

Molten Core Concrete Interaction and Development of Core Catcher

(2) Thermal shock effects for advanced high temperature ceramics

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Four monolithic refractory ceramics (Al_2O_3 , SiC, TiC and TiN) were exposed to severe thermal shock caused by thermite reaction. Such experiments were intended to simulate the exposure of a core catcher to hot debris of melted core in nuclear reactor. Moreover, the chemical interactions between tested materials and products of thermite reaction were investigated by holding samples in laboratory furnace for 5 hours at 1000°C in air. None of the materials entirely withstand such sudden temperature rise, of approximately 1000°C/s , especially the sample made of Al_2O_3 peeled into small pieces under thermite mixture. Both TiN and TiC cracked in the central part, perpendicularly to the reaction front and proceeding heat wave. The best performance was observed in SiC sample, which is caused by the lowest thermal expansion coefficient. Considering the application of SiC in the construction of core catcher, research on thermal shock resistance improvements have to be performed.

Keywords: Advanced ceramics, Al_2O_3 , TiC, TiN, SiC, thermal shock, corrosion resistance, Thermite reaction

1. Why advanced high temperature ceramics

It has been proven at least twice (by Chernobyl and Fukushima NPP) that reactor core can be melted in case of sever accident.. The temperature measurements form Chernobyl indicated that the basis under the melted debris reached 1600°C , which means that commercially used refractories are not able to ensure thermal protection and chemical stability at such temperature. For instance, much lower temperature causes severe damage in concrete just at 1000°C (Fig.1. A). Many spallations were formed due to chemical reactions and significantly deteriorated mechanical properties can be expected. Despite better chemical stability of Al_2O_3 , or alumina-based materials such as basalt, formation of spinels, or other eutectics significantly reduce the melting point which become lower, than 1600°C .

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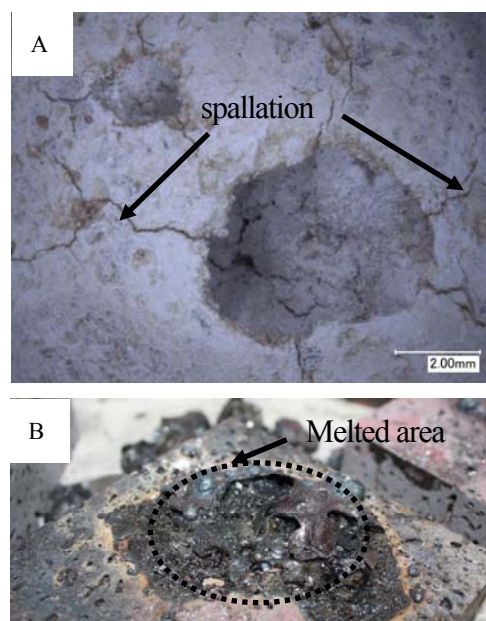


Fig.1 A) Microstructure of concrete exposed to 5h annealing at 1000°C , B) photo of basalt after thermite reaction

The poor refractoriness of basal at high temperature causes that basalt was melted while exposed to thermite reaction (Fig.1B). Therefore, more advanced and higher thermal stability materials

have to be considered for surface part of the new design core catcher. Therefore, in this study four monolithic advanced ceramics: Al_2O_3 , TiN, TiC and SiC (Fig.2) (30x10x5mm) were investigated under sever thermal shock caused by thermite reaction, as well as corrosion resistance.

2. Results and discussion

2.1 Effect of thermal shock

The best thermal shock resistance was observed in SiC (Fig.2), because only 16% of sample was broken (Table 1).

