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Particle Collection from Laser Decontamination

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1. Introduction

The use of a laser for surface decontamination of large number of nuclear facilities is a new and effective technique. A significant number of very small particles can be produced during the decontamination process [1-3]. The effective collection of particles is critical in determining the surface removal efficiency [4-6].

There was investigated the relationship of particle formation by the laser decontamination process using a laboratory contaminated specimen made from stainless steel 304. The objectives of this study were to characterize the particles generated during the decontamination process, and to determine an optimal collection system required to efficiently remove the particles generated.

2. Methods and Results

2.1 Methods

Two forms of ionic contaminant specimens on the surface of stainless steel 304 (SUS 304) were prepared using cobalt ammonium sulfate, $Co(NH_4)_2(SO_4)_2$ and cesium nitrate, $CsNO_3$ solution diluted with distilled water. Two particulate-contaminant specimens were also made by dispersion of europium oxide (Eu_2O_3) and cerium oxide (CeO_2) in distilled water. Each solution was slowly dropped on the surface of SUS 304 by injection and dried.

The experimental setup is shown in Fig. 1. A Q-switched Nd:YAG laser (Big Sky Laser Tech. Inc.) was used as the energy source for emitting 532 nm wavelengths, with a maximum energy of approximately 150 mJ per pulse. The laser pulse width was 8ns. The laser was fired at a repetition rate of 14 pulse/sec. A focusing lens with a diameter of 20mm and a focal length of 195mm was used. The fluence ranges for 532-nm wavelengths, which was calculated by dividing the applied laser energy by the affected area (beam size), were 4-20J/cm^2. The scanning mobility particle size (SMPS) system was used to characterize the particles generated during the decontaminant process, and to evaluate the particle collection characteristics of the filter system with HEPA filter media (PALL model A/E). The particle counts were measured by a SMPS system, consisting of Ultra fine condensation particle counter (UCPC) (TSI model 3025A) and a electrostatic classifier (TSI model 3080) with a long differential mobility analyzer (DMA) (TSI model 3081), both up stream and down stream of the HEFA filter. Particle size distribution was obtained by combining the particle size and concentration data. The particle size range measured by the SMPS system was 6-200nm at a sheath flow rate of 0.38L/min. The SMPS scanning time was 50s and 10s for up and down scan, respectively.

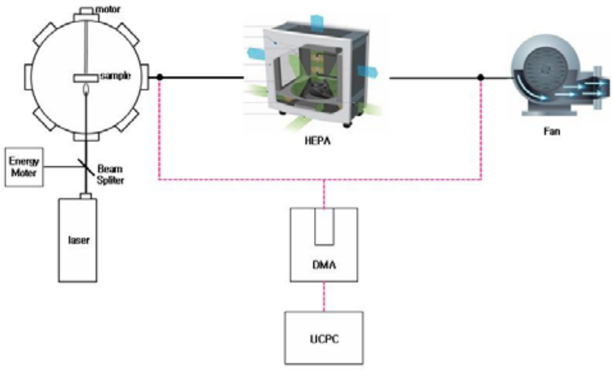

Fig. 1. Experimental setup for particle generation form laser decontamination and particle collection.

2.2 Particle size distribution

The size distribution results obtained from a 532-nm wavelength laser ablation at a fluence of 18 J/cm^2 is shown in Fig.2. The geometric mean diameter of particles produced from the ionic-contaminant embedded SUS 304 (Co and Cs) and the particulate-contaminant embedded SUS 304 (Eu and Ce) were 70nm and 80nm, respectively. Regardless of the contaminant material used, the size distribution and geometric mean diameter of the generated particles did not change significantly at the given fluence condition.

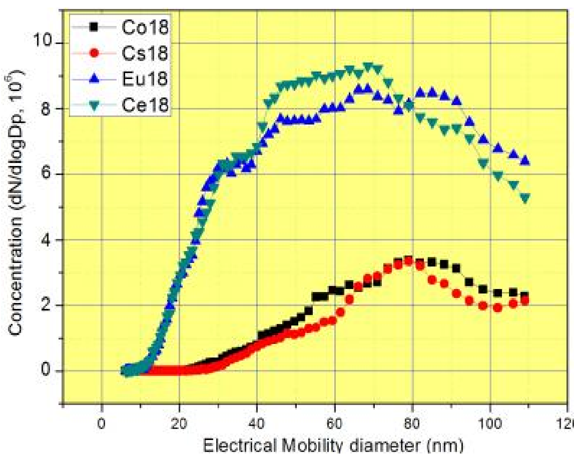

Fig. 2. PSD for laser ablation on radionuclides embedded SUS 304 at a fluence of 18 J/cm^2.

The total number concentration for each contaminant material was calculated by summing up concentrations (particles / cm^3) of all of the particles in the size range, from 6 to 220nm from the particle size distribution data.

The ionic-contaminant embedded SUS 304 produced more particles by a factor of about 3 than the particulate-contaminant embedded SUS 304. The reason for this results was believed that the boiling point of the particulate-contaminant embedded SUS 304 (Eu_2O_3 : 4118℃, CeO_2 : 3500℃) was higher than that of the ionic-contaminant embedded SUS 304 ($Co(NH_4)_2(SO_4)_2$: 735℃, $CsNO_3$: 671℃) with this laser ablation condition.

2.3 Collection efficiency

Collection efficiencies of commercial HEPA filter for the nanoparticles generated during the laser decontamination process were measured using a SMPS system. The experiment results are shown in Fig.3, in terms of the collection percentage with respect to the contaminated radionuclides.

Collection efficiency ranges at a fluence of 6 J/cm^2, and 18 J/cm^2 was 99.20-99.93%, and 99.36-99.94%, respectively. Nanoparticle collection efficiency increased slightly as the laser fluence increased for all contaminated materials.

It can be demonstrated that a large percentage of the removed contaminants can be captured before redeposition occurs and collected by a disposable dry HEPA filter.

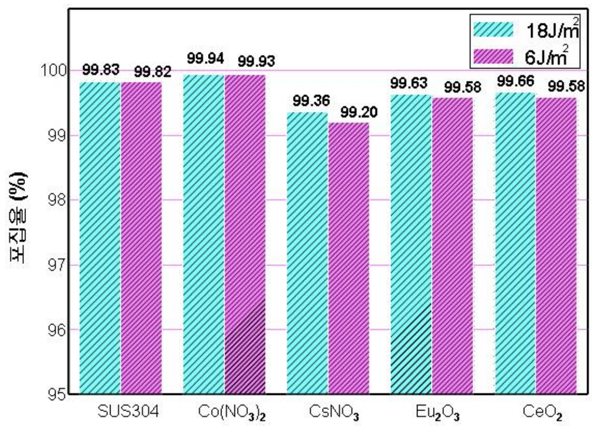

Fig. 3. Collection efficiency of HEPA for decontamination particles on radionuclides embedded SUS 304 at a fluence of 18 J/cm^2 and 6 J/cm^2.

3. Conclusions

A significant number of particles can be generated from a laser decontamination process for the contamination of cobalt, cesium, europium and cerium on a stainless steel surface.

The number concentration and size distribution of the particles were investigated on the variation of laser fluence for 532-nm laser ablation. The geometric mean diameter that appears to be independent of the applied laser fluence, were about 70-80nm for all contamination tested from SMPS data.

The collection of removed particles in the HEPA filter was studied. Most of the removed particles were found to be collected in the HEPA filler and a more efficient filter of the HEPA type would lead to >99.2% trapping of removed contaminants.

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