Abstract

Damage Characterization in SiC/SiC Composites using Electrical Resistance

SiC/SiC ceramic matrix composites (CMCs) under creep-rupture loading accumulate damage by means of local matrix cracks that typically form near a stress concentration, such as a 90° fiber tow or large matrix pore, and grow over time. Such damage is difficult to detect through conventional techniques. Electrical resistance changes can be correlated with matrix cracking to provide a means of damage detection. Sylramic-iBN fiber- reinforced SiC composites with both melt infiltrated (MI) and chemical vapor infiltrated (CVI) matrix types are compared here. Results for both systems exhibit an increase in resistance prior to fracture, which can be detected either in situ or post-damage.

Damage Characterization in SiC/SiC Composites using Electrical Resistance

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Procedure

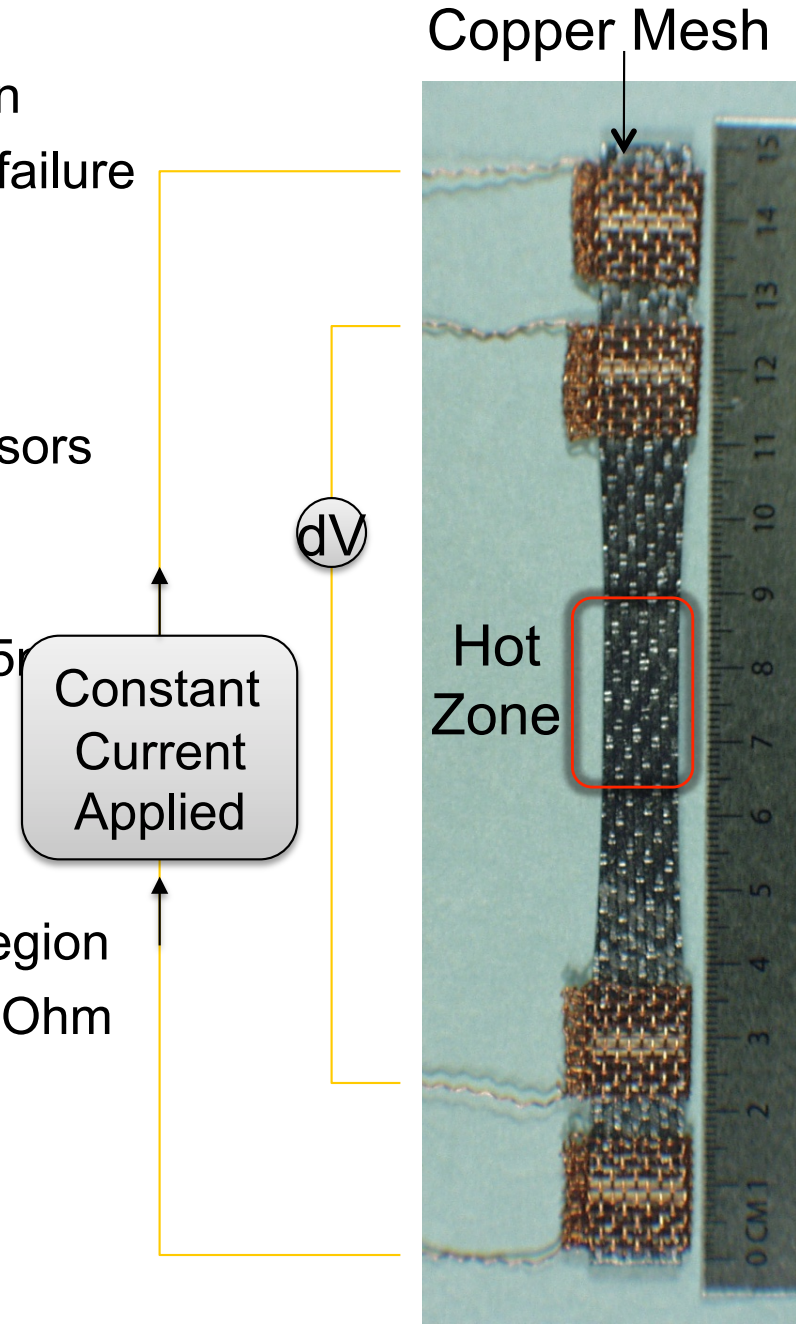
- 150 mm long specimens with contoured gage section
  - Room Temperature: Load/ unload hysteresis to failure at 4 kN/min
  - Elevated Temperature: Fast fracture and creep

- Acoustic emission monitored by 50kHz to 2MHz sensors just outside the gage section (room temp)

- Capacitance strain gage used with 1% range over 25r (does not interfere with resistance measurement)

