Ceramic Materials Selection of Fuel Crucibles based on Plasma Spray Coating for SFR

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1. Introduction

Thermal plasma-sprayed coatings of refractory materials can be applied to develop a re-usable crucible coating for metallic fuel, such as the U-Zr alloy proposed for sodium cooled fast reactors (SFR). The plasma-sprayed coating can provide the crucible with a denser, more durable, coating layer, compared with the more friable coating layer formed by slurry-coating, which was used to prevent the interaction between melt and crucibles. Plasma-sprayed coatings are consolidated by mechanical interlocking of the molten particles impacting on the substrate and are dense by the heat applied by the plasma [1]. The increased coating density is advantageous because it should not require frequent recoating and U-Zr melt penetration through the protective layer is more difficult in a dense coating than in a porous coating. In this study, we used Vacuum Plasma Spray (VPS) method to investigate permanent coatings for re-usable crucibles for melting and casting of metallic fuel onto niobium substrates. Niobium was selected as a substrate because of its refractory nature and the coefficient of thermal expansion (CTE) is similar to that of many of the candidate materials. After the HfC, ZrC, TiC, TaC, Y_2O_3, and 8% YSZ coatings were applied the resulting microstructure and chemical compositions was characterized to find the optimum process conditions for coating.

2. Experimental Procedure

Nb disc and rod with 10 mm in diameter were used as the substrates. The powders for coating were manufactured by F. J. BRODMANN & CO, Sinetsu and Metco and used for spray coating. Atomizing, sintered and crushed method were used for manufacturing. The powders showed a square and a globular shape, ranging from 16 μm to 45 μm in size. To provide a rough surface finish to enhance the adhesion of the coating layer the niobium substrate was grit blasted with alumina and cleaned using a standard ultrasonicator. Approximately 100 μm thick coatings were deposited. The coating microstructure before and after testing was characterized using a scanning electron microscope (SEM). The chemical compositions of the coated specimens were measured by energy-dispersive spectroscope (EDS). Coating phases were analyzed by X-ray diffraction (XRD) Plasma spraying was performed an industrial VPS system (German, GTV).

3. Results and Discussion

Preliminary experiment was performed to extract the effective process factor on coating quality before main experiment for improving the efficiency of experiment because of expensive powder for main experiment. The vacuum plasma sprayed coating was performed using HfC, ZrC, TiC, TaC, Y_2O_3, and 8% YSZ powders with 99% NB rod as substrate. The plasma spray process parameters that has to consider in VPS process was selected as the effective factor. It includes nozzle size, primary gas flow rates, secondary gas flow rates, arc current, working pressure, powder feeding rate, stand-off distance, and traverse speed for extracting the effective factor in preliminary experiment to perform the optimum spraying coating. SEM micrographs of the surface shape are shown in Fig. 1 after spraying coating.

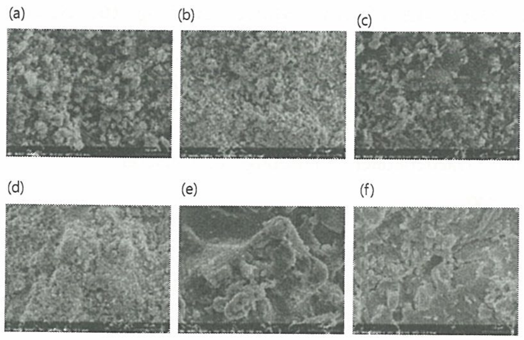

Fig. 1. SEM micrographs showing the condition of the coating layer plasma-sprayed on the niobium substrate; (a) ZrC, (b) HfC, (c) TiC, (d) TaC, (e) Y_2O_3, and (f) 8% YSZ samples.

As shown in figure, the surface condition of coating on ZrC, HfC, TiC, TaC powders has a poor distribution with un-melted conditions of many particles. But, in case of Y_2O_3, and 8% YSZ powders, the most of particles show the melted conditions even though the partially un-melted particles exists so that this results may be effected on adhesion and the different thickness of coating. Therefore, these results show that most of the series of carbide ceramic, such as ZrC, HfC, TiC, TaC so on, has a poor fluidity so that a surface conditions is not uniform while a series of oxide ceramic has a good coating conditions and state of melting is well defined.

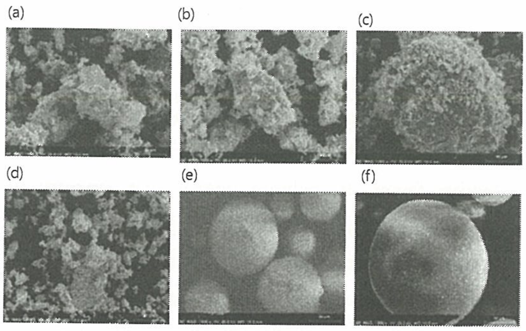

Fig. 2. SEM micrographs of powder particles; (a) ZrC, (b) HfC, (c) TiC, (d) TaC, (e) Y_2O_3, and (f) 8% YSZ samples.

It was observed that the thickness of coating was 79.1 μm for ZrC powder, 12.2 μm for HfC powder, 18.2 μm for TiC powder, 46.4 μm for TaC powder, 121.2 μm for Y_2O_3 powder, 168.6 μm for 8% YSZ powder. It shows the varied thickness of coating according to the coating material by SEM observation. This variation may be attributed to the shape of powders. The SEM micrograph, as shown in Fig. 2, shows the different shapes of coating materials. Most of carbide ceramics, even its size is different, show the square shape, while the oxide ceramics has the round shape. In general, the square shape of powder does not fluidize well compared to the round shape of powder so that the plasma spraying of carbide ceramics is not uniform.

4. Summary

The vacuum plasma coating was performed to analysis the characteristic and find the optimum process conditions for the vacuum plasma spray coating. It was observed that the square shape of powder in case of carbide ceramics does not fluidize well compared to the round shape of powder in case of oxide ceramics so that the plasma spraying is not uniform. The analysis through SEM and EDS mapping shows that the coatings represent excellent structural features with strong resistance against oxidation and satisfied result with vacuum plasma coating.

5. Acknowledges

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6. References

[1] E. Pfdender, Plasma Chem. Plasma Process, Vol.19, 1991.