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CEFAS Poster for Advanced Manufacturing Workshop 3/26/24

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Changing the World's Energy Future

Andrew James Gorman

Idaho National Laboratory

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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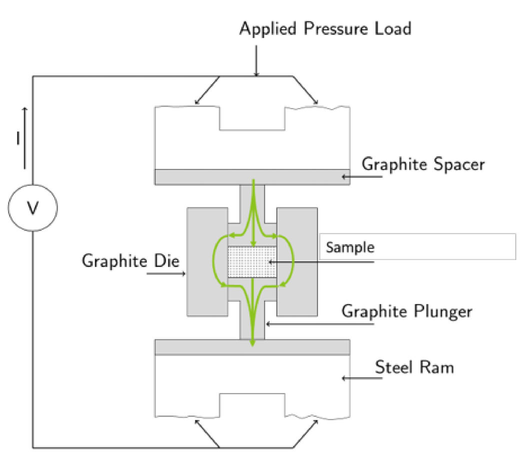
Continuous Electric-field Assisted Sintering (CEFAS) Prototype for Industrial Scaleup

Electric-field assisted sintering (EFAS) is an advanced manufacturing method for the consolidation and processing of ceramic and metal materials. It is a particularly excellent candidate for efficient materials processing as it has greater than 90% energy cost savings and improved CO_2 emissions compared to traditional sintering in a furnace. This is due to direct rapid heating of the materials and molds leveraging an electrification phenomenon called Joule heating where electrical current is passed through the sample/mold assemblies causing direct heating. The technique does have limitations though as it is traditionally a batch-process and suffers from scale up difficulties. To overcome this, researchers at Idaho National Laboratory changed the form factor of traditional EFAS instruments to develop and construct a continuous rolling electric-field assisted sintering (CEFAS) device.

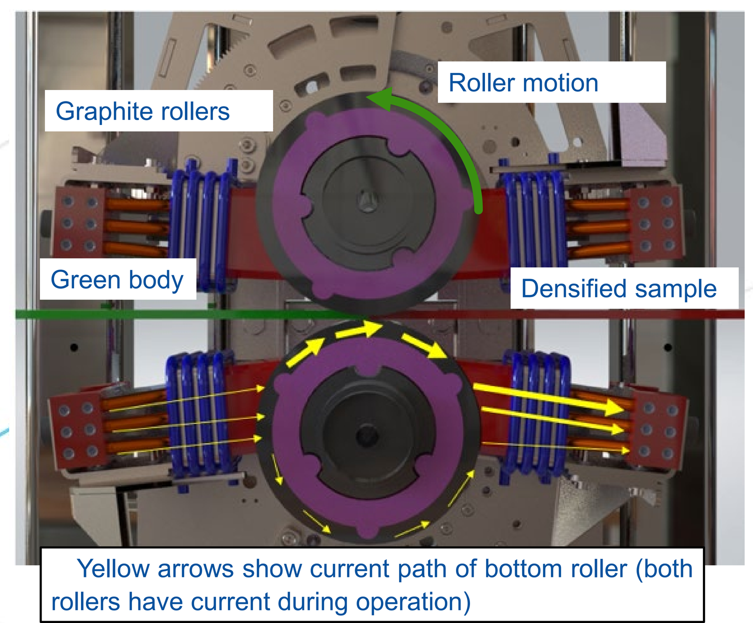
Electric-field Assisted Sintering

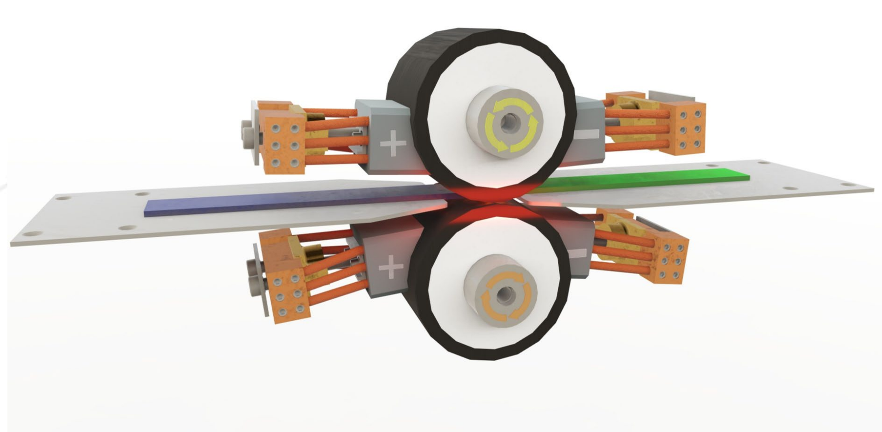
Electric current creates localized heating by passing electric current through *a graphite die* surrounding a sample. The Joule heating is combined with uniaxial stress from rams which consolidates ceramic or metal powders into fully dense parts.

