Silicon Carbide Composites for Flow Channel Insert Applications

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The use of silicon carbide (SiC)-based ceramics and composites as the insulating material for lead-lithium flow channels (flow channel insert; FCI) has been proposed in several advanced lead-lithium blanket concepts, including the proposed US Dual-Cooled Lead- Lithium (DCLL) Test Blanket Module (TBM) for ITER. In this application, an FCI serves as an electrical and thermal insulator in order to mitigate the MHD pressure drop and to allow a significantly higher coolant outlet temperature than the upper temperature limit for the steel duct structures. The FCI application generally requires the material to maintain its electrical and thermal conductivity within certain ranges throughout the operation, at the same time maintaining structural integrity and dimensional stability, although details of the requirements vary depending on the reactor/blanket specifications and the design philosophy.

To design appropriate FCI materials and structures, it is essential to understand both the transport and mechanical properties for the composite constituents, to clarify the neutron irradiation effects on those properties and dimensional instability issues, and to establish constitutive models of composite properties. In this paper, non-irradiated and irradiated electrical and thermal conductivities for high purity, chemically vapor-deposited SiC and near-stoichiometric SiC fiber, chemically vapor-infiltrated SiC matrix composites will be reported. Based on the experimental results, constitutive modeling of anisotropic electrical and thermal transports in two-dimensional woven fabric composites will be attempted. Finally, property values of these composites recommended for blanket design activities, directions of transport property-adjusted composite development, and the remaining critical R&D issues for applications in power reactor blankets will be discussed.