Resistance measured by four- point probe method

- Silver paint on surface and copper mesh in grip region
- Resistance monitored with Agilent 34420A micro-Ohm meter
- Gripped with Alumina wedge grips (for electrical insulation)

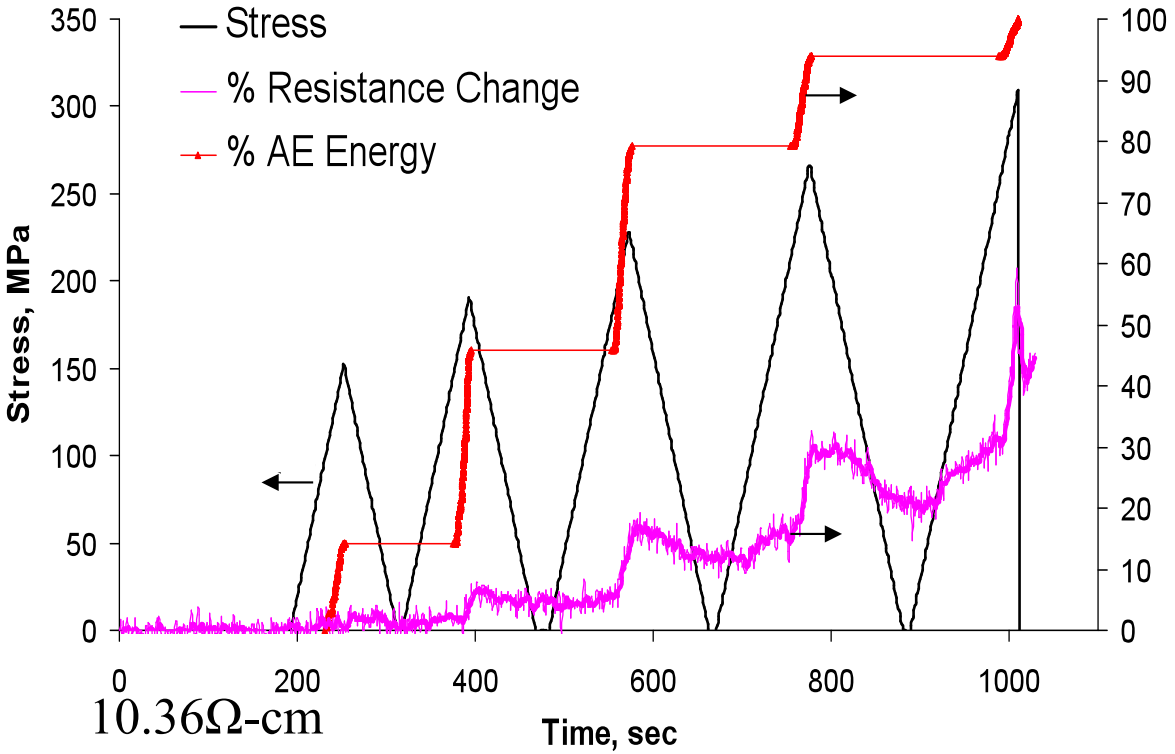


Room Temperature Damage Characterization

Syl-iBN/CVI Matrix Woven Composite (f = 0.3)

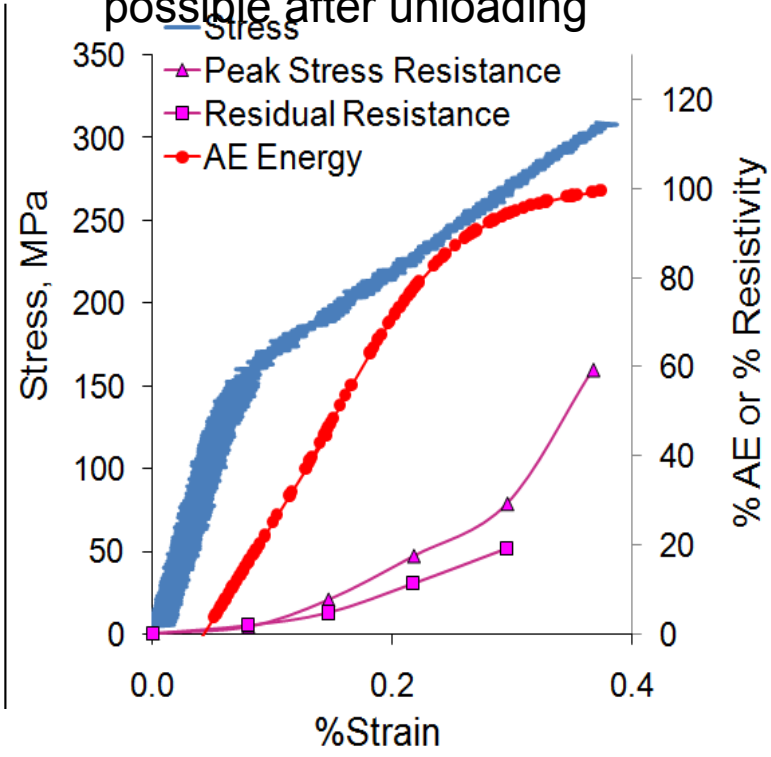
In situ resistance monitoring is possible

