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3D Printed Carbon Fiber Reinforced Carbon: An energy efficient alternative to graphite EFAS tooling

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Changing the World's Energy Future

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Idaho National Laboratory

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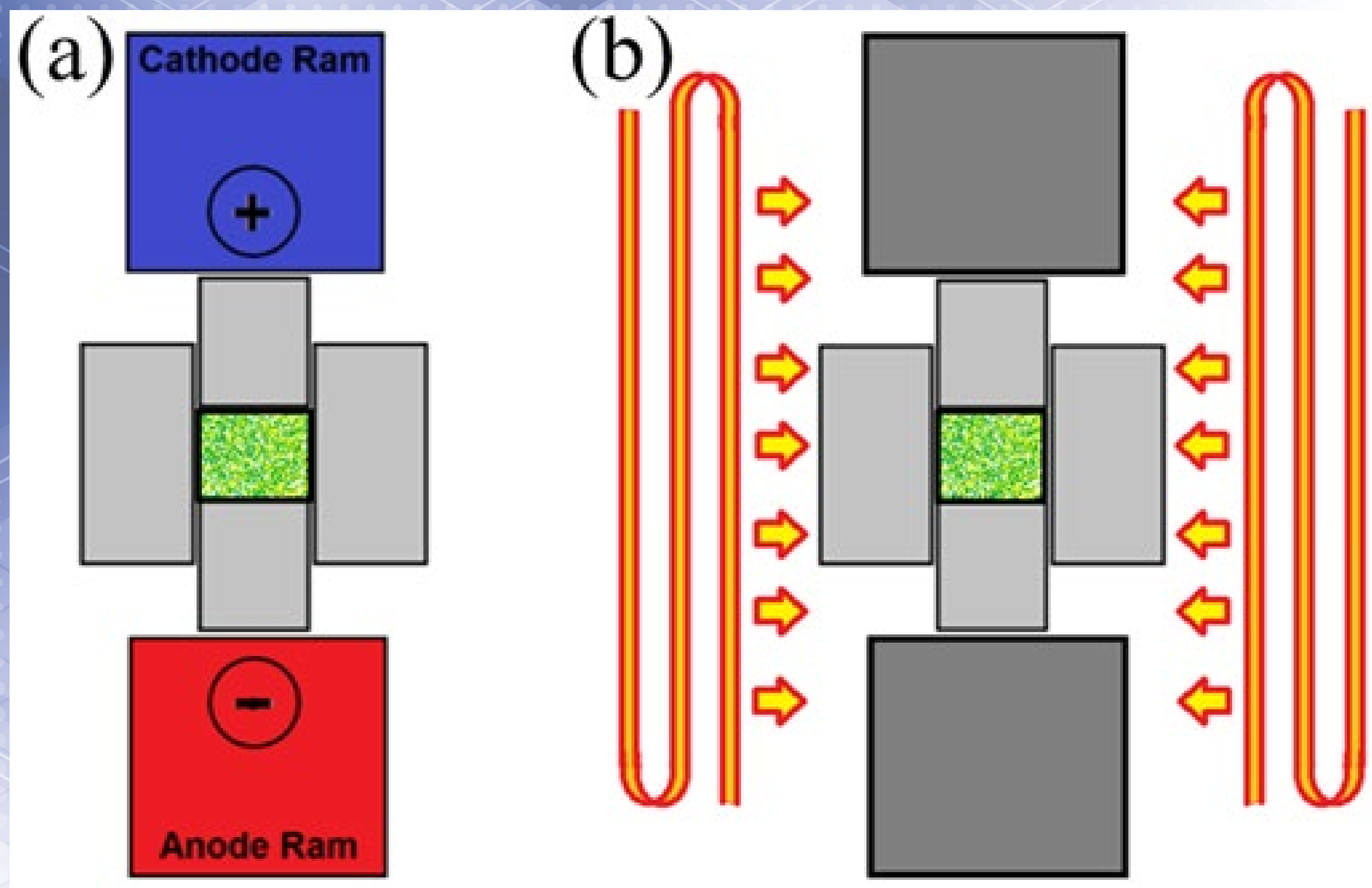
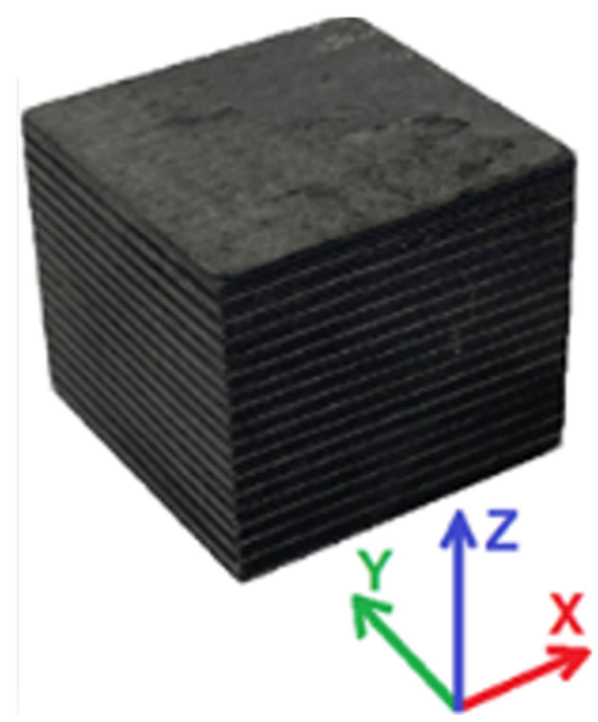
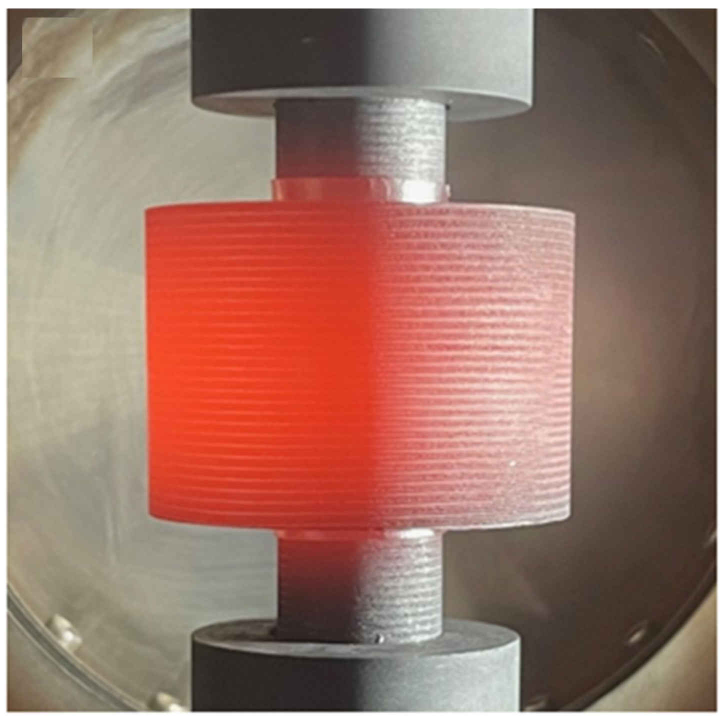
An Energy Efficient Alternative to Graphite EFAS Tooling

