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RAPID REACTIVE JOINING FOR REFRACTORY AND DISSIMILAR MATERIALS

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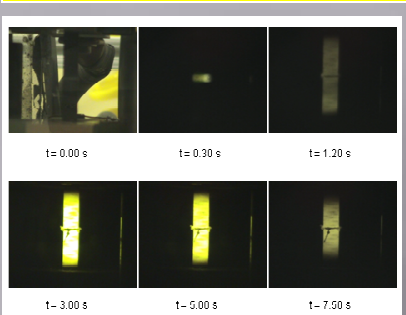
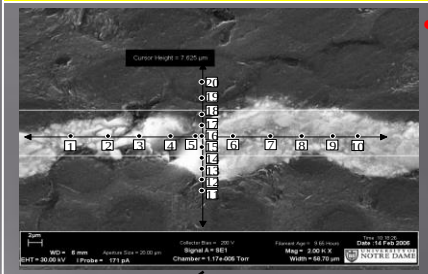
Joining of Refractory and Dissimilar Materials

Method is based on *rapid* (~seconds) *high temperature* (up to 4000 K) heterogeneous reactions

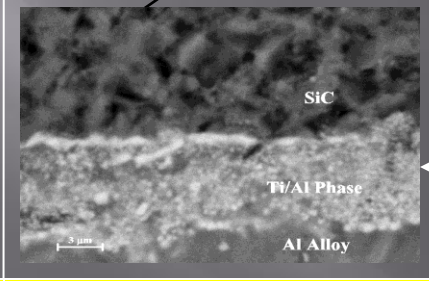


Allows joining of *refractory dissimilar* materials. For example:
- Carbon composite - Carbon;
- Silicon carbide – Metal alloys;
- Tungsten - Molybdenum

Current Accomplishments



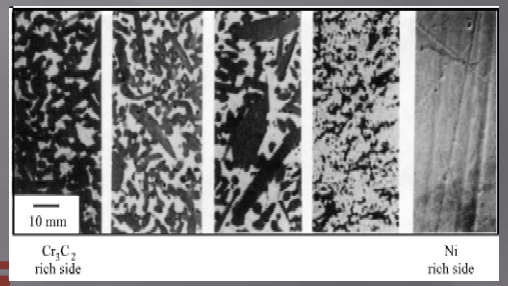
- Joining C – C composites
  - ← Carbon-Carbon Composite
  - ← Refractory joint layer
  - ← Carbon-Carbon Composite



- Joining Ceramic to Metal Alloy
  - ← Ceramics
  - ← Refractory joint layer
  - ← Aluminum Alloy

War fighter Benefit

- Reactive Joining for Lightweight Armor
- On Field Repair of Armor
- Synthesis of Novel Functionally Graded Materials



System Level Payoffs

Gain critical understanding of the joining process:
- What are the dominant mechanisms for joining of dissimilar refractory materials?
- How can the composition of the reactive layer be tailored to provide the desired properties of the joined materials?

Scientific Challenges

- Develop approach for spot-type welding of dissimilar refractory materials
- Developing rapid energy effective techniques for low cost on-field rapid repair of armor

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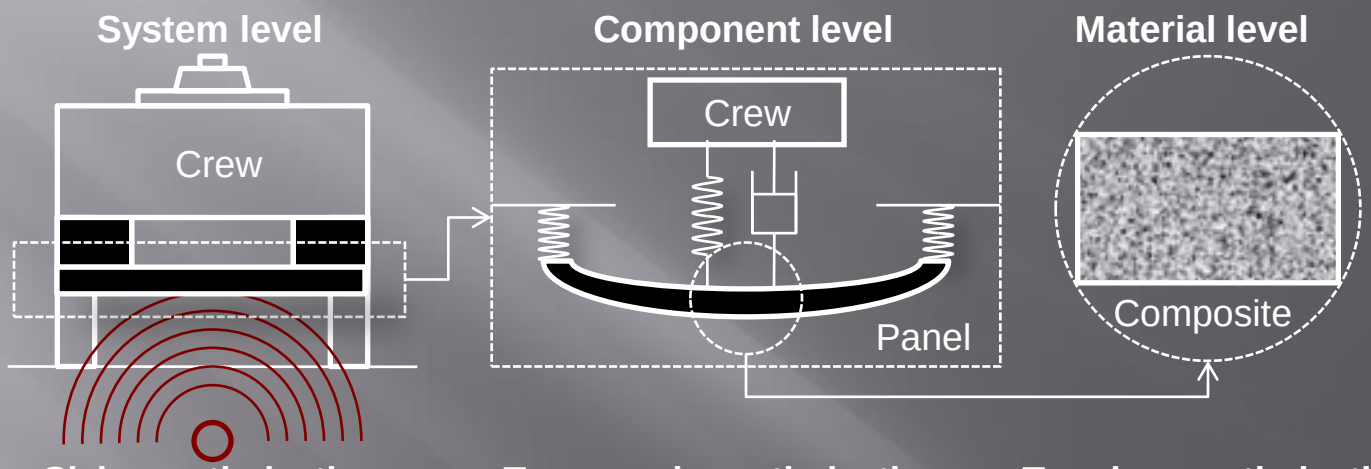
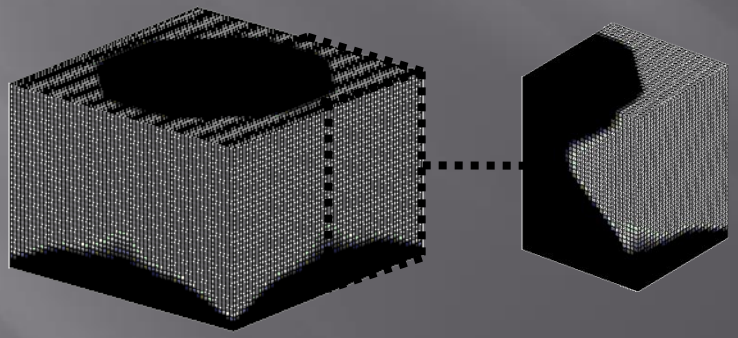
Design for blast mitigation

