Performance test of the Laser Ablation System in a Lead Shielded Glove Box

Yeong-Keong Ha, Sun-Ho Han, Ki-Chul Han, Kwang Yong Jee, Won-Ho Kim
Nuclear Chemistry Research Division, Korea Atomic Energy Research Institute, Dukjin-dong, Yuseong, Daejeon, 305-353, Korea, nykha@kaeri.re.kr

1. Introduction

In nuclear industry, burn up measurement by analysis of fission monitors in a spent fuel and the radial distribution of a fission product are essential for the operation of a reactor. Most analytical techniques for the burn up measurement are based on the dissolution of solid samples. The preparation process of solid sample has a lot of problems affecting the accuracy of the results. In addition, concerning the radial distribution of the fission products from core to rim in a spent fuel, the analytical method based on the dissolution is inadequate.

Probing the sample with a laser beam provides a route for studying the spatial distribution of elements in the solid sample due to its spatial resolution.[1,2] It could solve the problems such as incomplete dissolution of sample, precipitation of insoluble elements, loss of volatile elements during heating and contamination of the sample during preparation.

In this laboratory, we developed the lead shielded laser ablation system for the direct analysis of spent fuel.[3] The laser ablation system was installed in a lead shielded glove box and optically aligned. The performance for each component of this system was tested in this work.

2. Experimental Setup

The laser ablation system was developed for the direct analysis of the fission monitors and their radial distribution in a spent fuel. It consisted of a Q-switched Nd:YAG laser, image analyzer, XYZ translator with motion controller, ablation chamber, and various optics. This system was gamma shielded by lead shield glove-box for the analysis of radioactive material in the spent nuclear fuel (Figure 1).

2.1 Laser system

The tunable Nd:YAG laser from 1064 nm to 266 nm was used as light source for laser sampling. The laser could be operated with a pulse repetition rate from 1 to 20 Hz, and maximum pulse energy of 3 mJ. The laser beam was focused onto the sample surface by 90° reflection mirrors and a focusing lens (focal length 6cm).

2.2 Image system

To adjust sampling position and to observe the spot size and its shape, image system was installed. It was composed of CCD camera, TV tube, object lens and illuminator. The magnification of viewing optics was x500.

Figure 1. The lead shielded laser ablation system

2.3 XYZ Micro Translator

For the analysis of micro region, three linear translators were installed with motion controller. The travel distance was 50 mm and resolution was 1 ㎛.

2.4 Ablation chamber

Figure 2 shows the ablation chamber designed by this group. Fused silica window was used for UV laser and it can be replaced easily. A hinge was used for easy opening and closing. Ablated particles were transported to the ICP mass spectrometer by argon carrier gas.

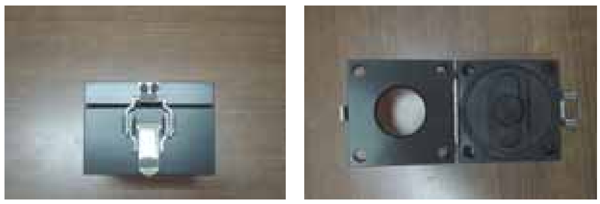

Figure 2. Ablation chamber; (left) front view, (right) top

view.

2.5 Gamma shielded glove box

The front panel consisted of a lead glass window, a couple of manipulator, and a pair of glove port. The rear panel has maintenance door and fused silica window for the UV laser entrance. The floor panel has three utility line holes for the translators, carrier gas and a image system. A lighting system was installed on the roof panel. The left side panel has cask adapter and specimen entrance hole.

3. Results and Discussions

3.1 Performance test for light source and its alignment

Laser beam should have Gaussian shape with the “flat-top” mode, which means good in homogeneity of power distribution.[4,5] Fig. 2 shows the changes of craters with respect to laser pulse energy. From the flat-bottomed, round shaped craters, we could see that the power distribution of the laser beam was homogeneous and it aligned well.

70% 65% 60% 55% 53%

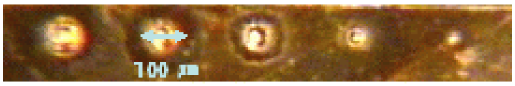

Figure 3. The changes in crater size as a function of laser power.

3.2 Travel distance and resolution of image system

For heterogeneous samples, μm-scale translation should be possible. The translator could travel 50 mm with a minimum movement of 1 μm. To examine accurate and precise movement of translation system, we moved the translator by 100 μm interval and the ablated sample specimen (zircaloy-4) was observed by image analyzer. Figure 4 shows the resolution of laser sampling. It may enable to analyze the radial distribution of isotopes in a spent fuel.

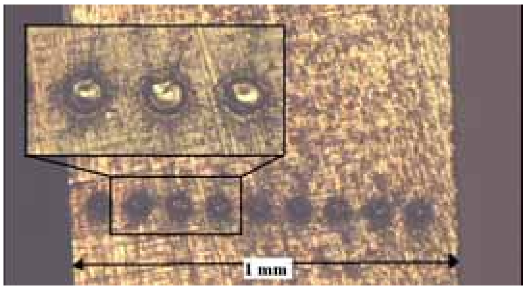

Figure 4. The spatial resolution of laser sampling. (55% laser power, 10 Hz)

4. Conclusion

The lead shielded laser ablation system was developed. The craters were almost round, indicating that the power distribution of the laser beam was homogeneous. The translator could travel 50 mm with a minimum movement of 1 μm. The specimen could be measured by 50 μm interval by this system.

Thus, the laser ablation system could be applied to the determination of isotope distribution from core to rim of irradiated fuel.

Acknowledgements

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