FABRICATION OF UNIFORM NIOBIUM COATING LAYER FOR THE COATED FUEL PARTICLE OF THE VERY HIGH TEMPERATURE REACTOR

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ABSTRACT

Due to the inherent safety characteristics and the capability to generate high-temperature coolant (helium) useful outlet for producing hydrogen or heat, the high temperature gas-cooled reactor (HTR) is considered to be one of the most promising advanced nuclear energy systems. The enhanced safety of HTR is based on the quality of the fuel pebbles. The traditional HTR fuel elements commonly utilize tristructural-isotropic (TRISO) type coated fuel particles, which contain uranium dioxide (UO_2) kernel, porous buffer pyrocarbon layer (buffer PyC), inner dense pyrocarbon layer (IPyC), silicon carbide (SiC) layer and outer dense pyrocarbon layer (OPyC) [1]. The SiC layer acts as a barrier against the diffusive release of metallic fission products and provides critical mechanical strength for the particle. However, the mechanical performance of the SiC layer takes place rapid degradation because of its phase transformation from β-SiC to α-SiC at 1700 °C, which restricts the performance of HTR at very high temperature [2,3]. As a result, replacing the SiC-coating layer by other materials becomes an important research field. Niobium possesses high melting point, high density, high temperature strength and hardness, good thermal conductivity and irradiation resistance.

In this work, niobium coated uranium dioxide (UO_2/Nb) was produced by hydrogen reduction of halides *via* a fluidized bed chemical vapour deposition (FBCVD) process. Thermodynamic calculation of the hydrogen reduction reaction was studied to analyse the feasibility and the reaction temperatures. In addition, the preparation apparatus, processing conditions, properties, microstructures and morphologies of the Nb coating were studied systematically.

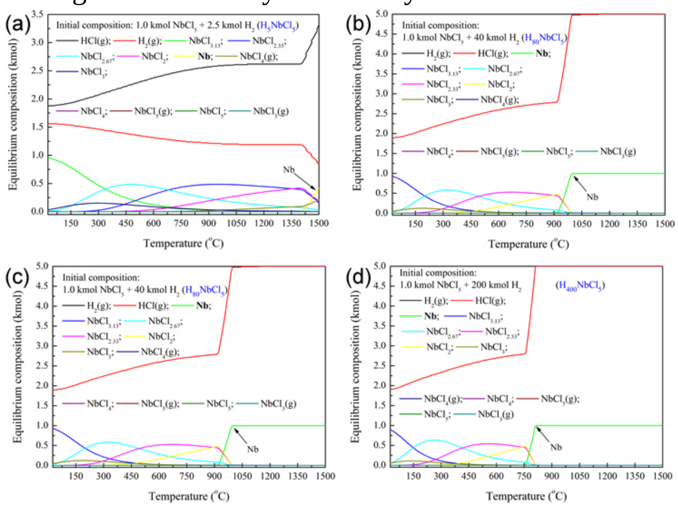

Fig. 1 Thermodynamic calculations of the hydrogen reduction reactions.

Equilibrium phases were ascertained in $NbCl_5$-H_2 binary system. The composition diagrams of the equilibrium phases were constructed by plotting the amount of the species as function of the temperatures, as shown in Fig. 1. The Nb phase formation temperatures decreases from 1400 °C to 750 °C with the increase of molar ratio of H_2 and $NbCl_5$. High content of H_2 can raise the reaction efficiency of $NbCl_5$.

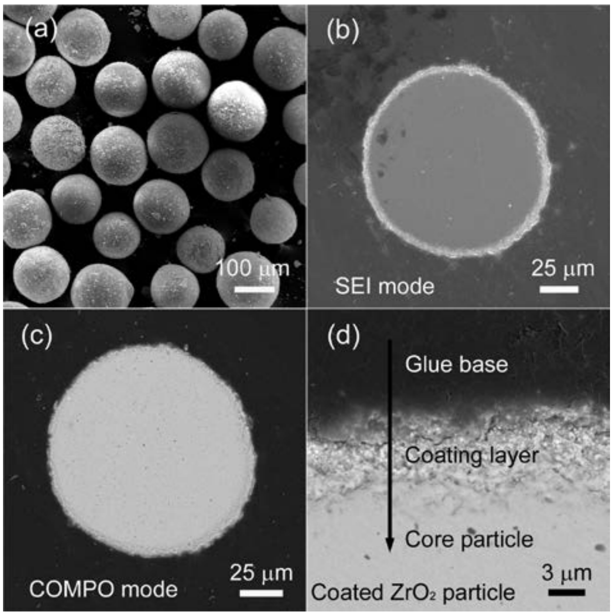

Fig. 2 Morphological characterizations of the coated fuel particles.

SEM observation reveals that the Nb coating has a compact microstructure, as shown in Fig. 2. Cross-sectional SEM image (Fig, 2d) of the coated fuel particle shows an average value of ca. 5 μm, which is relatively uniform.

A compact, uniform Nb coating has been successfully deposited on coated fuel particles using an $NbCl_5$+H_2+Ar gas mixture.

Acknowledgements

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