System, component, and material optimization





Topology optimization at material level

Optimum ceramic (black) – aluminum (white) cellular composite

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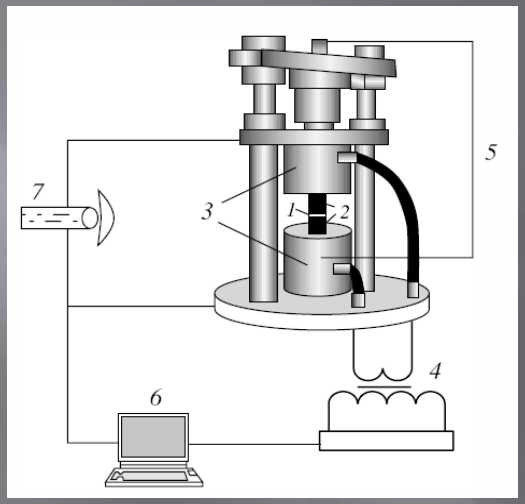
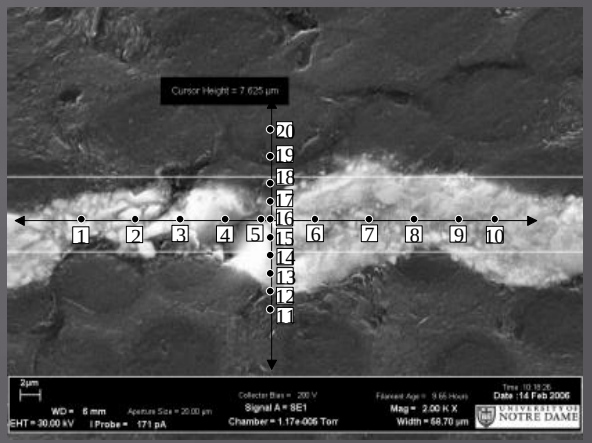
Reactive Resistance Welding

Low cost rapid joining of dissimilar refractory materials

C-C brakes





A thin layer of desired reaction composition is placed between two disks of the material to be welded

Preheating brings of the reaction mixture to the ignition temperature.

After initiation, a rapid (up to 10^4 K/s) high temperature (up to 3000 K) reaction occurs in a thin layer in the vicinity of the joint, leading to chemical interaction between the melt and disks to be joined.

A rapid press allows instant loading of the stack: enhancing the mechanical properties of the joint.

