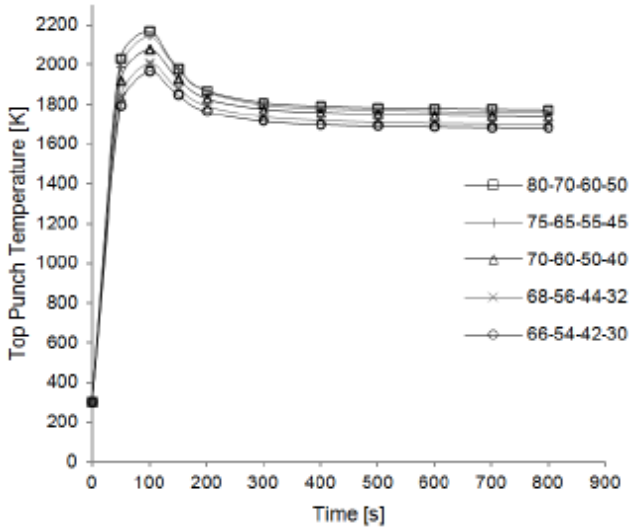


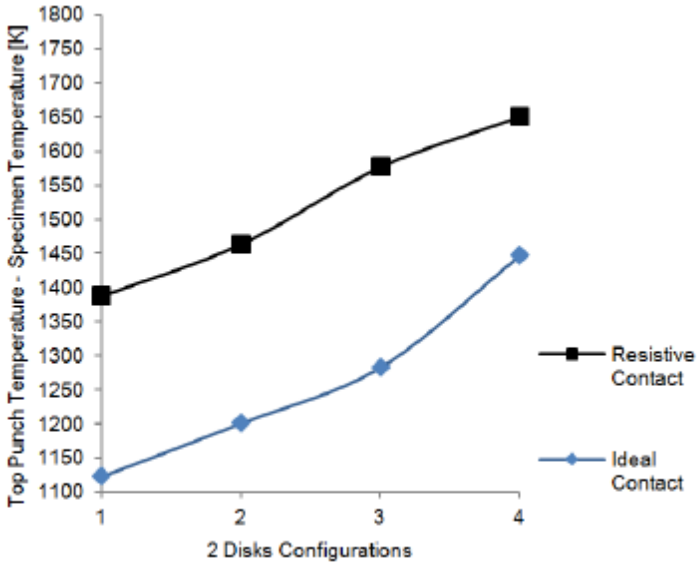


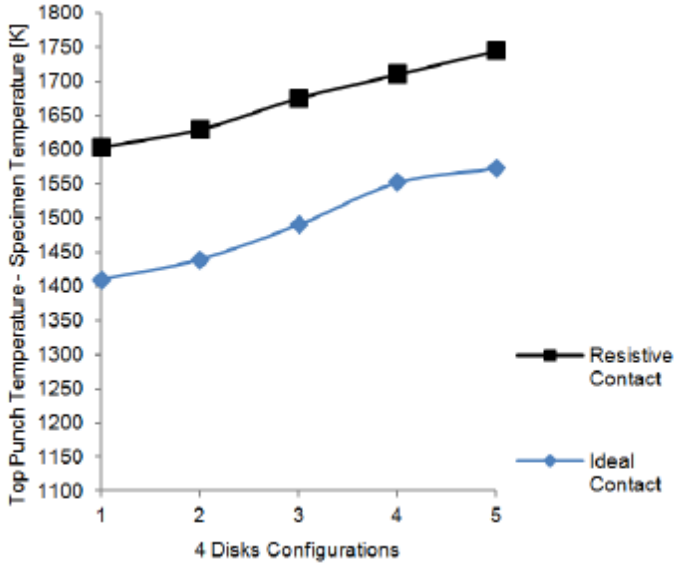
Y.-S. Lin, M. A. Meyers, and E. A. Olevsky, Adv. App. Ceram., 111, 269-274 (2012)

