1–1 Evaluation of the Temperature Range of Melted Debris in the Reactor at the Nuclear Accident

— The Influences of Pu and Zr upon the Melting Temperatures of (U, Pu, Zr)O_2 —

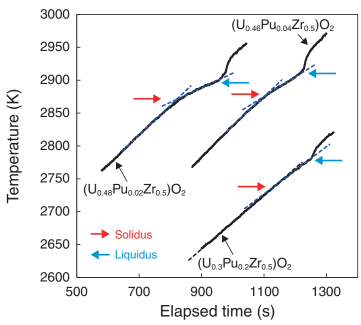

Fig.1-4 Typical heating temperature curves of specimens of ($U_{0.5-y}$ Pu_y $Zr_{0.5}$)O_2
The rate of temperature increase became low between the starting and ending points of the melting of the specimen. These points are determined as solidus and liquidus temperatures.

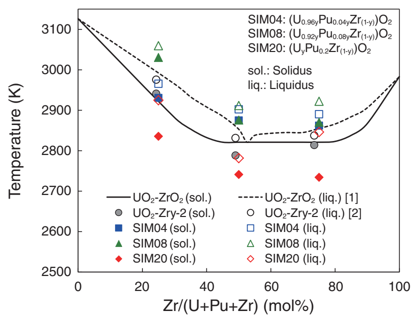

Fig.1-5 Solidus and liquidus temperatures of sim-debris as functions of Zr-content
In specimens containing similar Pu-contents, the melting temperatures of specimens with Zr contents approximately in the range from 50 to 75mol% seemed to be lower than those of other compositions.

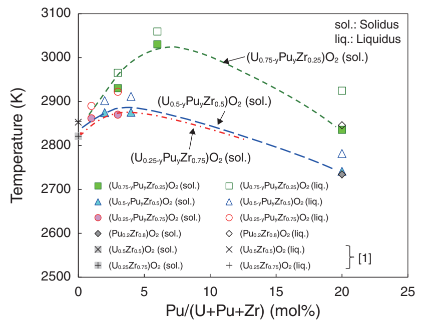

Fig.1-6 Solidus and liquidus temperatures of sim-debris as functions of Pu-content
The solidus and liquidus temperatures of (U, Pu, Zr)O_2 had a local-maximum value in the Pu-content range from 0 to 20mol%.

[1] Lambertson, W. A., Mueller, M. H., J. Amer. Cer. Soc., vol.36, issue 11, 1953, p.365-368.
[2] Kato, M. et al., Mater. Res. Soc. Symp. Proc., vol.1444, 2012.

As a part of the decommissioning plan for the reactors damaged at the TEPCO's Fukushima Daiichi NPS (which was the site of a severe accident), some strategies for removing debris from the reactors and storing it are being discussed. In these considerations, predicting the melt progression during the accident based on theoretical evidence and evaluating the current state of the debris based on its thermal and mechanical characteristics are necessary. The influences of Pu upon these characteristics are important for the prediction because subassemblies of uranium-plutonium mixed oxide (MOX) fuel were loaded into Unit 3 of the plant. Melting temperature is an important thermal characteristic for melt-progression analysis. In addition, it is important for predicting debris states because the central part of the debris is expected to have been in a molten state for a long time owing to its decay heat.

In this study, nine specimens of (U, Pu, Zr)O_2 with different chemical compositions were prepared as simulated corium debris (sim-debris). The melting temperatures of the specimens were measured by the thermal-arrest technique described as follows. The specimen was encapsulated in a tungsten capsule in vacuum. This capsule was heated at a constant rate by a high-frequency induction furnace. The temperature of the specimens were measured with a two-color pyrometer sighted on a black-body hole at the bottom of the tungsten capsule. Fig.1-4 shows typical heating-temperature curves of specimens.

The solidus and liquidus temperatures of all specimens are shown in Fig.1-5 as functions of the Zr-content. Examining specimens containing similar Pu-contents in Fig.1-5, the melting temperatures of those containing between approximately 50mol% and 75mol% of Zr seemed to be lower than those with other compositions. From this, it was found that Zr had a similar influence on the melting temperatures of both (U, Pu, Zr)O_2 and (U, Zr)O_2.

The solidus and liquidus temperatures are shown in Fig.1-6 as functions of Pu-content. The temperatures of (U, Pu, Zr)O_2 were higher than those of (U, Zr)O_2 at the same Zr-content when the Pu-content was less than approximately 10mol%. In contrast, these temperatures were lower than those of (U, Zr)O_2 when Pu-content was 20mol%. From these results, it was found that the solidus and liquidus temperatures of (U, Pu, Zr)O_2 had a local maximum value in the Pu-content range between 0 to 20mol%. The results obtained in this study are expected to contribute to the prediction of reactor-core situations and severe-accident analysis.

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Reference

Morimoto, K. et al., The Influences of Pu and Zr on the Melting Temperatures of the UO_2–PuO_2–ZrO_2 Pseudo-Ternary System, Journal of Nuclear Science and Technology, vol.52, issue 10, 2015, p.1247-1252.