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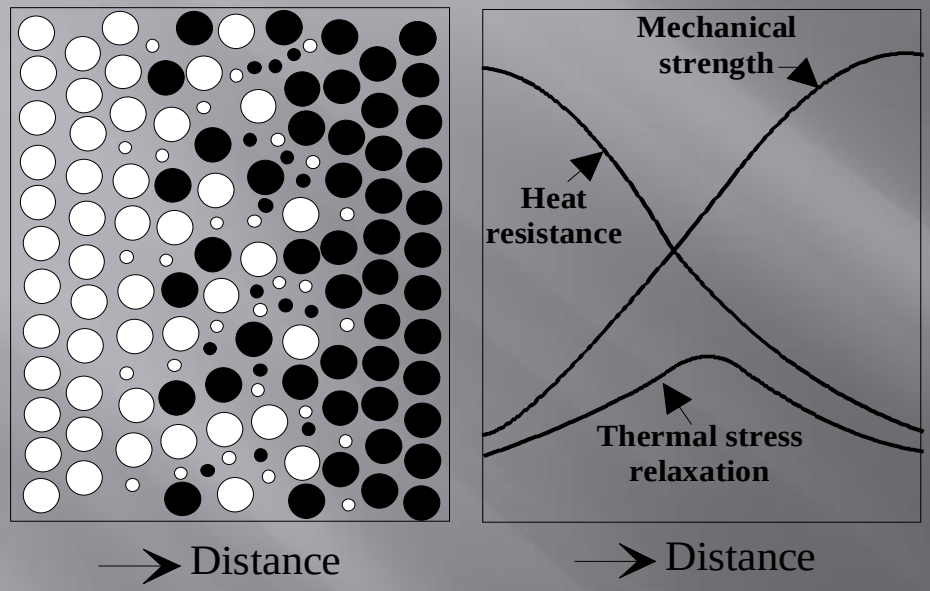
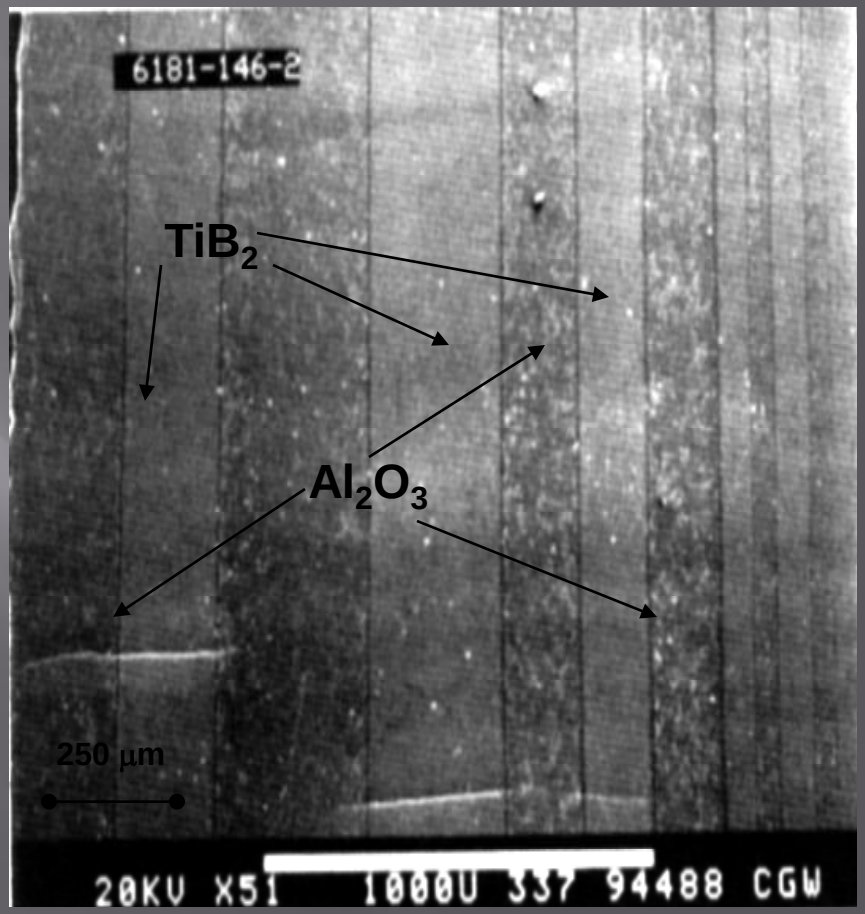
Functionally Graded Materials





Local tailoring of properties – need to preserve gradients and limit long range diffusion