60% increase in resistivity at failure for CVI



Resistance is permanently affected

Inspection of damage is possible after unloading



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Room Temperature Damage Characterization

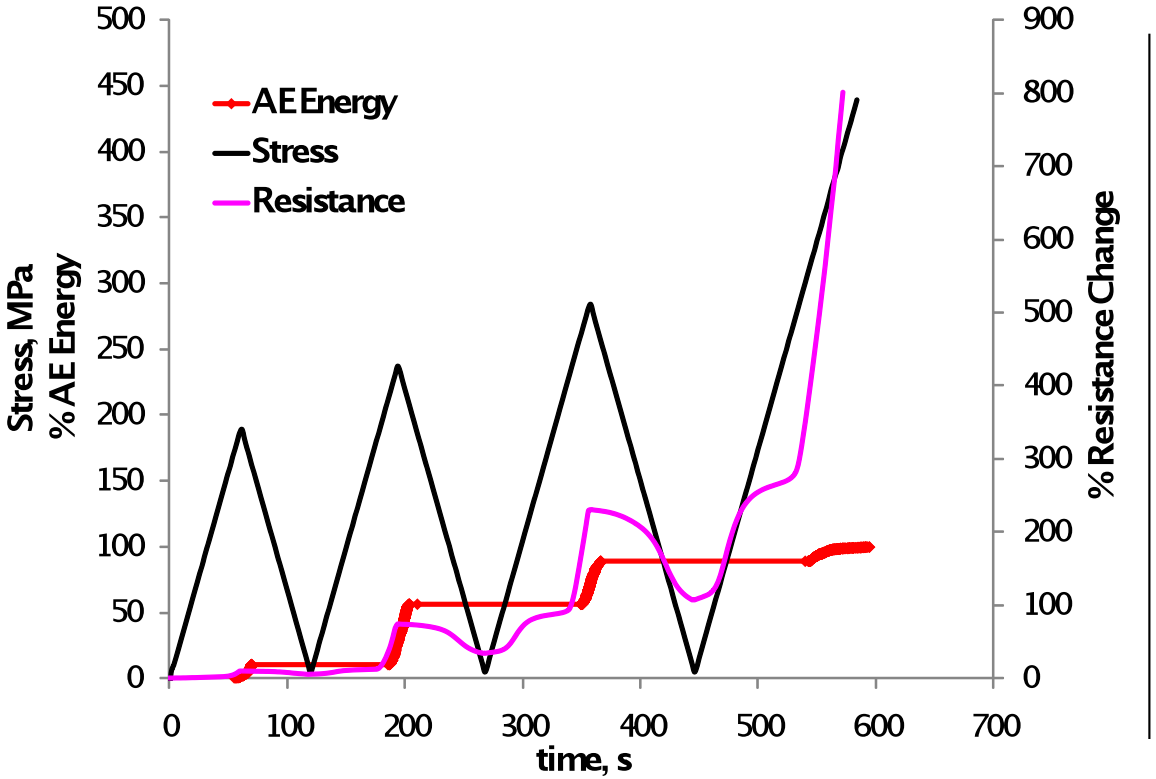
Syl-iBN/MI Matrix Woven Composite (f = 0.35)