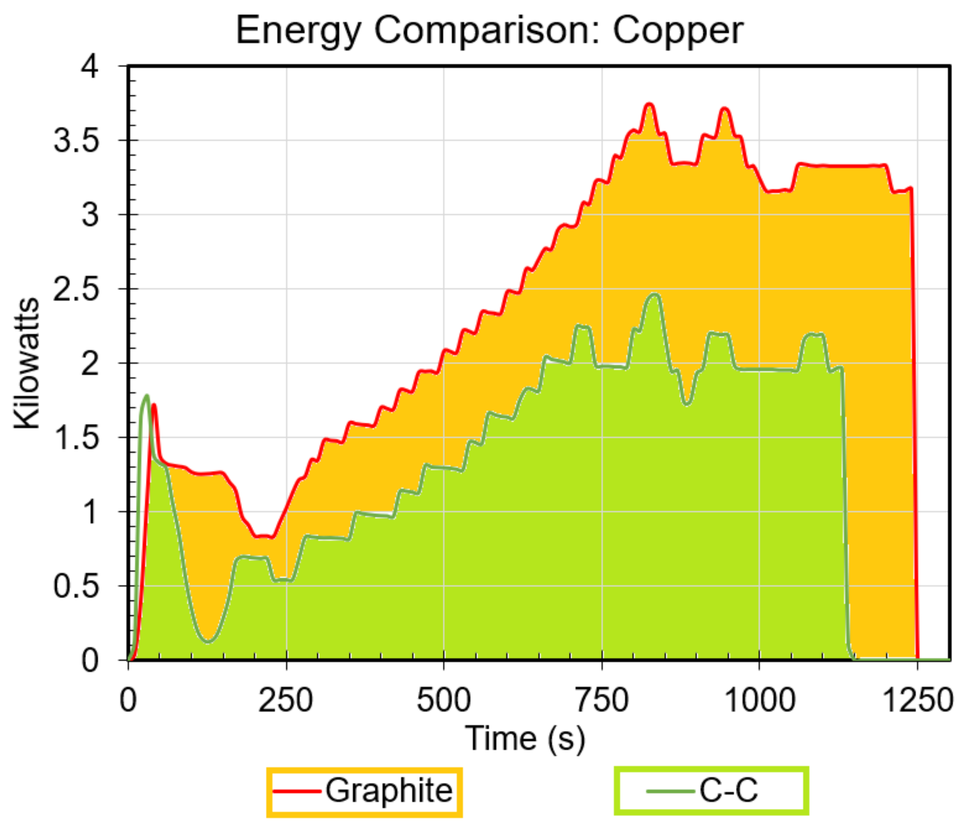


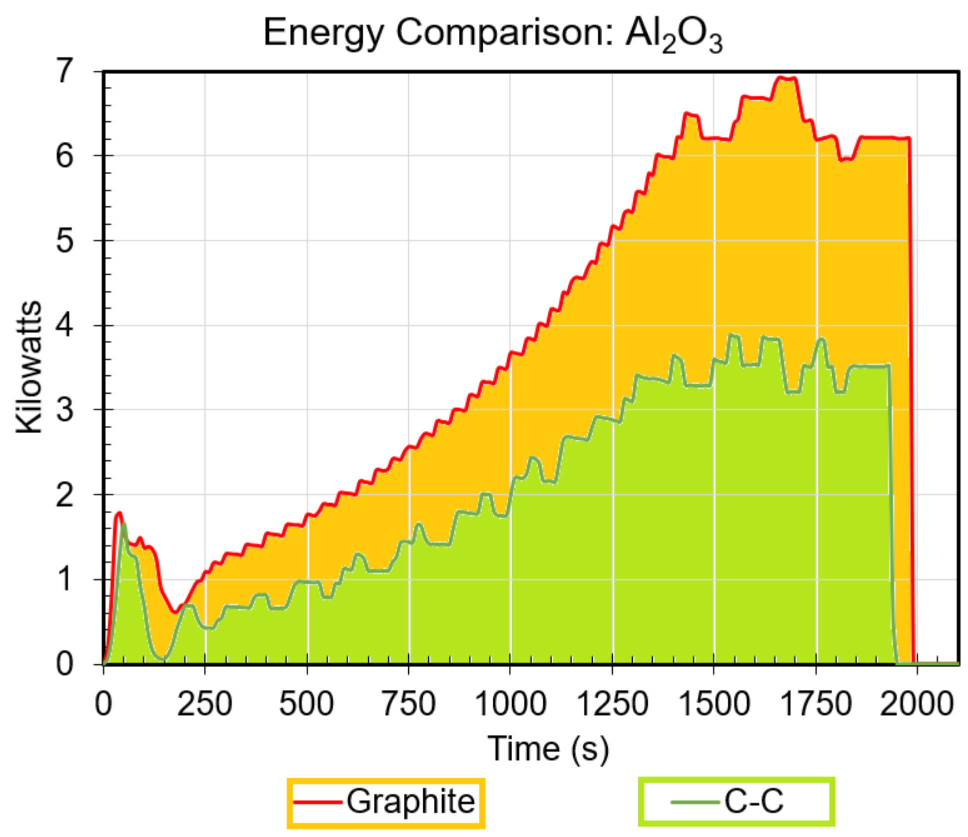
Schematic representations of a) Electric Field Assisted Sintering (EFAS), and b) hot pressing. EFAS uses the tooling itself as the heating element by means of Joule heating as current is passed through the system.