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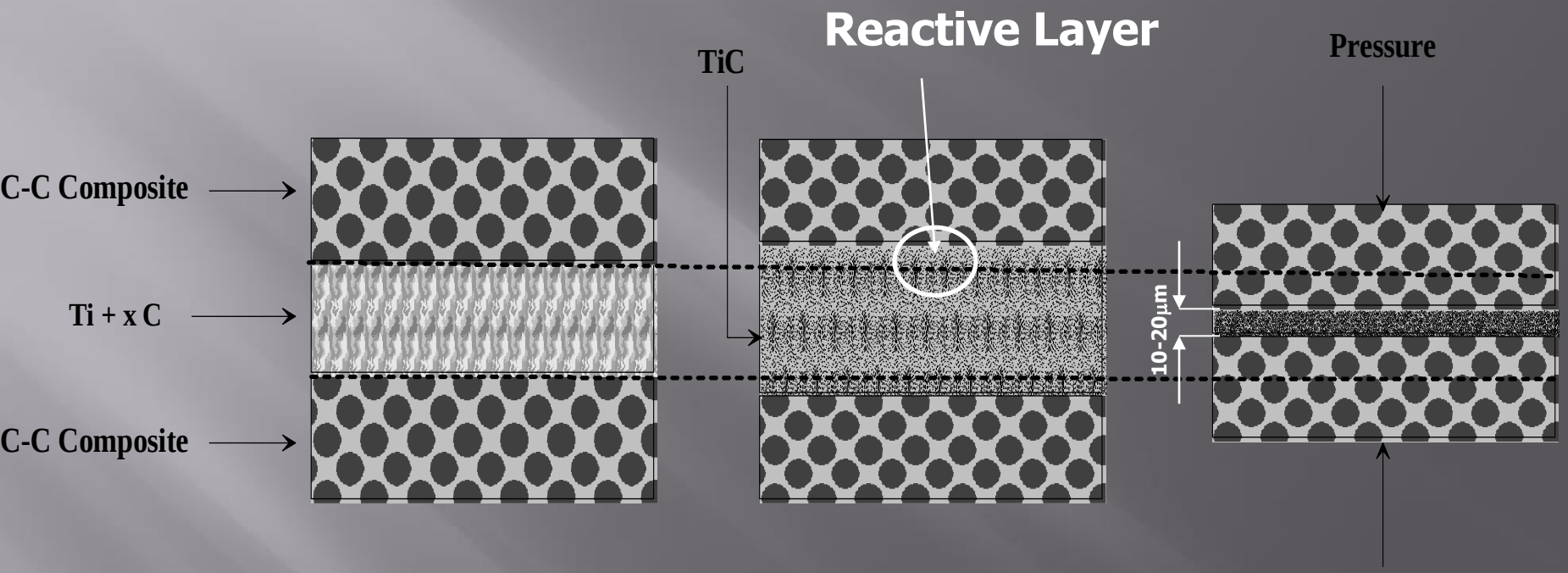
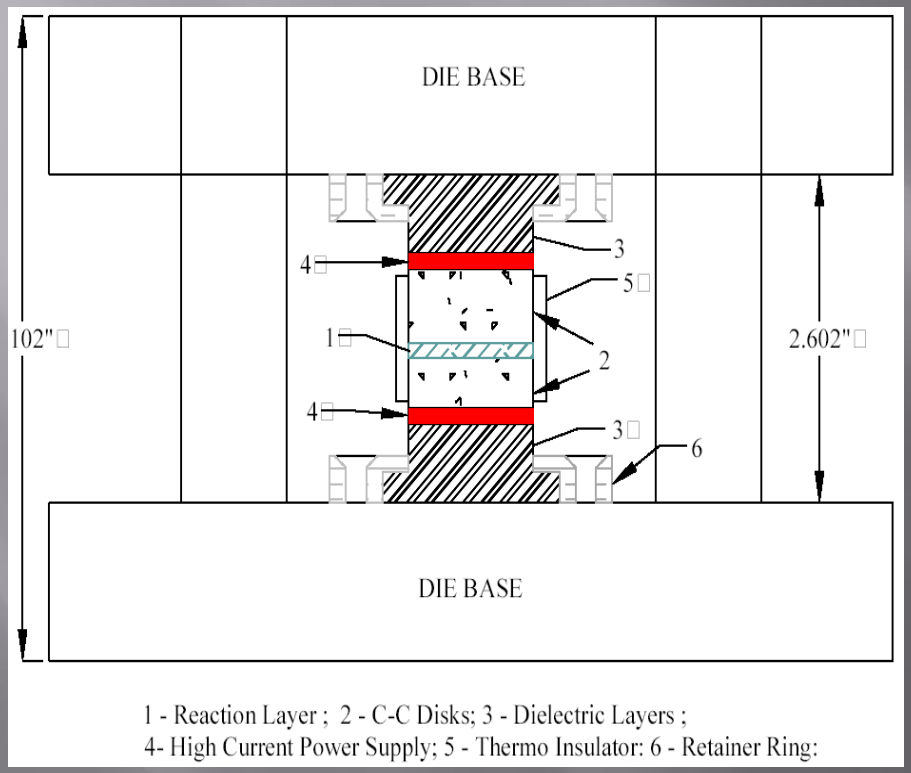
Concept of Reactive Joining