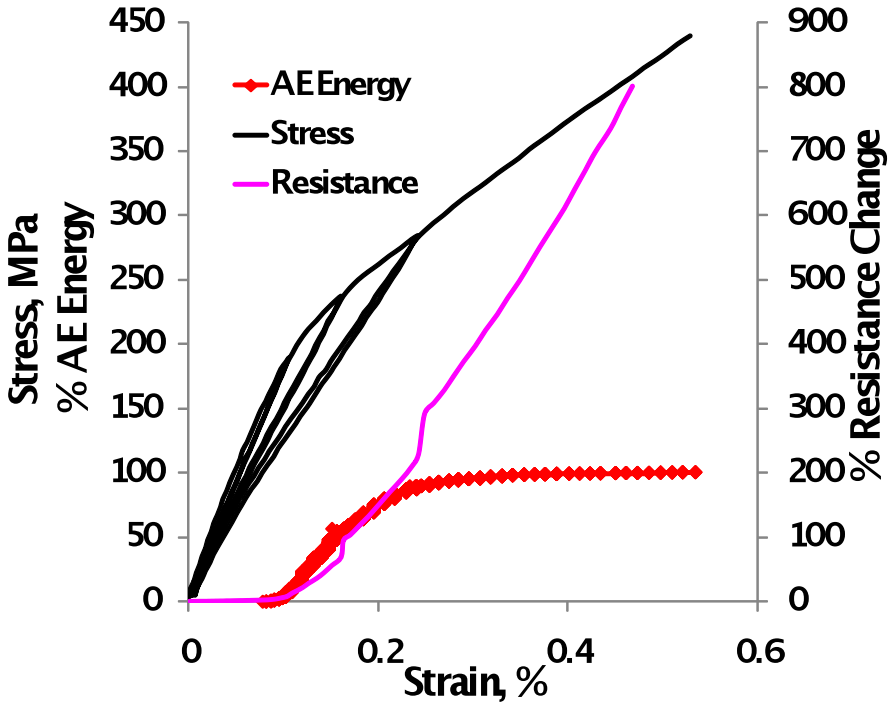
Same general trend as CVI

>800% resistance change at failure (exceeded voltmeter range)

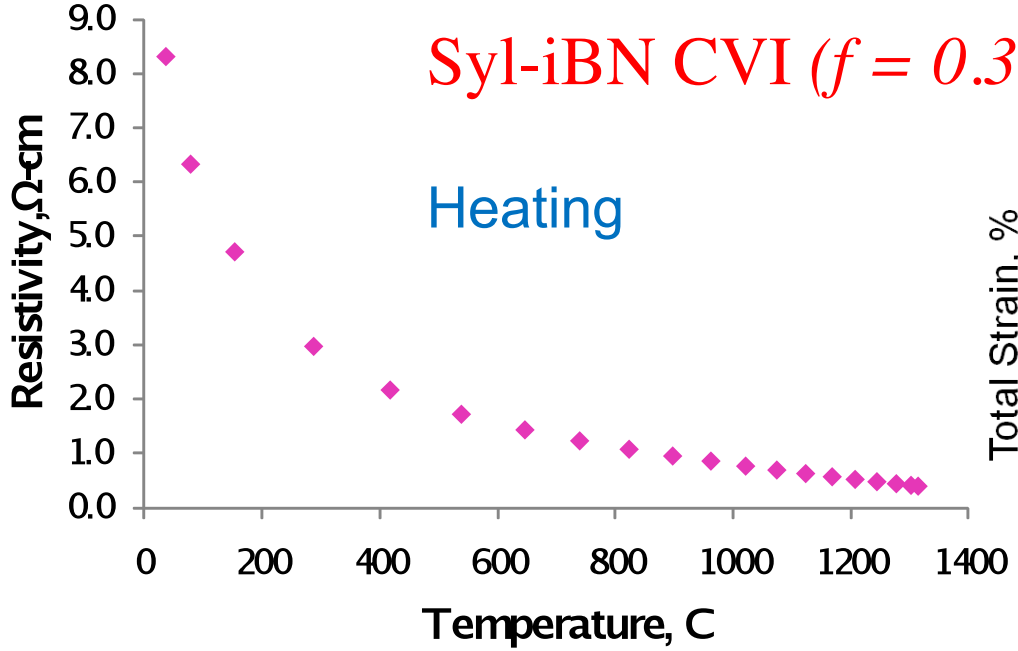
MI matrix has amorphous free Si, which increases conductivity

