Transactions of the Korean Nuclear Society Spring Meeting
Taebaek, Korea, May 26-27, 2011

Laser removal of contaminants from aluminum surface using Q-switched Nd:YAG radiation at 1064, 532 and 355nm

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1. Introduction

Radioactive contaminants on material surface must be decontaminated to reduce the radiation exposure of workers before the refurbishment of the old nuclear facilities. Laser ablation is a relatively new surface decontamination method and the method meets the following requirements[1]: safety, high decontamination factor, cost-effectiveness, waste minimization and feasibility of industrialization. The objective of the work is to study the effect of wavelength on the removal of Cs^+ and Co^{2+} ions on aluminum surfaces by laser. Laser beam from Q-switched Nd:YAG operating at the fundamental (1064nm), second harmonic (532nm) and third harmonic (355nm) wavelengths was irradiated on the surfaces of contaminated specimen.

2. Methods and Results

2.1 Specimen Preparation

Aluminum specimens were polished, washed with ethyl alcohol, dried and photographed. They were dipped into an ultrasonic cleaner for 30 minutes and dried. For an artificial contamination, a small amount of solution containing Cs^+ and Co^{2+} was thrown on specimen surfaces, respectively. After drying, they were analyzed by SEM (scanning electron microscopy, JEOL Ltd. Model: JSM-6300) and EPMA (Electron probe micro analyzer).

Table 1. Chemical composition of the aluminum surfaces before decontamination (relative atomic molar %) .

Element	N	O	Al	Ag	H	Cs	Co
$Co(NH_4)_2(SO_4)_2$	trace	13.6	81.3	0.4	trace	-	4.7
$CsNO_3$	trace	26.8	68.7	0.2	-	4.3	-

2.2 Laser irradiation

Q-switched Nd:YAG (Quentel Co. Model: Brilliant b) with a fundamental, second harmonic and third harmonic generation was employed. The repetition rate was 10Hz (three wavelengths) and pulse duration was 6ns (1064nm), 5ns (532nm) and 5ns (355nm). The specimen was mounted on a stage that allowed the specimen holder to move of 25mm x 25mm in the X and Y directions. Fig.1 shows the schematic diagram of the experimental apparatus.

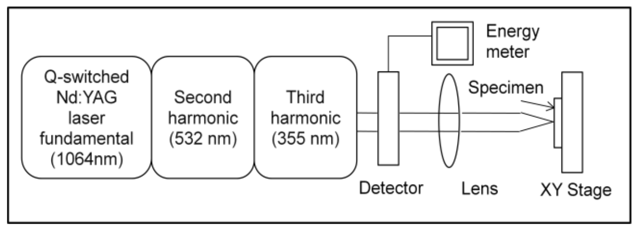


Fig.1. Schematic diagram of experimental apparatus.

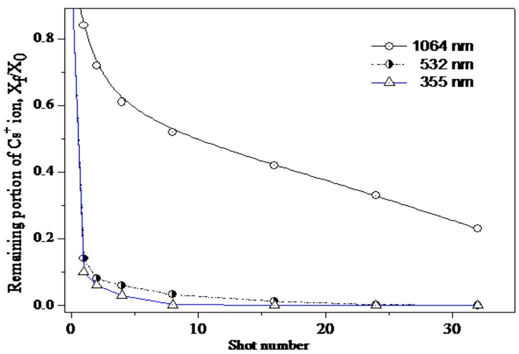
2.3 Test results

The samples were irradiated at all wavelengths for the optimization of laser fluences and were analyzed by EPMA. Laser decontamination of aluminum specimens was achieved over a range of fluences for each wavelengths. It could be shown that a crater was formed during the laser irradiation. Rafique et al.[2] reported that the hydrodynamic effects were apparent with a liquid flow which formed a recast material around the periphery of the laser focal area. Table 2 lists the decontamination performance of aluminum specimen under the optimized conditions. The optimized laser decontamination fluence of fundamental (1064nm) was 57.3J/cm^2, second harmonic (532nm) was 13.3J/cm^2 and third harmonic (355nm) was 8.3J/cm^2.

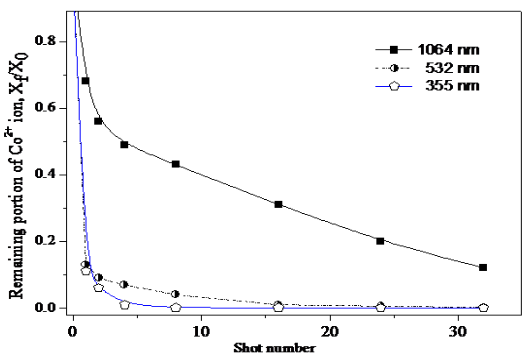
Table 2. Decontamination performance under the optimized condition.

	1064nm (900mJ/pulse) Fluence : 57.3J/cm^2 Shot number : 40	532nm (450mJ/pulse) Fluence : 13.3/cm^2 Shot number : 20	355nm (200mJ/pulse) Fluence : 8.3J/cm^2 Shot number : 10
Cs (%)	99.0	99.2	99.6
Co (%)	99.2	99.5	>99.9

For all the three wavelength conditions Co^{2+} ion was easier to decontaminate. As the increase of the wavelength, shot number and fluenec became to decrease. This means that the application of lower wavelength is more efficient among the tested wavelengths. For all the decontamination conditions, decontamination factor exceeded 100. At 355nm wavelength condition, the contaminants were satisfactorily decontaminated during the first 10 laser shots.



(a)



(b)

Fig. 3. Remaining portion of contaminants on aluminum surfaces against the number of laser shuts under three wavelength conditions (fluence :12J/cm^2), (a) Cs^+ ions (b)Co^{2+} ions .

Fig. 3 shows the change of the relative atomic molar ratio of 2 kinds of contaminants on aluminum surfaces against the laser shut numbers. For 532nm and 355nm wavelength conditions, most of contaminants were removed within 10 laser shots. However, contaminants were poorly removed within 30 laser shots at 1064nm. The order of removal efficiency at 12J/cm^2 of fluence condition is 355nm>532nm>1064nm. Nanosecond-laser ablation has been explained by the basis of thermal, mechanical, photochemical, photophysical and defect model [3]. It is assumed that the photochemical reaction at 355nm enhanced the removal of contaminants.

3. Conclusion

Q-switched Nd:YAG laser decontamination tests were performed on aluminum specimens artificially contaminated with Cs^+ and Co^{2+}. This study showed that 355nm (8.3J/cm^2) was most excellent in the decontamination performance on 2 kinds of ions on aluminum specimens. It will be necessary to study the ablation mechanism. The study of laser irradiation on the Type 304 stainless steel and concrete contaminated with the surrogate contaminants is carried out.

Acknowledgement

This work was carried out under the Nuclear R & D Program funded by the Ministry of Education, Science and Technology.

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