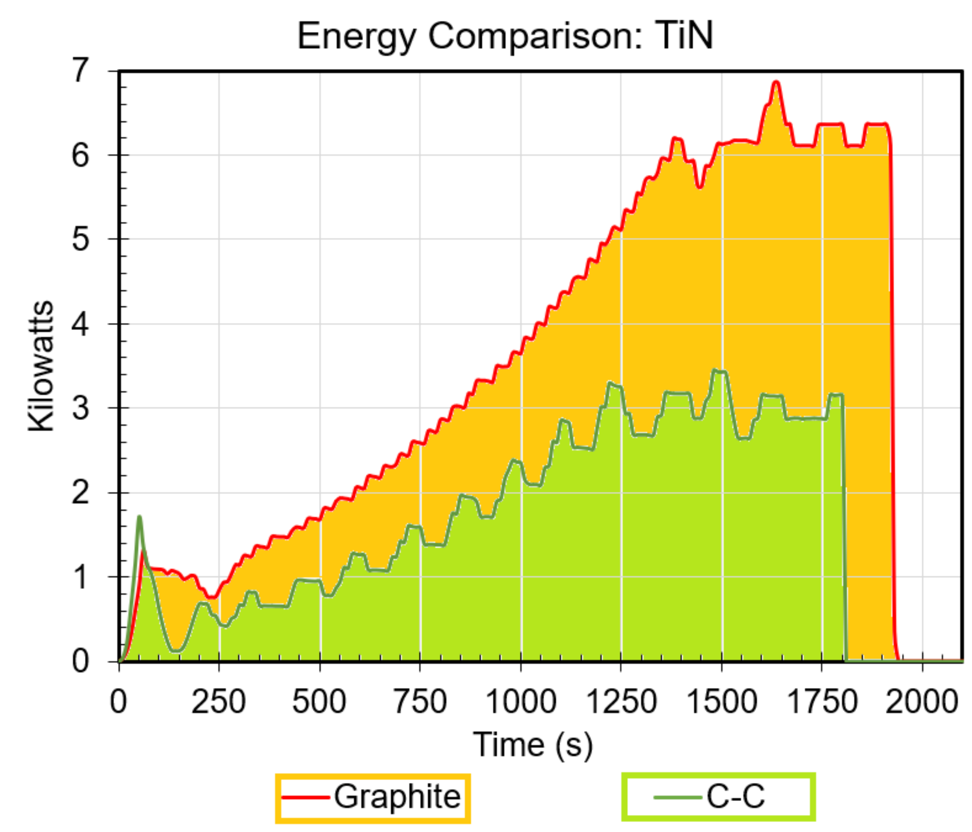
Carbon fiber preforms are printed in a Quasi-Isotropic layup, where the fibers are aligned to the X and Y axes, and ±45° in plane. Thermal and electrical conductivity values along the fiber axes are comparable to graphite but are extremely low through the Z axis. Low conductivity (high resistivity) in the axis of current flow enables more efficient Joule heating.





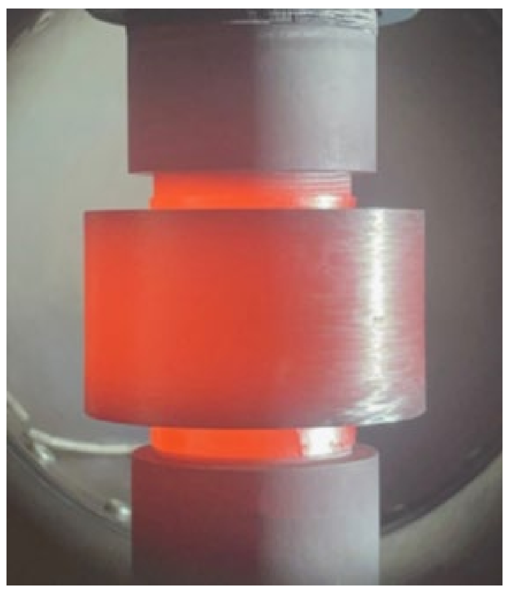






Energy usage with time for samples sintered in C-C tooling, compared to control samples run in identical graphite tooling under identical processing conditions. C-C tooling runs are shorter as a result of faster heating during the warmup step, in which a fixed current is passed through the tooling until it reaches 300 °C. Actual energy usage in kWh is listed in the table below, along with the resultant material properties and the ram temperatures recorded during sintering.

Tooling Type	Sintered Material	Grain Size (µm)	Density (g/cm^3)	Density (% Theoretical)	Energy Used (kWh)	% Difference	Max Ram Temp. (°C)	% Difference
Graphite	Copper	11.00	8.89	99.2	0.828	n/a	239	n/a
C-C	Copper	10.10	8.87	99.0	0.457	-44.8	155	-35.1
Graphite	Alumina	0.861	3.86	97.7	2.095	n/a	360	n/a
C-C	Alumina	0.722	3.79	95.9	1.114	-46.8	241	-33.1
Graphite	Titanium Nitride	0.332	5.23	99.8	1.979	n/a	358	n/a
C-C	Titanium Nitride	0.297	5.21	99.4	0.940	-52.5	224	-37.4



Scale up to larger tooling, and experimentation with fiber orientation is underway. 32 mm (left) and 75 mm tooling (right) has been created and tested. Energy savings have been shown to be comparable to that found in the 20 mm tooling comparisons. 150 mm tooling is currently being fabricated.

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