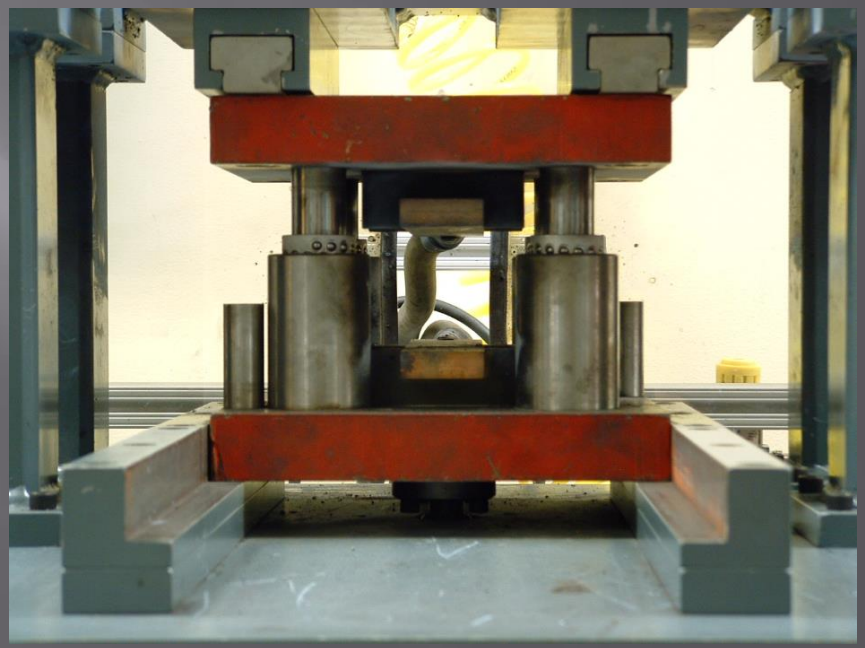


Chemical interaction between C-C composite and reactive media

Press Die for Rapid Reaction Joining

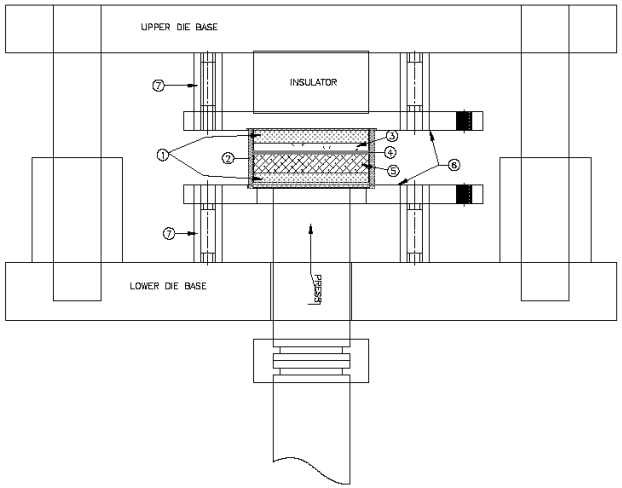


1 - Reaction Layer ; 2 - C-C Disks; 3 - Dielectric Layers ;
4- High Current Power Supply; 5 - Thermo Insulator: 6 - Retainer Ring:



Reaction zone observable: measure temp.!

Set-Up for Rapid Reactive Joining



NO.	ITEM
1	SILICON OXIDE
2	GRAFITE RING
3	SILICON CARBIDE
4	BONDING AGENT
5	ALUMINUM DISK
6	COPPER ELECTRODE
7	INSULATOR

3”

Hexagonal tile for large plates testing

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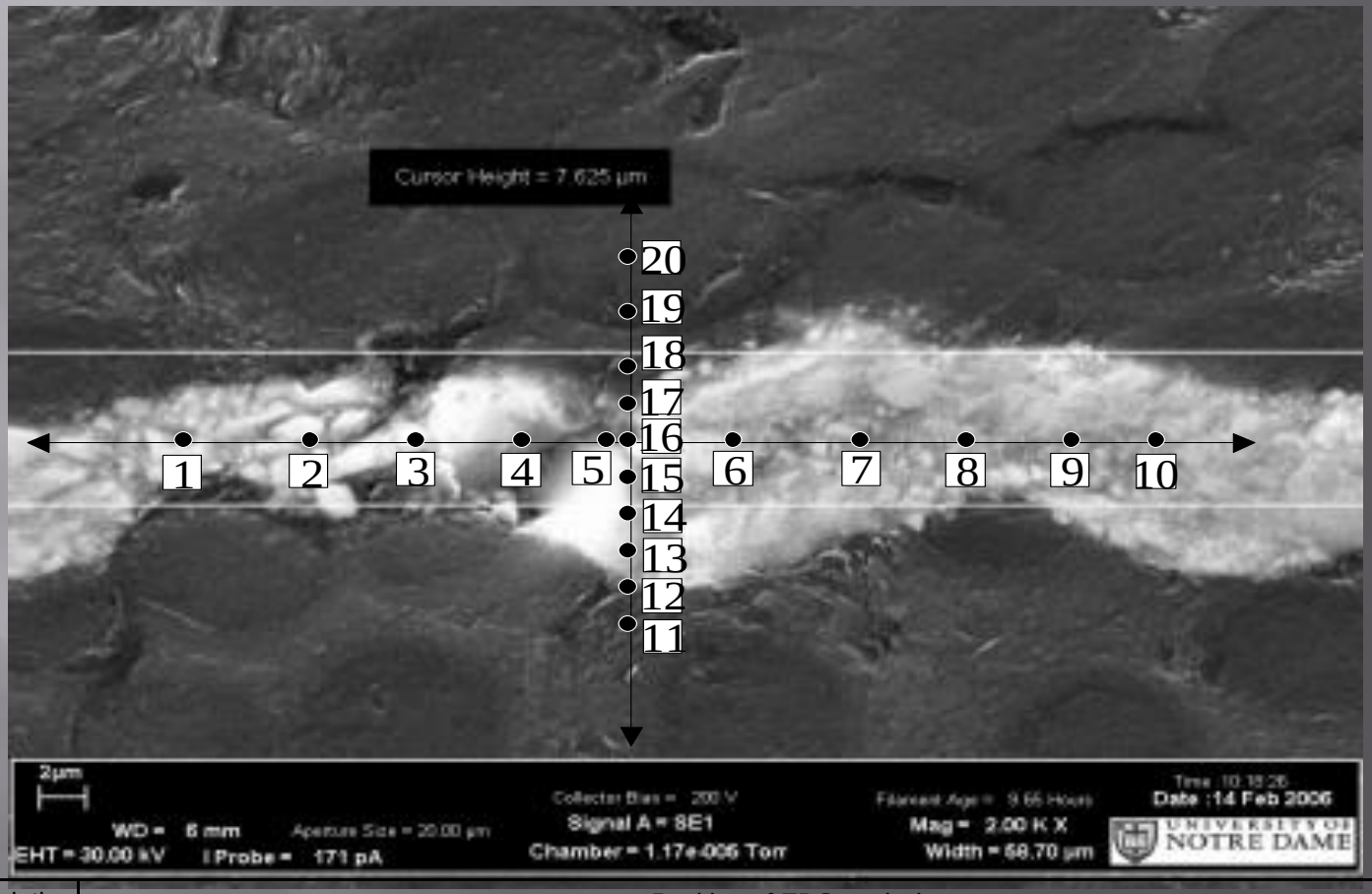
Joining of the Refractory Composites



