Behavior of a Metallic Precipitate in an Irradiated Simulated Fuel

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A specimen of simulated fuel which was irradiated at HANARO research reactor as much as 3,300 MWd/tU of burn-up at the condition of 36 kW/m of maximum linear power was studied by a shielded EPMA (Electron Probe Micro-Analyzer). In order to obtain an accurate analysis and to compare the result, chemical analysis and EPMA were also performed for an un-irradiated fresh simulated fuel. This study concentrated on the metallic precipitates of the irradiated simulated fuel specimen which contained lots of fission products. Among the several properties of the metallic precipitate, the size and concentration were investigated. It was also observed a large metallic inclusion in the irradiated simulated fuel and X-ray photographs were taken to analyze the properties of the large metallic inclusion.

Fig. 1(a) depicts the distribution of the metallic precipitate in the radial direction. From the center of the specimen, 10 parts with the same distance of 400 ㎛ are selected arbitrarily and 200 SEM magnifications were taken. Among the several metallic precipitates, the average size was obtained from 5 different images. The metallic precipitates observed in the fresh simulated fuel were 0.5~1.0 ㎛, while those of the irradiated simulated fuel were 2~3.5 ㎛ in diameter. it is believed that the initially produced precipitates during sintering were grown by coalescence with newly produced fission products during a irradiation. And it was found that the size of the metallic precipitate became smaller from the center to the surface in the specimen. Fig. 1 (b) shows the quantitative results for the Mo element at 50 points in the radial direction. It is well known that Mo exists as an oxide form in a fuel matrix. Because a metallic precipitate is distributed abnormally in a fuel, an analysis of Mo was performed with EPMA on the grain boundary rather than in the grain. Among the several EPMA methods, a TV mode was chosen with a magnification of 10,000 times. Although the concentration of Mo may increase in a metallic precipitate, a trend of Mo can be estimated if an analysis is performed at an arbitrary point with the same distance in the radial direction. In Fig. 1 (b), the concentration profile of the molybdenum dissolved in the fuel matrix, trend represents that the concentration of molybdenum at the fuel surface is scattered more than that at the center. The oxidized molybdenum was assumed to be dissolved in the oxide fuel matrix. This is a result of the fission process because oxygen cannot be completely be bonded by the generated fission products [1].

It was found that the concentration of Ru had a similar behavior of Mo with the same EPMA analysis methods. The data was also extracted by following the same procedure for Mo in Fig. 1 (b). Considering a low burnup of the irradiated simulated fuel, it is understood that the precipitates of the perovskite phases were developed during the fabrication process of the irradiated simulated fuel (oxide/reduction, slitting process). The ceramic nucleation cluster may develop during a sintering process and a solid solution diffusion process. Therefore, it is understood that the main reason for a size change of the metallic precipitate at different regions is its different formations at different temporal conditions during an irradiation in the HANARO.

Fig. 1 (d) depicts a projection of the radial concentration change for the metallic precipitate section

of the Molybdenum-Ruthenium-Palladium phase diagram at 1700℃[2]. The oxidation and reduction processes had an effect on the formation of the metallic precipitates. Also a large metallic inclusion was found and some quantitative results were provided including weight percents for some major elements. To investigate more reliable results for the metallic precipitate and large metallic inclusion in an irradiated simulated fuel, more post-irradiation tests should be performed with various kinds of fuels. It is believed that the approach of this study will be helpful for analyzing the performance of impurities in an irradiated fuel.

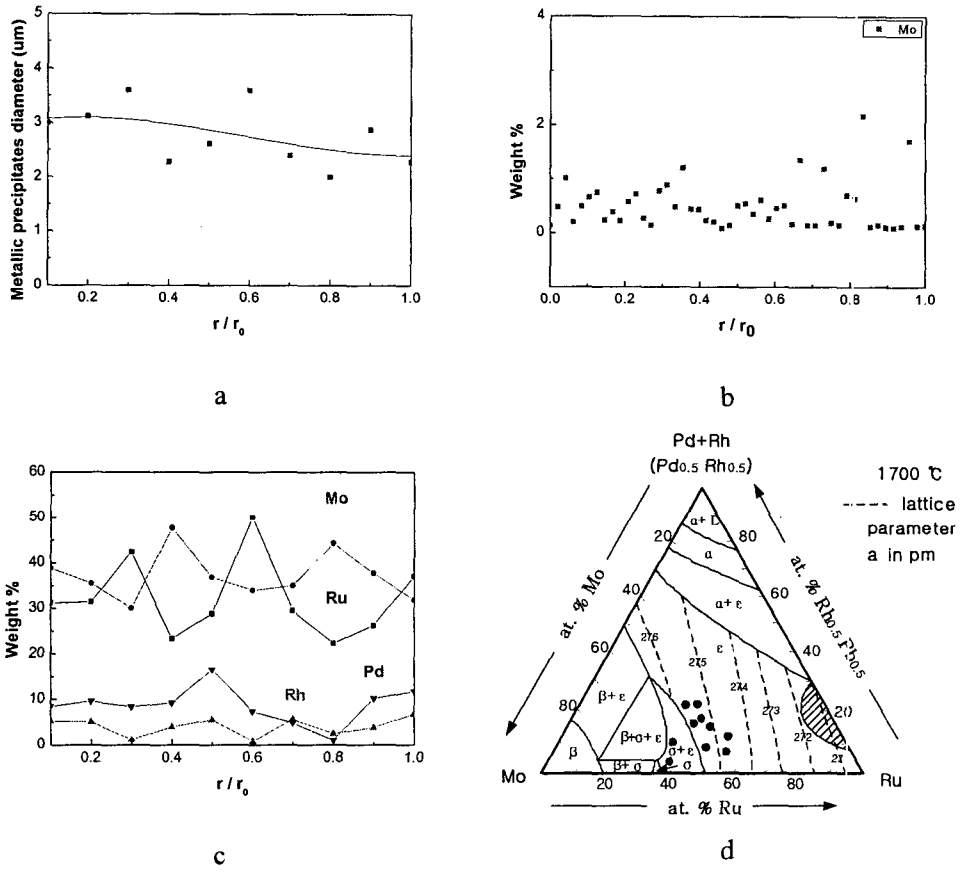

Fig.1. Size and composition of the irradiated simulated fuel. (a) Size of metallic precipitate, (b) Distribution of Mo concentration (X10,000), (c) Wight percents of various metallic precipitates, (d) The hexagonal Mo-Ru-(Rh+Pd) precipitates of irradiated simulatedfuel. The compositions are projected onto the Mo-Ru-$Rh_{0.5}$ $Pd_{0.5}$ section at 1700 ℃.

Reference

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