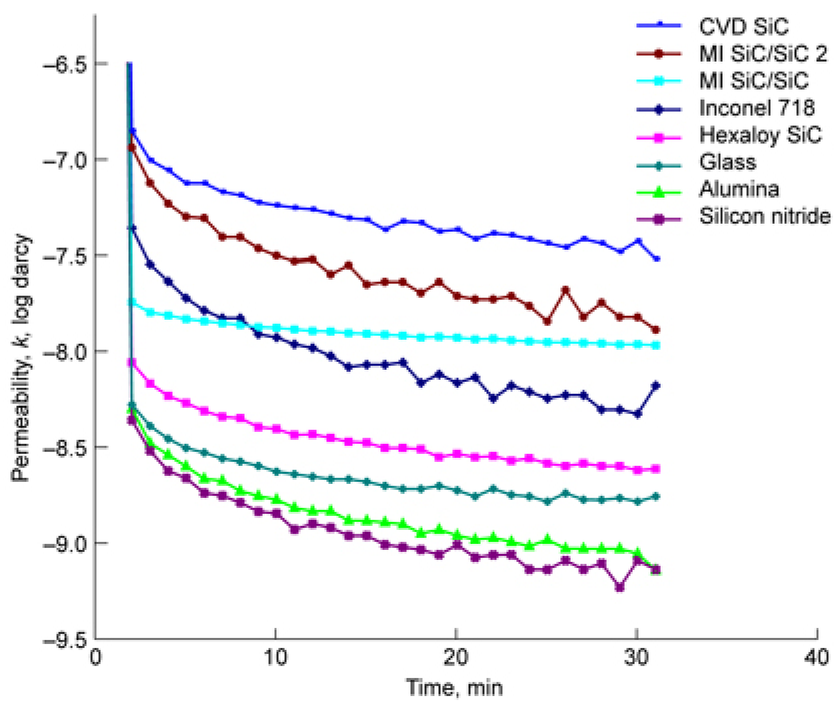
Permeability of Candidate Stirling Heater Head Materials Measured

Researchers at the NASA Glenn Research Center are evaluating high-temperature materials for Stirling heater heads for second- and third-generation Stirling radioisotope power systems that would help to increase the system efficiency to 30 to 35 percent and the system specific power to 8 to 10+ W/kg. Ceramic materials could make it possible for the convertor hot-end temperature to be increased to 1050 to 1200 °C, in comparison to the current 650 °C with an Inconel 718 heater head. A hermetically sealed Stirling heater head must retain a constant internal pressure of nearly 400-psi helium (He) throughout its useful life (120,000 hr) at the design operating temperature. Therefore, He permeability was measured for eight potential materials and compared with the permeability of the current heater head material, Inconel 718.

The eight materials included silicon nitride (Si_3N_4), silicon dioxide (SiO_2), both sintered and chemical vapor deposited (CVD) silicon carbide (SiC), alumina (Al_2O_3), two types of melt-infiltrated (MI) SiC/SiC composites, and a carbon/SiC composite (C/SiC). Glenn submitted samples of each material to Porous Materials, Inc., Ithaca, New York, for permeability analysis. At room temperature and 30-psi He, four materials--Si_3N_4, Al_2O_3, SiO_2, and sintered SiC--demonstrated lower permeability than Inconel 718. The CVD SiC and all the composite materials were significantly more permeable to He than the baseline material.



Permeability coefficient, K_{He}, in log darcy versus time in minutes. Smaller negative numbers indicate greater permeability. For example, silicon nitride and silica are less

permeable to He than Inconel 718 is.
Long description of figure.

These initial results show that ceramic materials are feasible replacements for the baseline Inconel 718. Glenn purchased from Porous Materials, Inc., a newly designed diffusion permeameter that is able to measure permeability at temperatures up to 1000 °C, and pressures up to 400 psi He. This will enable additional in-house permeability testing at temperatures and pressures relevant to the Stirling heater head. These measurements are necessary to select the best ceramic material for use at the higher temperatures.

Material	Darcian permeability,[a] K,[b] m^2
Si_3N_4	7.15×10^{-22}
Al_2O_3	7.09×10^{-22}
SiO_2	1.70×10^{-21}
Sintered SiC	2.48×10^{-21}
Inconel 718	6.51×10^{-21}
MI SiC/SiC #2	1.27×10^{-20}
CVD SiC	2.97×10^{-20}
MI SiC/SiC #1	1.06×10^{-20}
C/SiC	8.84×10^{-16}

[a]All materials were tested at room temperature and 30-psi He in the Porous Materials, Inc., diffusion permeameter, with two exceptions. The CVI SiC was tested at 20-psi He (leakage occurred at higher pressure), and the CVI C/SiC was measured in the gas permeameter with air as the fluid because of the much higher flow rate through the material.

[b]Permeability was reported by Porous Materials, Inc., in darcy. (One darcy = 10^{-8} m^2.) Permeability coefficients K_{He} were calculated from reported values by the relationship $K_{He} = (P_d/P_u)(D/A)S_{eff}$, where P_d is the pressure in the down tube, P_u is the pressure in the up tube, D is the specimen thickness, A is the specimen area, and S_{eff} is the effective pumping rate.

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