Direction relative to joint layer	Position of EDS analysis									
	Element concentration wt. %; Ti / C									
Along	1	2	3	4	5	6	7	8	9	10
	76.9 / 23.1	78.5 / 21.5	76.7 / 23.3	80.9 / 19.1	78.5 / 21.5	65.5 / 34.5	73.7 / 26.3	68.2 / 31.8	76.0 / 24.0	76.3 / 23.7
Normal	11	12	13	14	15	16	17	18	19	20
	9.0 / 91.0	26.9 / 73.1	58.7 / 41.3	76.2 / 23.8	79.5 / 20.5	81.3 / 18.7	73.0 / 27.0	41.4 / 58.6	21.3 / 78.7	8.2 / 91.8

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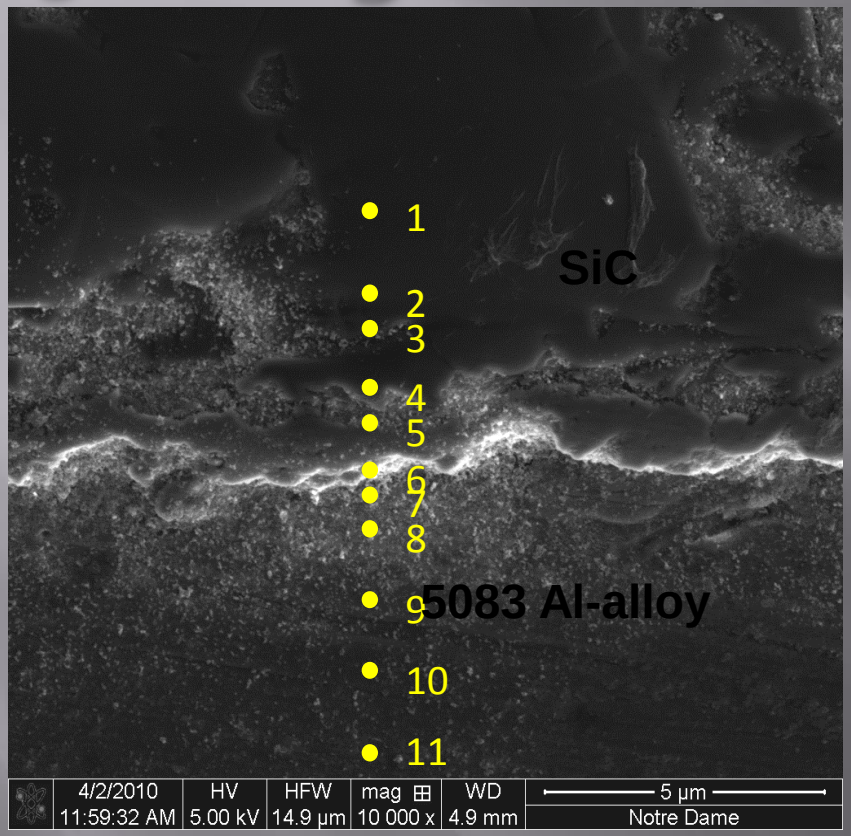
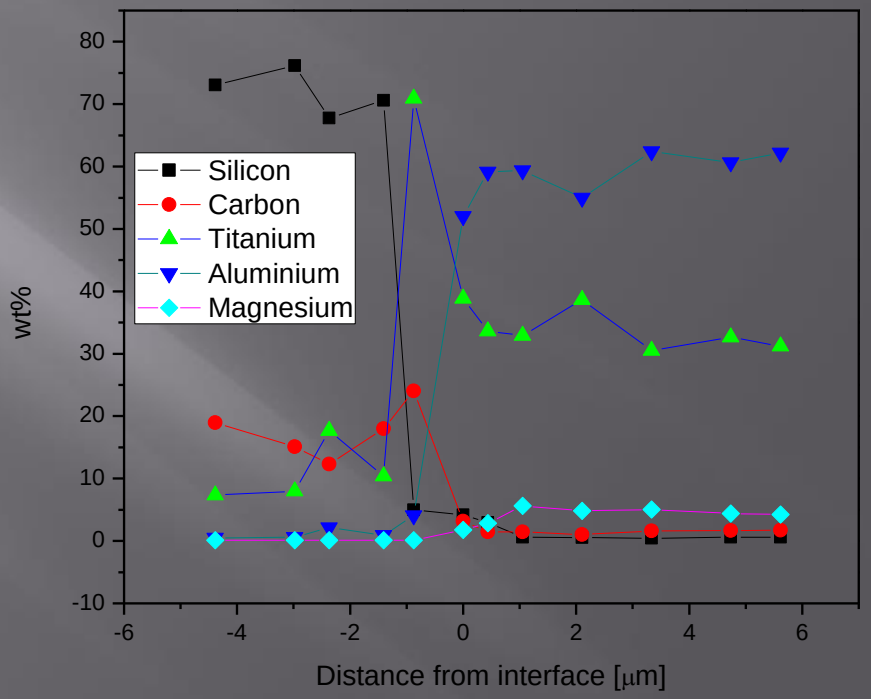
Joining of the Dissimilar Materials





