6–3 Toward the Realization of High Temperature Gas-Cooled Reactor for Safe Reduction of Plutonium Inventory —Microstructure Observation of a Simulated Fuel Kernel—

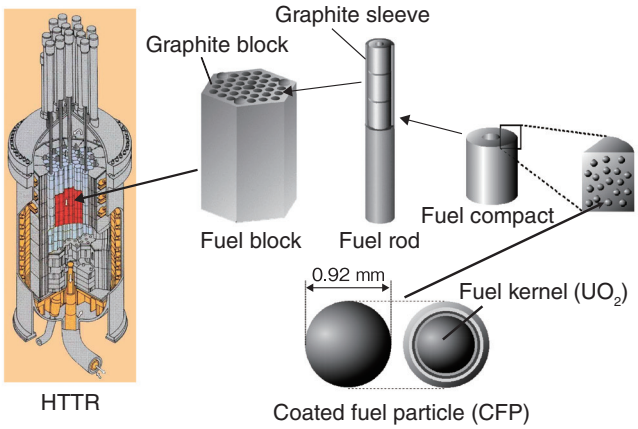

Fig.6-6 Fuel of the High Temperature Engineering Test Reactor (HTTR) in Japan Atomic Energy Agency *1, *2
A UO_2 fuel kernel was coated with four-layered coating layers to form a coated fuel particle (CFP) with a diameter of approximately 1 mm. Compacts were put into a graphite sleeve to form a fuel rod.

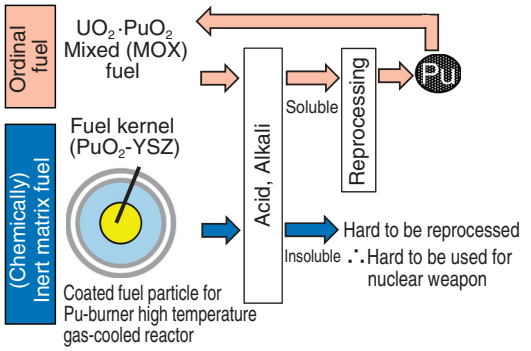

Fig.6-7 Structure of the CFP with (chemically) inert matrix fuel and its nuclear proliferation resistance
The yttria-stabilized zirconia (YSZ) used in this CFP as the inert matrix is chemically stable and insoluble in acid and alkali. YSZ makes the fuel difficult to reprocess and increases the nuclear proliferation resistance of fuel.

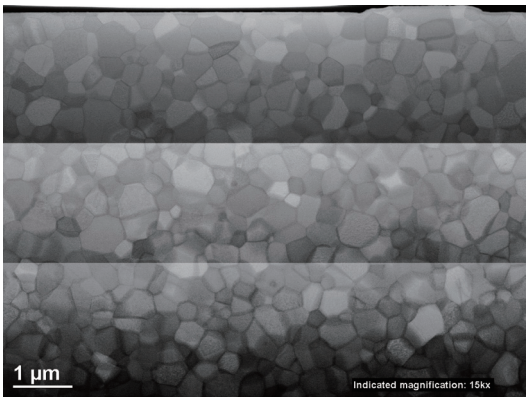

Fig.6-8 Microstructure of the center region of the CeO_2-YSZ kernel (scanning transmission electron microscopic bright-field image)
There are hardly spaces between crystal grains. If the crystal grains are not densely distributed, the fuel kernel may not contain enough Pu.
(reprinted from Aihara, J. et al., Influences of the ZrC Coating Process and Heat Treatment on ZrC-coated Kernels used as Fuel in Pu-burner High Temperature Gas-cooled Reactor in Japan, Journal of Nuclear Science and Technology, Vol.58, 2021, p.107-116. Published online: 23 Aug 2020, Taylor & Francis Ltd, by permission of Taylor & Francis Ltd, http://www.tandfonline.com)

The Japanese government made an international commitment not to possess excess amount of plutonium (Pu) in its utilization plan. A high temperature gas-cooled reactor (HTGR) has inherent safety features; hence, the concept of the Pu-burner HTGR was proposed to safely reduce the amount of recovered Pu.

The minimum unit of the HTGR fuel is coated fuel particle (CFP) with a diameter of approximately 1 mm. Fissile materials and fission products are contained in each CFP. The CFP used in the High Temperature Engineering Test Reactor (HTTR), which is a HTGR test reactor constructed in Oarai Research and Development Institute in JAEA, employs a UO_2 fuel kernel coated with four-layered coating layers (Fig.6-6). In the Pu-burner HTGR concept, the CFP, whose fuel kernel consists of inert matrix fuel, is employed. The inert matrix fuel should be chemically stable and should be hard to reprocess (Fig.6-7). The nuclear proliferation resistance of the CFP with inert matrix fuel kernel should be high. In this study, yttria-stabilized zirconia (YSZ) containing PuO_2 (PuO_2–YSZ) was employed as the fuel kernel.

The Nuclear Fuel Industries, Ltd. took charge of the development of fabrication technology of the PuO_2–YSZ kernel and fabricated the simulated PuO_2–YSZ kernels. We observed the microstructure of a fabricated simulated PuO_2–YSZ kernel as a part of the inspections.

Cerium (Ce) was used as the material simulating Pu. The chemical properties of Ce imitate those of Pu. A solution was prepared by dissolving Ce, Y, and Zr nitrate powders in water. The prepared solution was dropped into ammonia water to form gelated particles. These gelated particles were then sintered to form the CeO_2–YSZ kernels.

We observed the center region of the fabricated CeO_2–YSZ kernel and found that the crystal grains were densely distributed (Fig.6-8). This result indicates the possibility that the fabrication method of the fuel kernel similar to that described above is proper. If the crystal grains are not densely distributed, the fuel kernel may not contain enough Pu.

This study includes the results of the “Development of Security and Safety Fuel for Plutonium Burner HTGR” performed under the Innovative Nuclear Research and Development Program by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

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*1 Goto, M. et al., Conceptual Design of Small-Sized HTGR System (II) - Nuclear Design -, JAEA-Technology 2012-017, 2012, 29p.
*2 HTGR Research and Development Center, Japan Atomic Energy Agency, What is HTGR ?, https://www.jaea.go.jp/04/o-arai/nhc/en/faq/index.html (accessed October 14th, 2021).

Reference

Aihara, J. et al., Influences of the ZrC Coating Process and Heat Treatment on ZrC-Coated Kernels Used as Fuel in Pu-Burner High Temperature Gas-Cooled Reactor in Japan, Journal of Nuclear Science and Technology, vol.58, issue 1, 2021, p.107–116.