JOINING OF SIC-SIC COMPOSITES BY EMBEDDED-WIRE CVD

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Over the past 15 years, Free Form Fibers (FFF) has gained important expertise in manufacturing silicon carbide materials through its heavy research and development efforts on laser-induced chemical vapor deposition (LCVD). FFF is capable of producing stoichiometric SiC fibers for composite reinforcement by LCVD, which is a process that is material agnostic and can easily tailor fiber material properties for specific applications. More recently, our SiC fibers have been processed into non-woven sheets by a commercial partner and implemented as the reinforcement phase in SiC matrix-based composite samples. The advantages of using non woven preforms instead of woven fabrics are two-fold. The first addresses porosities (open and closed) left in the SiC/SiC composite part made from fabrics. The second advantage offered by SiC non wovens over woven fabrics is the reduction of fiber damage during composite processing caused by contact between SiC fibers.
A new process called embedded wire CVD (EWCVD) was developed by FFF as an innovative approach to produce high purity, high density CMC structures in an extremely economical manner. This technique builds upon the fact that the dimensionality of mass-transport has a large influence on CVD/CVI. Mass-transport to a fiber growth front in LCVD (diffusion to a point) is about a billion times that of 1-dimensional diffusion in thin films, accounting for the effect of anisotropy. Two-dimensional diffusion to a line, too, is much more efficient than that of a 1-D diffusion to a plane. Embedded wire CVD exploits this phenomenon. EWCVD was developed in order to infiltrate a shell fiber preform without the use of high temperature CVD furnaces, and to limit thermal exposure to the infiltrated preform.

An important application of EWCVD is in the long-sought goal of accomplishing joining (‘welding’) of ceramic and ceramic-based composite components together. FFF has demonstrated homogeneous joining of SiC fiber-reinforced SiC matrix composites without the use of extraneous materials that limit the performance of the joint structure. The technical approach is quite simple and straight forward. In a nutshell, patches of non woven SiC sheets are embedded with a resistive wire, then are wrapped around the area where the two parts are to be joined. The assembly is placed into an unheated process chamber containing the precursor gases and resistively heated via the wire. SiC fibers within the preform wick the heat away, causing mass-transport CVD to occur onto the fibers, with a strong thermal gradient oriented from the inside out. This is an important departure from traditional hot wall CVD, in which matrix formation progresses from the outside in, with essentially no thermal gradient at the infiltrated surface, that typically leaves the composite riddled with closed porosities.
EWCVD has also been implemented in the development of SiC thin wall composite shells for the replacement of metal-based cladding to contain uranium oxide fuel pellets in nuclear power applications. As a high temperature ceramic that is mechanically stable over a range of temperatures, is resistant to oxidation, and exhibits low neutron absorption, SiC is currently being reviewed as a candidate for nuclear fuel cladding as either a monolith, a SiC fiber-reinforced SiC matrix (SiC/SiC) composite, or a hybrid of metal and SiC/SiC composite. A draw back to using SiC or SiC/SiC for cladding lies in the manufacturing process step of hermetically sealing the ends of the fuel rods with SiC end-plugs. EWCVD has also been deployed to address this issue and form a fully dense, hermetic end cap seal. Further extension of the EWCVD technology to other thin shell applications in the aerospace field is being explored.