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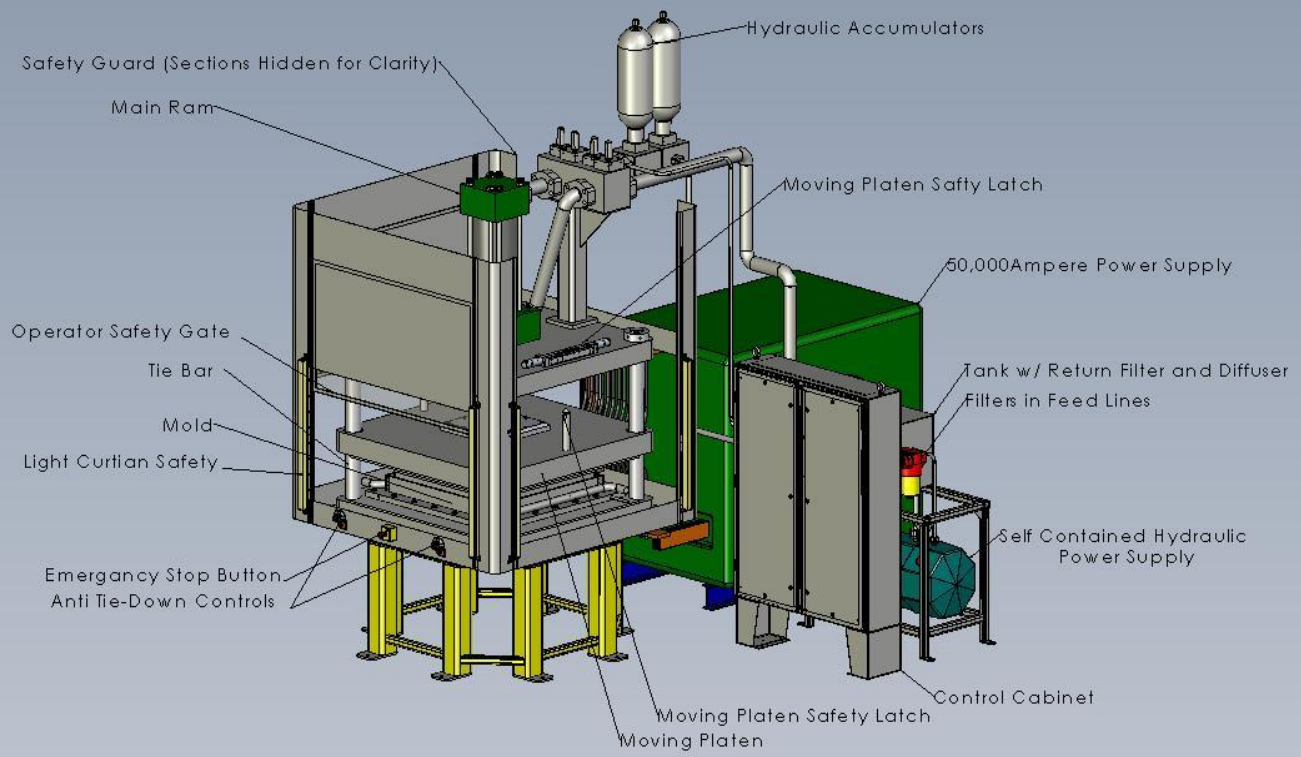
Industrial Machine for RRJ