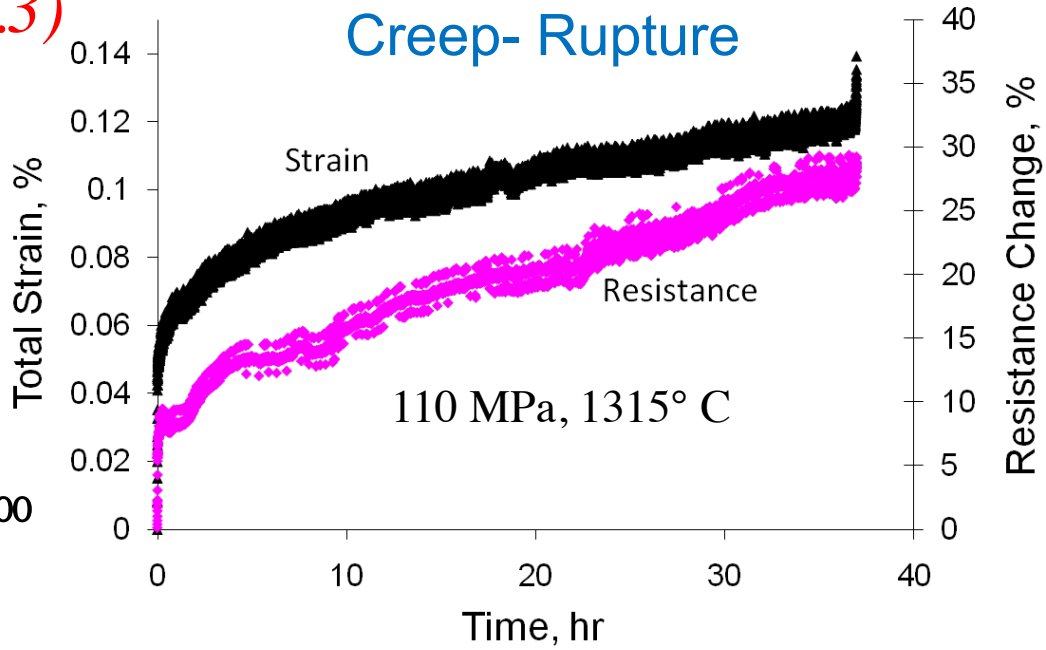
Since MI matrix is more conductive, resistance is more affected by matrix damage

