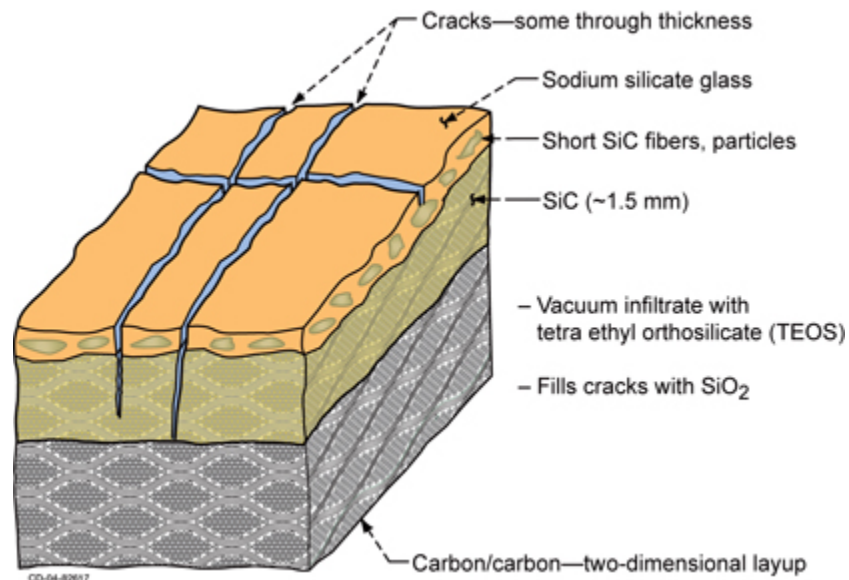


# As-Fabricated Reinforced Carbon/Carbon Characterized

Reinforced carbon/carbon (RCC) is a critical material for the space shuttle orbiter. It is used on the wing leading edge and the nose cap, where maximum temperatures are reached on reentry. The existing leading-edge system is a single-plate RCC composite construction with a wall thickness of approximately 1/4 in., making it a prime reliant protection scheme for vehicle operation.



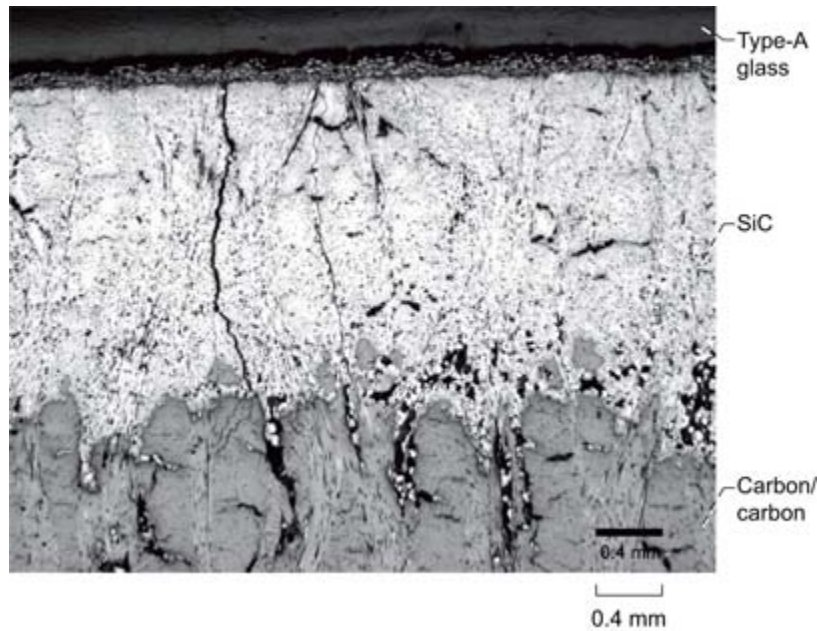
*RCC material used for the shuttle orbiter.*

Long description of figure 1. Illustration showing cracks along with layers of RCC material: sodium silicate glass, short silicon carbide fiber particles, silicon carbide (about 1.5 millimeters), vacuum infiltrate with tetra ethyl orthosilicate (TEOS), and carbon/carbon two-dimensional layup.

The preceding schematic illustrates the RCC material. The RCC material and the leading-edge design were developed concurrently in the 1970s utilizing existing state-of-the-art technologies. For safe operation, the hottest leading-edge panels are currently limited to 50 missions because of the oxidation of the carbon composite substrate. This limit was established through empirical correlations of calculated mass loss with strength reduction. Extensive testing and flight qualification have been done on this material, and it is an integral part of the orbiter. The Columbia accident was caused by damaged RCC on the wing leading edge that was unable to provide the proper protection for the wing components.

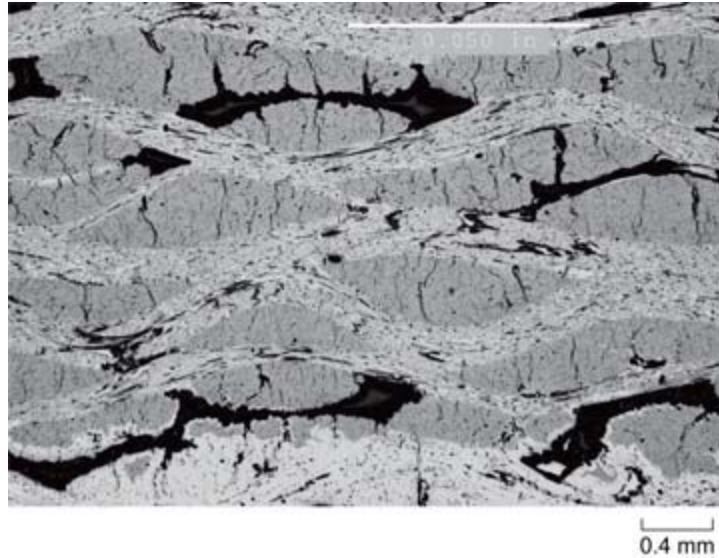
As part of the Return To Flight efforts, an RCC aging team composed of members at the NASA Glenn Research Center, NASA Marshall Space Flight Center, NASA Johnson Space Center, NASA Langley Research Center, and Argonne National Laboratory was

established to examine RCC in the as-fabricated, flown, and furnace-oxidized state. Leading-edge material with actual exposures of up to 30 missions is now available to assess the severity of actual strength reduction through testing with current analytical techniques. Characterization is done with nondestructive evaluation, microstructural examination, and mechanical testing. A detailed microstructural examination of as-fabricated RCC is an essential part of this task so that we can understand the baseline material. Samples were obtained in various stages of the process and examined with optical and electron optical techniques. Surfaces and mounted, polished cross sections were examined. Quantitative image analysis was used to determine porosity in the polished cross sections, and gas adsorption techniques were used to measure internal surface areas.



*Polished cross section showing outer layers.*

The microstructure of the as-fabricated material had large variations in a variety of areas including the porosity, coating morphology, and crack density. The preceding photomicrograph shows the Type-A glass, the silicon carbon (SiC) layer, and the carbon/carbon substrate. The following photomicrograph shows a region of the carbon/carbon substrate. The origin of these pores can be traced to processing steps. Many of the voids are due to shrinkage of the resin material during pyrolysis.



*Polished cross section showing pores in substrate.*

Establishing a well-documented database for the as-fabricated material in combination with existing databases will assist in assessing aging effects from high-temperature and environmental exposure of the flown and furnace- or arc-jet-conditioned material.

**Find out more about this research:** <http://www.grc.nasa.gov/WWW/EDB/>

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