# SCIENCE AS A VOCATION AND CAREER

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## BRIEF OF THE PHYSICAL PROPERTIES OF SIC FOR ACCIDENT TOLERANT FUEL CLADDING MATERIAL

Small neutron absorption cross-sections, much higher oxidation resistance, chemical inertness, much higher melting point, lower irradiation growth and stability in nuclear waste, SiC has a lot of advanced offerings compared to traditional zirconium cladding [1] These advantages make it very attractive When it was considered an accident tolerant fuel coating. In fact, the use of these materials can go back to the 1960s when they were used in high-temperature gas reactors for distinct antioxidants [2]. Now research wants to expand the use of this material to feed cladding materials. Furthermore, this material is also considered a matrix material in fully coated ceramic fuel for minimum irradiation swelling rate [3].

To assess their feasibility in accident tolerant fuels, Oak Ridge National Laboratory [3], Massachusetts Institute of Technology [4] and several other research institutions around the world have conducted lots of experiments inside a heap and outside of a stack to assess its applicability in LWR. For example, Oak Ridge National Laboratory performed a high-temperature oxidation test on chemical vapor deposition samples at the Severe Accident Test Station, and these samples were exposed to vapor at a high temperature ranging from 1473 K to 1973 K resulting in the inherent characteristic of SiC It can greatly enhance fuel safety in accident conditions [5]. Researchers from the Massachusetts Institute of Technology simulated and evaluated the behavior of the SiCf / SiC cladding under normal conditions using modified FRPCON code based on experimental data from them in-heap tests. What's more, new simulation tools, like the bison, are under development to simulate this new cladding under normal conditions and accidents.

Generally, two categories are suggested in the SiC cladding designs including full ceramic and metal-assisted ceramic, which can also be divided into composite, composite monolithic (double structure), and monolithic composite monolith (triplex structure) for full ceramic and metal composite design (double structure), Composite-metal-composite (triple structure) of metals with the help of ceramic design [3]. It should be noted that there are still no standards for designing or manufacturing reinforced cical cladding fibers, and standards are under development. The object reviewed in this paper is limited to the whole fiber reinforced cladding. General manufacturing steps regardless of designs are as follows [1]:

A) Depending on the structure of the SiC pipes, the SiC fibers are blended into the tubes in various ways, including thread winding and braiding;

B) by the method of chemical vapor deposition, the interphase layer is added;

C) A SiC matrix is added by chemical vapor infiltration;

D) The environment barrier coating can be added with different techniques.

and environment barrier coating constitute the full SiCf/SiC cladding, these four parts are to provide different functions specifically.

Regardless of the triple or double structure, the composite SiC layer is deposited in a matrix to improve the mechanical performance of the cladding. The SiC / SiC compounds reviewed in this paper are limited to the SiC fiber reinforced continuous compounds with fully crystallized SiC. Nuclear grade SiC fibers include HiNicalon Type-S (HNS) and Tyranno SA3 [7]. These fibers can provide similar mechanical performance but distinctly different thermal performance [7]. This paper will conclusively display the SiC cladding with Nicalon and HNS fibers.
Since the fiber can provide the best mechanical performance in the direction of the fiber axis, the size of the SiC fiber and the method of building the composite layer deeply affect the final performance of the SiC cladding. Nowadays, braiding, regardless of 2-direction (2-D) or 3-direction (3-D), is becoming popular due to its better wear resistance and compatibility. Figure 1 shows three typical examples of fiber architecture. Therefore, the complex level of SiC cladding simulation becomes higher by introducing the types of fiber materials and their structures.

Although SiC / SiC compounds have excellent mechanical properties and damage tolerances, adequate bonding strength is still required when enabling their normal functions. Therefore, the interphase, which combines the matrix and the composite fiber layer by providing bond strength, is typically added via Chemical Vapor Deposition technology. Interphase parameters, such as its thickness, will affect the performance of the cladding with reference to the previous report, but no systematic evaluation of the SiCf / SiC tubular materials was reported.The prospects for human use of nuclear energy remained cloudy until 1939 when Han and Strassman discovered fission under corpuscular radiation.

As a relatively mature technology to obtain a thin enough long SiC tube, chemical vapor infiltration appears to be the most stable and reliable method for producing a SiC matrix with very high purity and low porosity over a wide range. However, a large facility is needed if the tube length wants to fulfill the LWR application requirements and it will also take longer in the deposition process for the lower internal porosity of the tube. There are some research institutions that have the capacity to produce SiC long tubes (about 1 meter) so far [4]. The other method for producing the tube is called the NITE process (nano-infiltration and transient fusion phase). However, it contains secondary phases attributable to oxide additions, hot water or steam in normal operation and high temperature steam accidents conditions can lead to significant dissolution of the SiC matrix material, which is a critical challenge to the application of LWR [6].

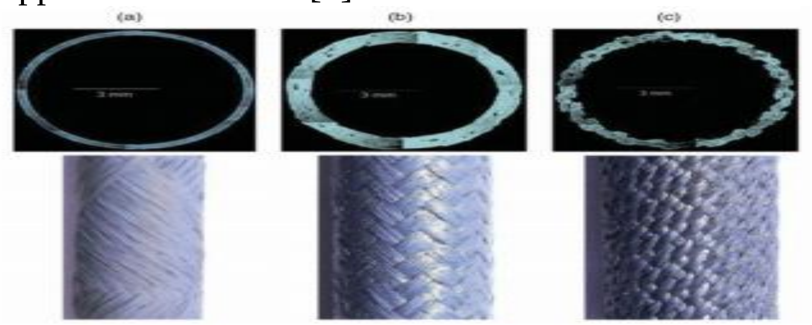

*Figure 1. Three typical examples of SiC fiber architecture of chemical vapor infiltration SiC tube. Reprint from Sauder 2014 [6].*

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## HISTORY OF IRT REACTOR DEVELOPMENT

Practical applications of nuclear energy for military and civilian purposes had begun with the structure of research reactors. After lunching the F-1 reactor and establishing nuclear weapons programs, I.V. Kurchatov accelerated theoretical and experimental research at the Institute of Atomic Energy (IAE) in Russia to develop research reactors designed for various purposes. The first integrated nuclear experimental research program in the USSR had been devoted for reactor testing in addition to the investigations of nuclear fuels and materials as a part of an MIR reactor and a hot materials science laboratory in April 1952. The first light water-cooled reactor of VVR-2 type which designed to use enriched uranium with a channel-free core and served as a prototype for the sequentially developed VVR-S reactors has been developed in 1954 at the Research Institute. In 1957 and at the Research Institute; the first research reactor of a temperate and water-cooled swimming pool IRT in the USSR was built. in 1957 at the IAE.

The IRT 1-MW nominal power reactor was developed under the umbrella of the Research Reactors and Reactor Technologies section. V. V. Goncharov was the division head and an assistant to I.V. Kurchatov, and the top of the planning office was P. I. Shavrov. The senior scholars whom would top accredited for the event of IRT were V. V. Goncharov, Yu. Nikolaev and Yu. F. Chernilin, while the primary director of the reactor was Cherniline. L. A. Goncharov calculated the ferroconcrete shielding of the reactor tank and experimental horizontal channel campaigns. The actual start of the IRT reactor occurred on November 26, 1957, under the direct supervision of A. P. Aleksandrov. All this happened within the presence of F. Perrin, who was the most important nuclear energy commissioner in France. This was