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Laser ablation of metal surfaces contaminated with Cs^+ ions

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1. Introduction

Laser cleaning is a relatively recent technique for removing pollutants from surfaces that is currently finding applications in many fields. In a nuclear industry, there is a great interest to develop an efficient dry decontamination process. During the application of the dry decontamination process, the generation of a secondary waste is negligible. The radioactivity of hot cells in the DFDF (Dupic Fuel Development Facility) is presumed to be high and the predominant radionuclide is Cs-137. A Q-switched Nd:YAG laser with a 1064nm and 450 mJ/pulse was employed to study the decontamination characteristics of type 304 stainless steel specimens artificially contaminated with Cs^+ ion. Decontamination characteristics analyzed by SEM and EPMA.

2. Methods and Results

In this section some of the experimental methods, procedures and results are described.

2.1 Specimen Preparation

Type 304 stainless steel specimens were used in the present experiment. The specimens were polished with abrasive papers. After they were washed with ethyl alcohol, they were dipped into an ultrasonic cleaner for 30 minutes and dried. For an artificial contamination, Cs^+ ion containing solution was thrown onto a specimen surface. After all of the specimens were fully dried, they were analyzed by SEM and EPMA.

2.2 Laser irradiation

Q-switched Nd:YAG laser fabricated in KAERI was employed. A pulse duration of Q-switched Nd:YAG laser was 14 ns. Maximum applied repetition rate was 20 Hz. The system emits fundamental wavelength at 1064 nm, and specimen was irradiated for 42 shots. A JSM-6300 scanning electron microscope (SEM) was employed to examine any laser induced alterations to the original surface. EPMA analysis was used to identify the chemical composition. Fig. 1 shows the experimental apparatus.

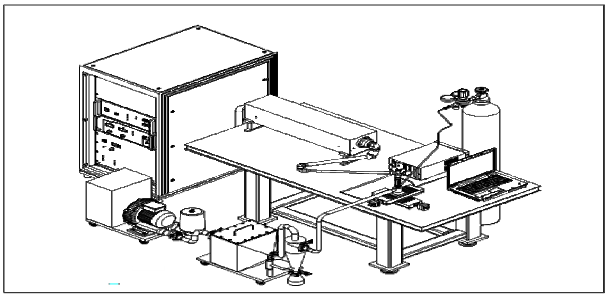

Fig.1. Experimental apparatus for laser decontamination experiment.

2.3 Test results

Fig. 2 shows the SEM photographs of a specimen after 42 shots of a laser irradiation. The high laser heating rate cause the significant amount of metal area to be melted. The chemical composition of the stainless steel surface as shown in Fig. 2 is listed in Table 1. The Cs^+ ion at Fig.2 ($CsNO_3$+CeO_2) is fully eliminated.

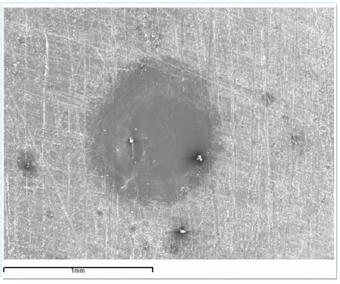

Fig.2. SEM photograph of stainless steel surface contaminated with $CsNO_3$+CeO_2 after 42 laser shots.

Table 1: Chemical composition of the stainless steel surface (after decontamination)

Remarks	Ce	O	Si	Cr	Fe	Ni	Cs	K
$CsNO_3$ + KOH	0.00	4.50	1.03	16.94	69.80	7.73	0.00	0.00
$CsNO_3$+ KNO_3	0.00	24.66	0.57	11.57	56.46	4.75	0.00	1.99
$CsNO_3$	0.00	10.73	0.24	15.36	65.72	7.83	0.12	0.00
$CsNO_3$ + CeO_2	2.53	19.09	4.77	22.42	45,92	5.27	0.00	0.00

Fig. 3 shows the relative atomic molar percent of Cs^+ ion on stainless steel surface after laser irradiation. As shown in Fig. 3, Type 304 stainless steel specimen was contaminated with $CsNO_3$ + CeO_2 solution. The relative atomic molar percent of Cs^+ ion in Fig. 3 is listed in Table.1. All the tests were performed at the pulse energy of 450 mJ/pulse and the repetition rate of 20 Hz. Contrary to the Cs^+ ion content of the stainless steel specimen surface before laser irradiation, negligible amount of Cs^+ ion is found after laser irradiation. This means that all the Cs^+ ions was ablated by a laser application. These phenomena can be explained by two reasons. 1) As the Cs^+ ion is a semi volatile element, Cs^+ ion evaporated at a high temperature during a laser application. 2) Fe, Ni, and Cr which are the main elements of stainless steel were ablated thermally by a laser irradiation [1]. The Cs^+ ion was concurrently ablated.

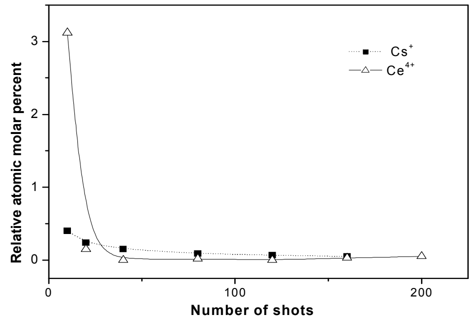

Fig. 3. Relative atomic molar percent of Cs^+ ion and Ce^{4+} ion after laser application against the number of laser shots, 57.3 J/cm^2 and 14 shots/sec, CeO_2 in 0.015 M $CsNO_3$,

Conclusion

Decontamination tests using a Q-switched Nd-YAG laser system were performed on stainless steel specimens artificially contaminated with Cs^+ ion. Cs^+ ion on the type 304 stainless specimens were removed satisfactorily by the laser decontamination method with a little generation of a secondary waste. But the $CsNO_3$ solution was not removed satisfactorily from a specimen surface by laser irradiation. The results show that laser decontamination method can be applied to the real metal surfaces contaminated with radioactive cesium. Finally, the present method also has a possibility to decontaminate the equipment in hot cells or to reduce the volume of radioactive wastes generated from nuclear facilities with a little occupational exposure to workers.

Acknowledgement

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