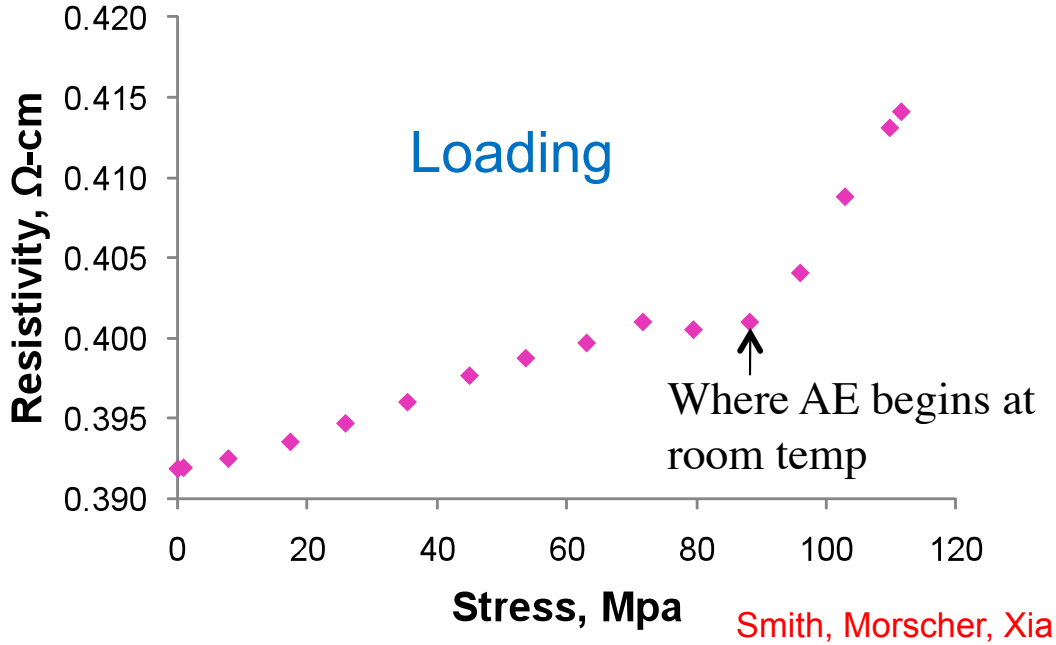


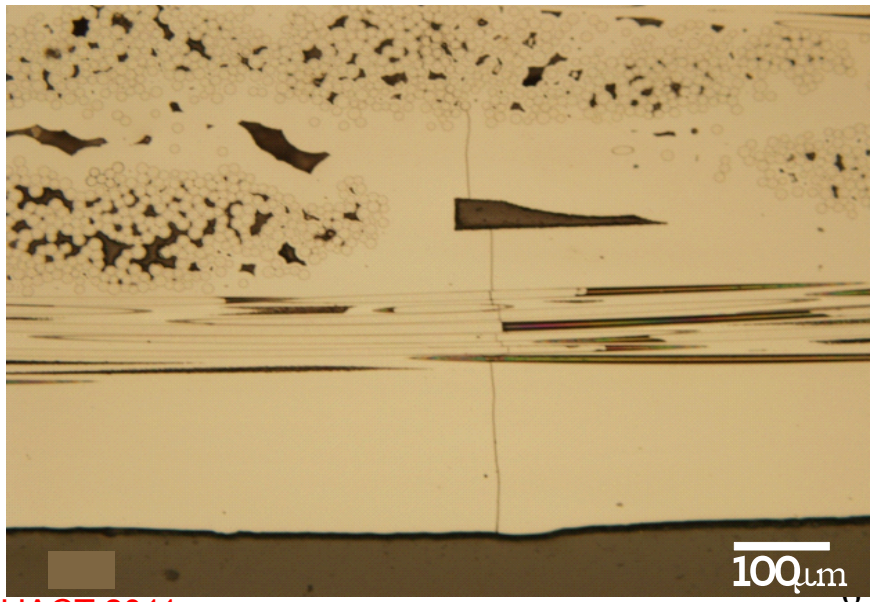


High Temperature Response









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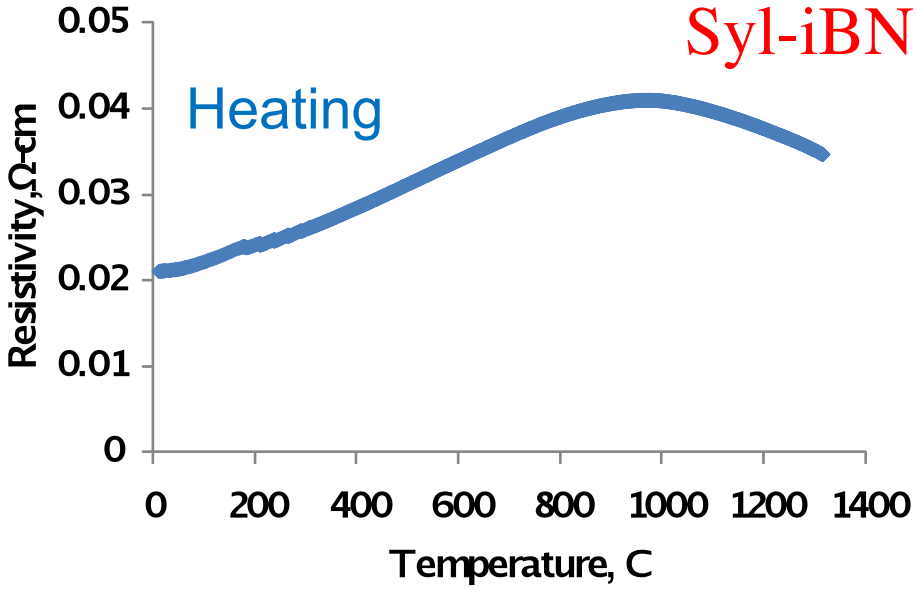