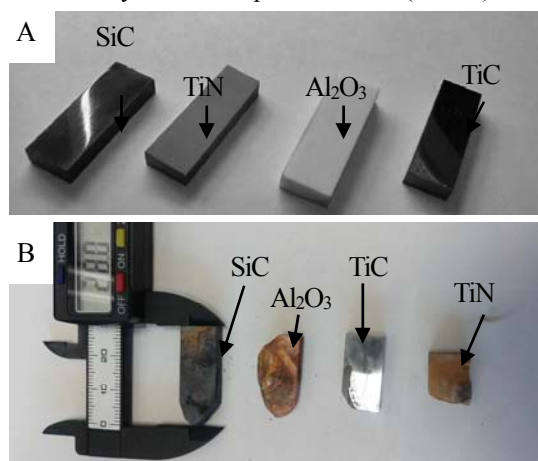


Fig.2 Samples used for thermal shock evaluation: A) before test; B) after thermite reaction

Table 1 Mass loss caused by thermal shock

Material	Mass loss [%]
Al_2O_3	51.4 (Peeling)
TiC	41.0
TiN	51.3
SiC	16.11

2.2 Corrosion resistance

Significant differences in formation of corrosion products were observed (Fig. 3). The most thick scale grew up on the surface of TiC (300 μm), smaller on TiN (200 μm). Different effects (formation of binary FeAlO_3 oxide) were observed in Al_2O_3 . The most remarkable corrosion resistance was observed in SiC, where only thin layer (about 10 μm) with reduced carbon and increased oxygen content was formed (Fig.4), however the SiO_2 is characterized by higher than TiO_2 melting point.

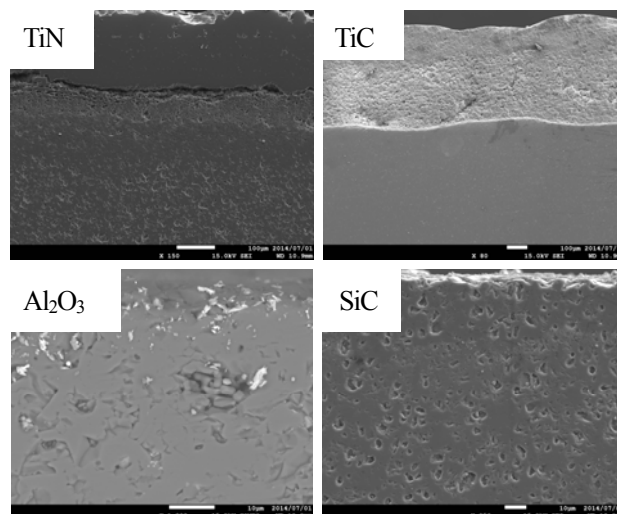


Fig.3 The SEI of the reaction zone (from the surface) after thermal shock and corrosion test at 1000°C for 5h.

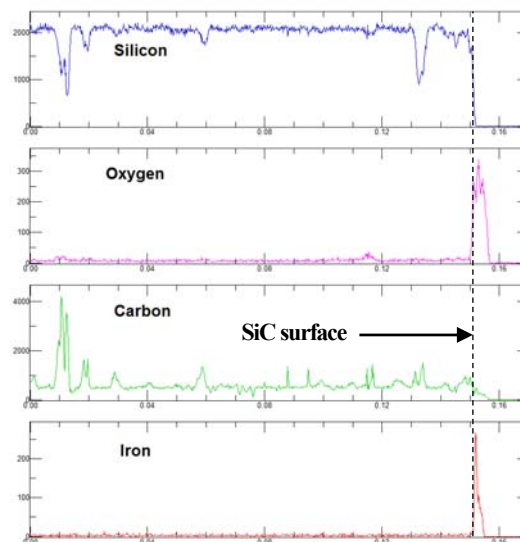


Fig.4. The line profile of elements near the surface of SiC after thermal shock and corrosion test at 1000°C for 5h.

Conclusions:

The results indicated that among considered materials SiC revealed both the best thermal shock resistance as well as the best refractoriness and corrosion resistance at 1000°C. Thus, it is the most perspective material for thick coating which could cover the most exposed to melted debris surface of core catcher.

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