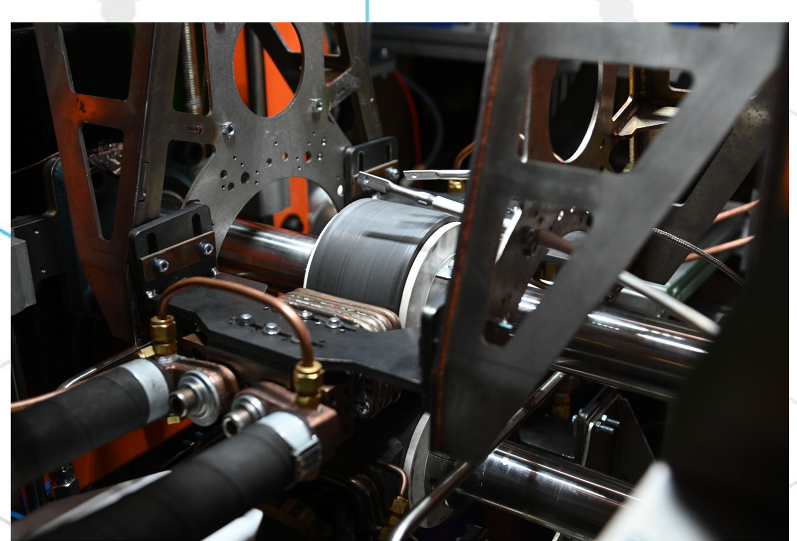


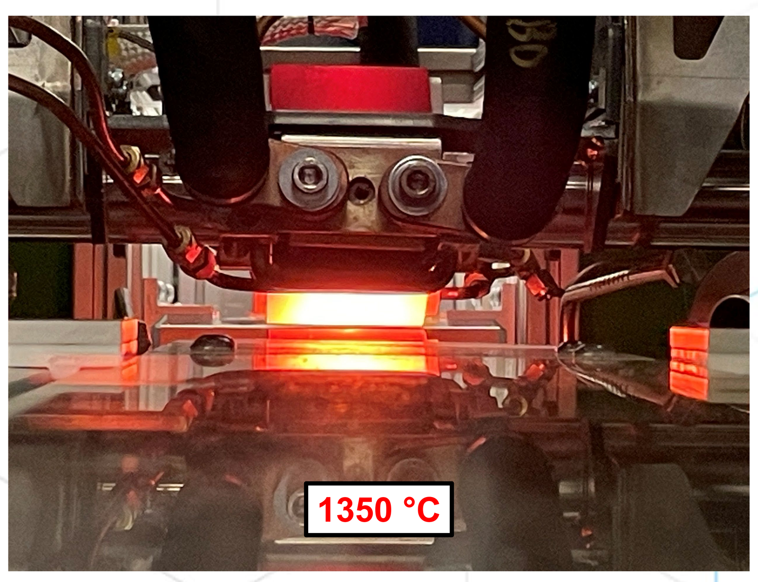
Continuous Electric-field Assisted Sintering

Electric current creates localized heating by passing electric current either 1) *across* the rollers or 2) *between* the rollers and through the sample. The Joule heating is combined with uniaxial and shear stresses which consolidates the green bodies into fully dense parts





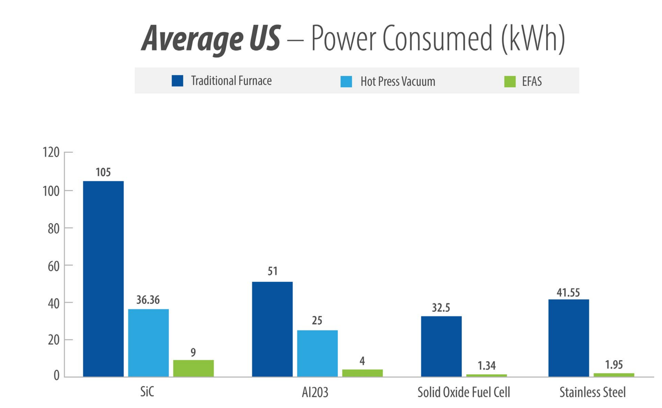




Why EFAS?

Benefits

- **Reduced time and cost**
  - **from traditional sintering ≈ 90%**
  - **from hot pressing ≈ 70%**
- Rapid sintering cycles
  - < 1 hour for research sized sample; 1+ hours for 12" parts
- Relative ease to reach high temperatures up to 2,500 °C
- Highly non-equilibrium, allowing sample quenching
- Usable with many materials systems
- Manipulation of the heating profile by modification of spatial current density
- Unique electrical field affects/mechanisms
- Fully dense samples almost always possess reduced final grain size compared to traditional methods



	CO_2 emissions for a single part consolidation (kg)			Energy cost for a single part ($)			
	Furnace	Hot Press	EFAS[6]	Furnace	Hot Press	EFAS[6]	EFAS % Reduction
Silicon carbide[1,2,3, 5]	40.7	14.1	3.5	8.77	3.04	0.75	- 91%
Alumina[1,4,5]	19.8	9.7	1.6	4.26	2.09	0.33	- 92%
Solid oxide fuel cell[6]	12.6	--	0.5	2.71	--	0.11	- 96%
Stainless steel[6]	16.1	--	0.5	3.47	--	0.16	- 95%

Quick Facts

	Properties
Production type	Continuous
Forces	Uniaxial and shear
Current operating temperature	1350 °C
Current	6000 A per roller
Heating rates	< 1000 °C/min
Sample length	Unlimited
Sample width	≤ 75 mm
Processing time*	4 – 375 mm/min

* Highly dependent on material and sample geometries

Material Systems

Metallics	Ceramics	Composites
Steel	Zirconia based ceramics	Cermets
Titanium	Yttrium oxides	SOEC/SOFC
Refractory metals	Yttrium oxides	Ceramic metal matrix composites
High entropy alloys	Alumina	Metal matrix composites
Nickel based alloys	Nitrides	Fiber reinforced composites

References

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6. Calculated from DCS-5 system runs at INL

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