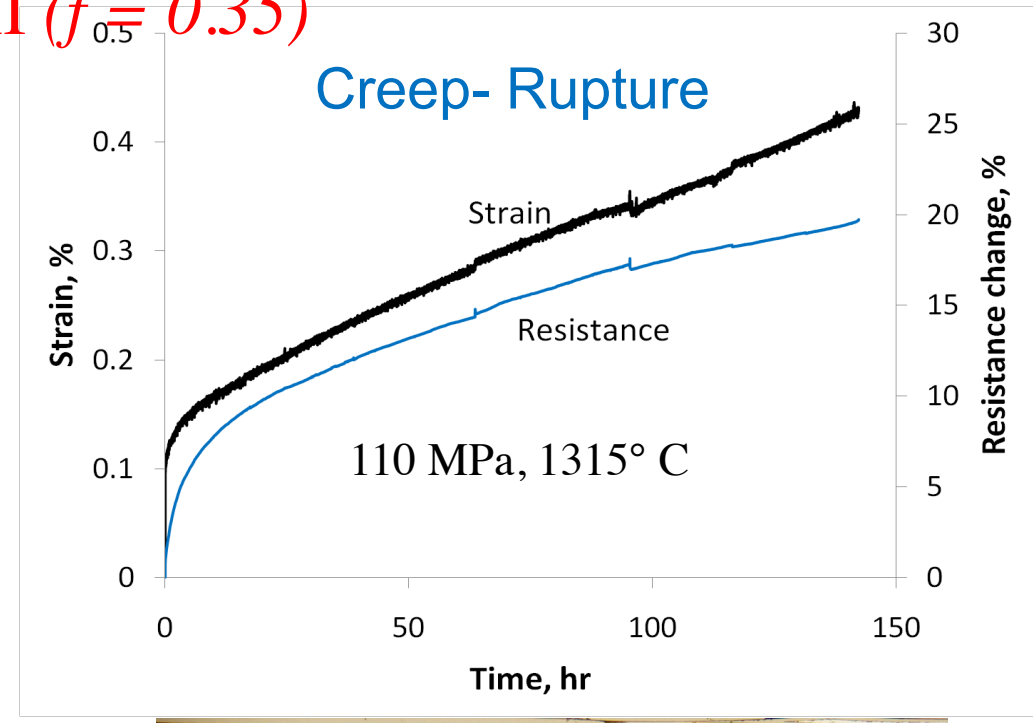
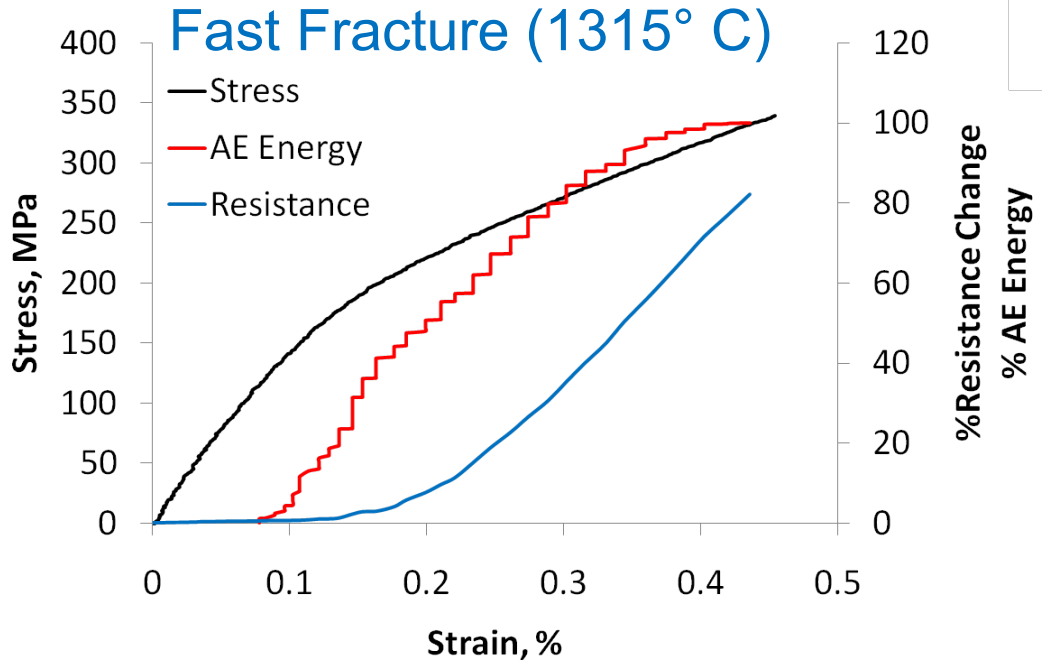
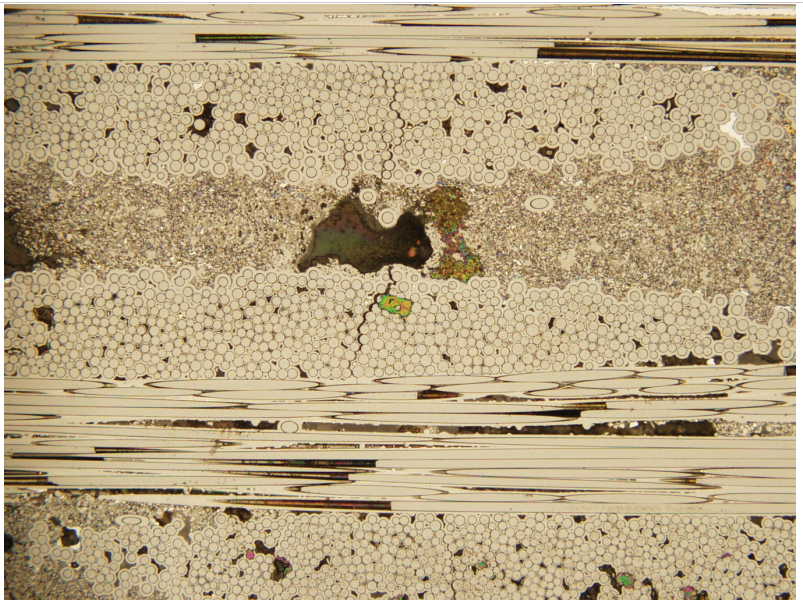
High Temperature Response

Syl-iBN MI ($f = 0.35$)