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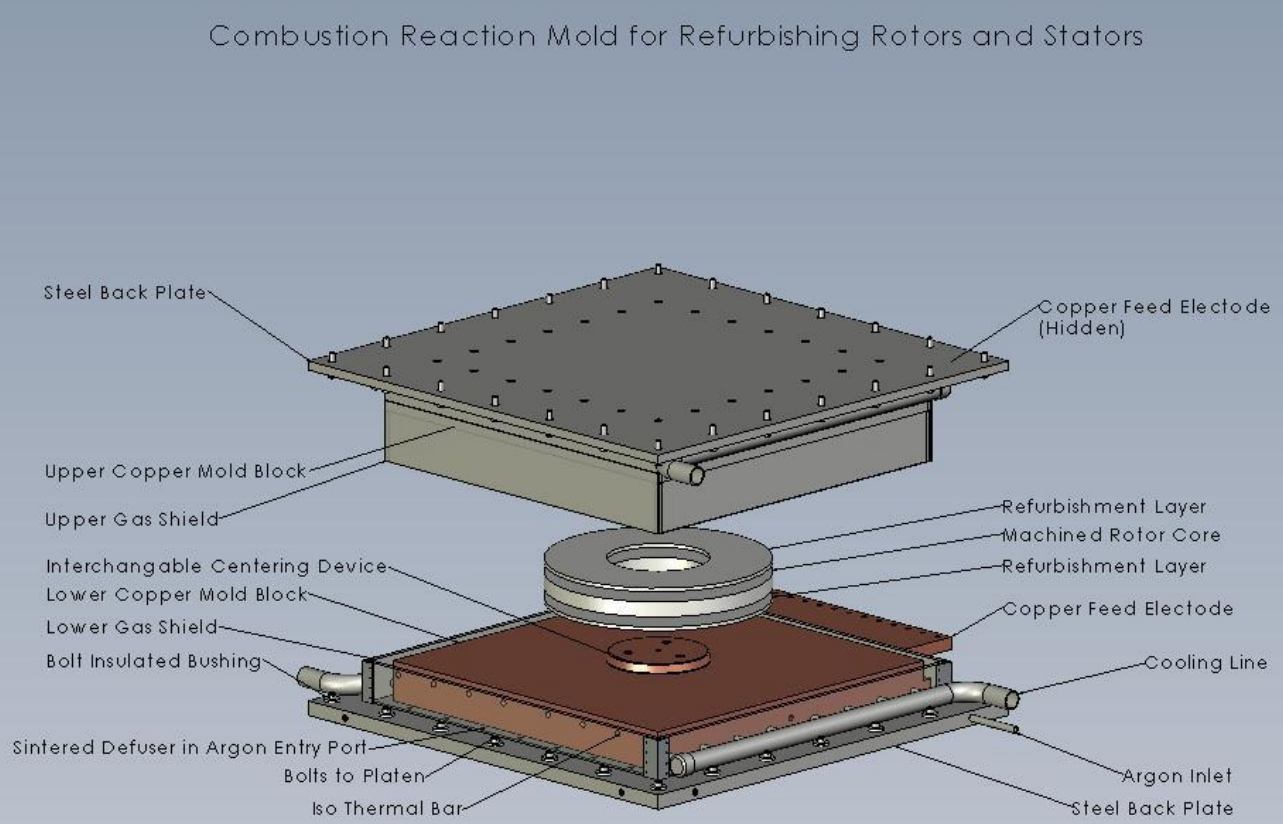
Scaling Up - Die



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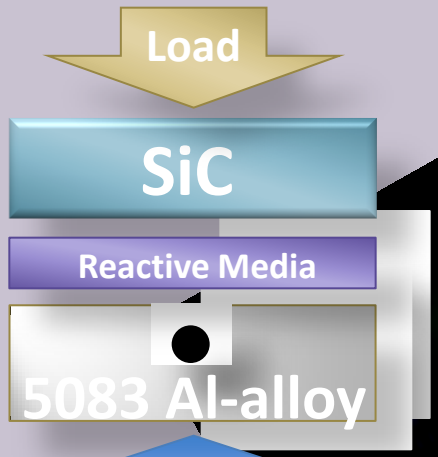
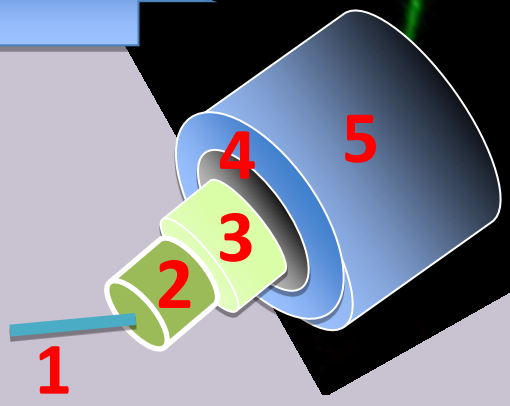
Sensor embodiment

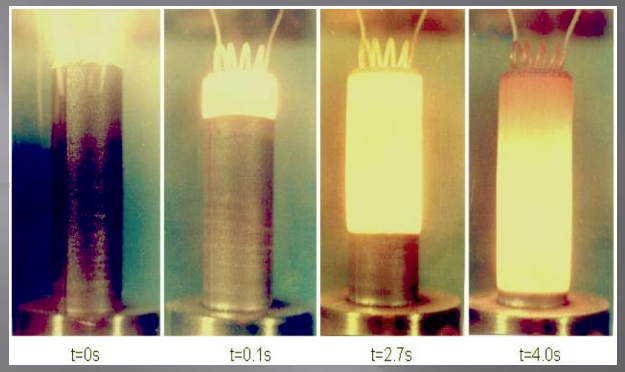


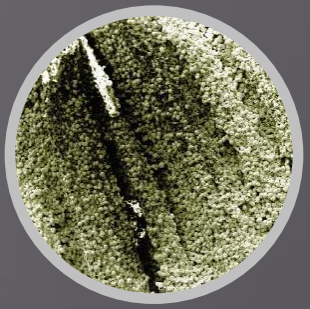


1. Core: 8 μm dia.
2. Cladding: 125 μm dia.
3. Buffer: 250 μm dia.
4. Jacket: 400 μm dia.
5. Refractory coating

Rapid Reactive Joining

| High temperatures (> 2000 K) | High temperature gradients (up to 106 K/s) |
| Short reaction times (0.1-10 s) | Low energy consumption | Simple equipment |





Ability to join in different atmospheres with preliminary preheating

produce composite (metallic-non-metallic) nano-layers on the polymer fiber surface.