Overheating Phenomenon





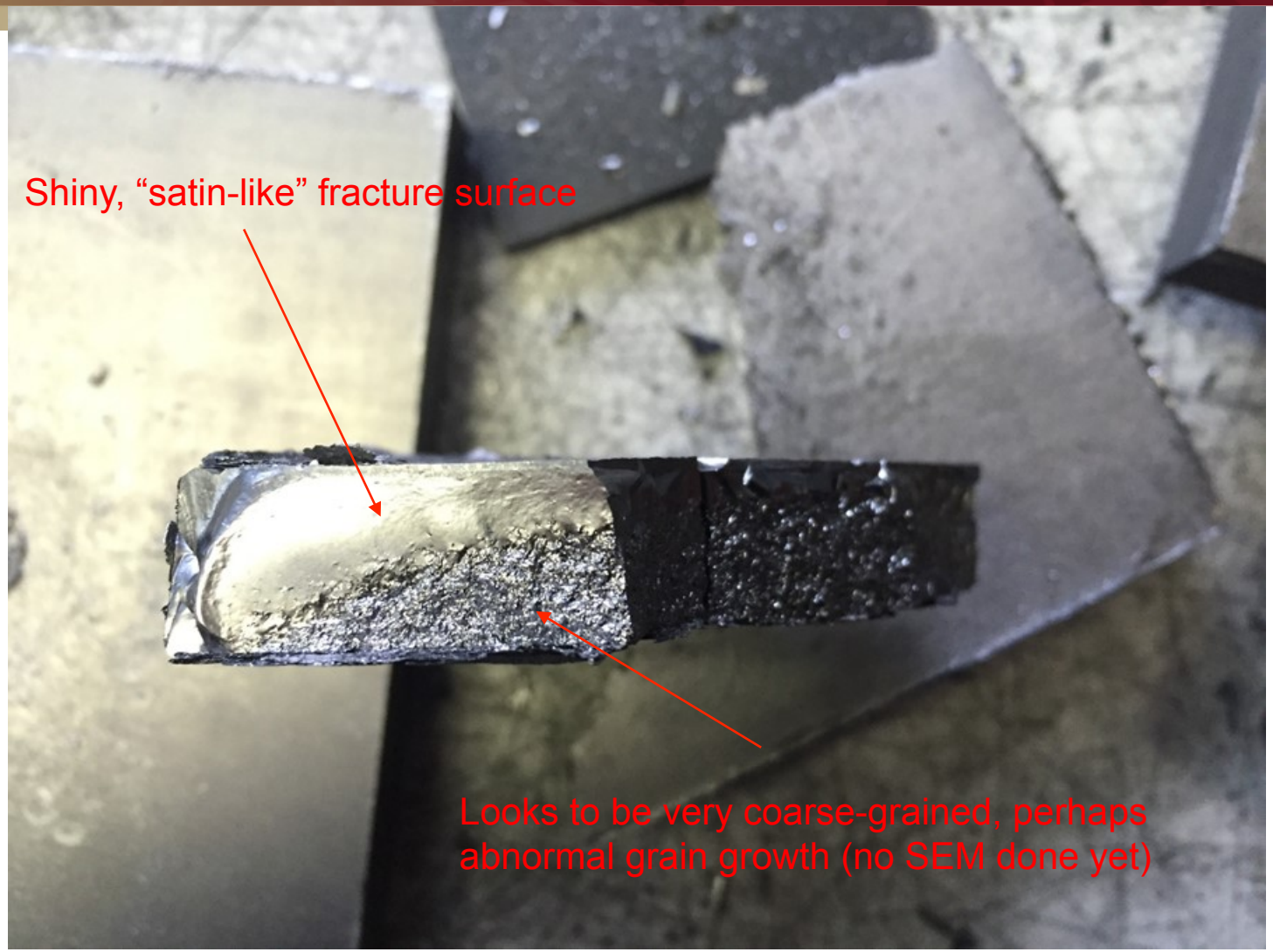




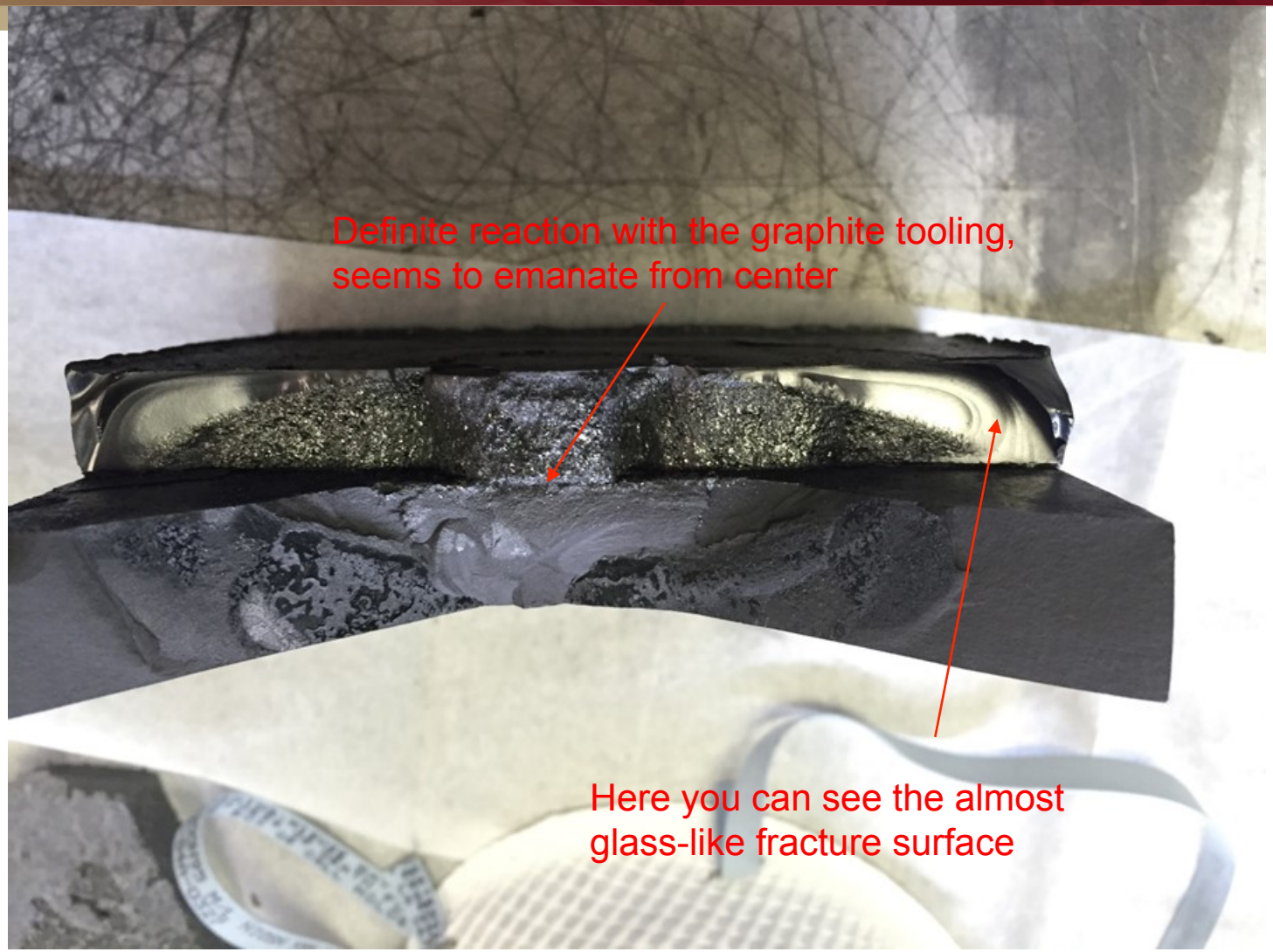
When things go bad…

Violent Reactions

B_4C Anomaly



B_4C Anomaly



B_4C Anomaly

Overheating

Conclusions

- FAST is a highly emerging technology, however there are major challenges with scale up
- It's applicability to DoD applications has been matured significantly over the past 5 years
- While FAST is starting to be utilized in industry, the fundamental mechanisms are still not completely understood (needs significant investment in M&S)
- FAST is quickly maturing into viable manufacturing technology for NNS, multifunctional and functionally graded materials

Acknowledgements

- Funding for a majority of this work was from an OSD DMS&T program on Field Assisted Sintering Technology.

- Mr. Robert Aalund from Thermal Technology LLC for FAST/SPS locations and conversations on automation

- Mr Kendall Mills for being the “boots on the ground”