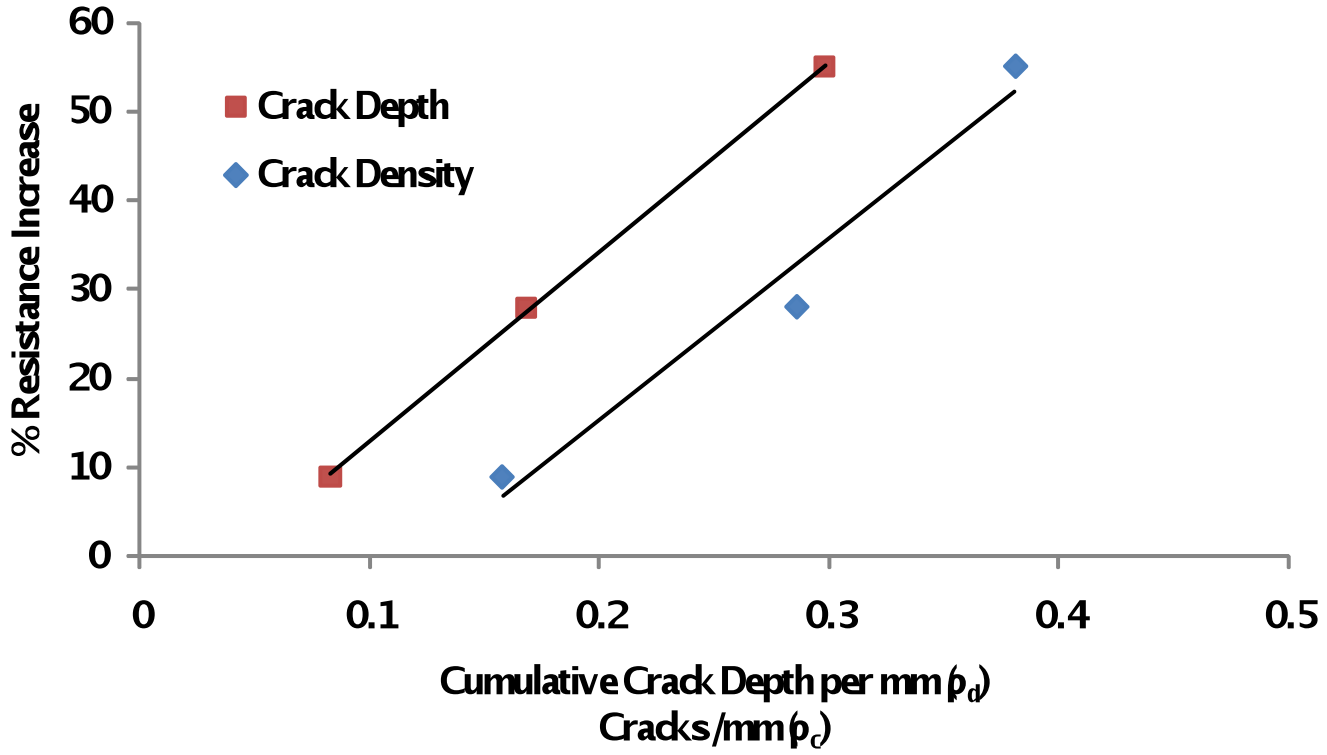






Resistance and Matrix Cracking

Syl-iBN CVI *(f = 0.3)*



- Three samples from a single panel, subjected to creep loading at 1315° C
- Direct relationship between final resistance and measured crack density/ dep

Results

The electrical resistance of SiC/SiC CMCs with Sylramic-iBN fibers was measured during both room temperature and creep-rupture testing. The results show that electrical resistance increases as load is increased or as creep progresses. The MI matrix is much more electrically conductive and shows a significant increase in resistance (>800%) for room temperature monotonic loading. Both MI and CVI composites increased in resistance by 20-30% for creep at 110 Mpa and 1315°C. The microstructures of the composites were examined to reveal cracks. The resistance change correlates well with matrix crack density and depth. This is the major concern for health monitoring and life-prediction, since cracks of this nature eventually lead to failure. Residual room temperature resistance changes have also been seen for interrupted tensile tests. Thus, resistance can potentially be used for in-situ monitoring at high temperature, or as an inspection technique after unloading.

Summary and Conclusion

- Electrical resistance increases with increasing stress and creep time
- Resistance can be sensed either in situ or as after unload (as a post-damage inspection technique)
- Changes in resistivity can be related to crack density, which is the life-limiting damage for these materials
- Melt infiltrated matrix shows especially high sensitivity at room temperature
- Results are quantitative, unlike for other NDE methods

Future Work

- Compare different composites – varying composite constituents and fiber architecture
- Quantify the effect of high temperature micro-structural changes on resistance
  - Sensitivity to crack formation
  - Sensitivity to fiber breaks
  - Sensitivity to oxidation
- Determine lead attachment schemes for different applications and conditions

Acknowledgements

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