Identifying Radioactive Materials in Dirty Bomb Terror Scene Using Laser-Induced Breakdown Spectroscopy

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1. Introduction

According to Incident and Trafficking Database (ITDB), a total of 1174 incidents that indicate the intent to acquire radioactive material for trafficking or malicious usage are confirmed until 2016 [1]. Recently, terrorist groups such as ISIS and Al-Qaeda have shown more interest in obtaining these hazardous materials. Their goals are to make radiological dispersal devices (RDDs) which are also called dirty bombs. If dirty bombs explode, the surrounding areas will be contaminated with radioactive materials. Those terrorism induces significant health effects with panic.

To minimize the damage caused by dirty bomb terrors, rapid and precise identification of the radioactive materials in early phase is required. The most conventional radiation detector is the Geiger-Muller counter (GM counter). It is portable, however, it cannot distinguish the types of radiation. Secondary-Ion Mass Spectroscopy (SIMS) or Thermal Ionization Mass Spectroscopy (TIMS) is used for isotopic analysis, but it takes at least a day. To overcome these limitations, Laser-Induced Breakdown Spectroscopy (LIBS) has been studied. Previous studies show that LIBS can be used for nuclear forensics with its ability of prompt and accurate nuclear materials analysis [2, 3]

The aim of the present work is to assess the feasibility of identifying radioactive materials by LIBS. Moreover, the best matrix to detect radioactive materials were found by comparing LODs of each matrix.

2. Methodology

2.1 Sample Preparation

Argonne National Laboratory suggested 9 attractive isotopes of interest in RDDs, based on not only portability of the isotopes, but the level of radioactivity they emit [4]. Among them, $SrCl_2$, CsCl, Co, and Ir that were chemical forms of radioactive materials often found in sealed source were chosen as target materials. Since terrorism is highly likely to occur in crowded cities, matrix was chosen as common substances in the city such as aluminum, stainless steel, polyester, and PET.

To simulate the terror scene, target materials are dissolved into highly purified water that ranges from 0.2 ppm to 20 ppm, and sprayed 80 times onto matrix homogeneously using a sprayer. The matrix was heated to 130 ℃ by a heating plate to make sprayed water evaporated continuously without lumping which prevented the coffee-ring effect.

2.2 Experimental Setup

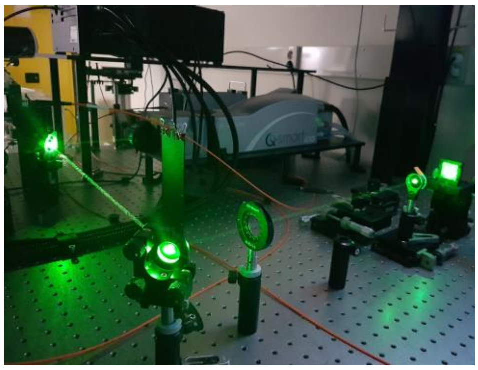

Fig. 1. LIBS System.

To perform LIBS, a compact Q-switched Nd:YAG laser (20 Hz, 532 nm, 220 mJ per pulse, 5 ns pulse width) was used to ablate targets. After ablated material is dissociated into excited ionic and atomic species, the plasma quickly cools down, and then the excited ions and atoms emit characteristic emissions as they return to ground states. Since continuum and characteristic emissions produced by plasma light are superimposed, light must be separated to analyze each substance. To obtain spectra of targets, an Echelle spectrograph (195 mm focal length, f/7, 200 – 975 nm of operating range) combined with intensified-CCD (13 × 13 μm^2 pixel size) was used.

3. Results

Fig. 2 shows a spectrum of aluminum as a matrix with strontium chloride as a target material among several samples. As shown in the figure, when strontium was sprayed on aluminum, the persistent emission lines of strontium were newly observed while those of the aluminum were constantly observed.

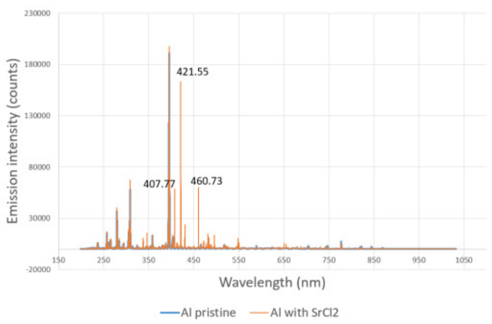

Fig. 2. LIBS spectrum comparison of pristine aluminum and aluminum sprayed with strontium.

In order to calculate limit of detection (LOD) values, the calibration graphs of concentrations of the strontium chloride were obtained. As shown in fig. 3, R^2 of each calibration line exceeded 0.94, indicating that the intensity of the emission line is well fitted to the concentration of the strontium.

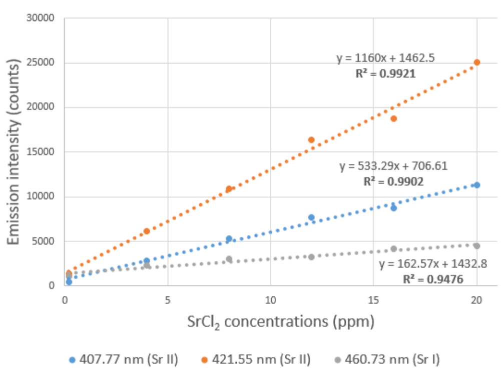

Fig. 3. Calibration graphs for aluminum with strontium sample at 407.77 nm, 421.55 nm, and 460.73 nm.

4. Conclusion

The results of the experiment show that all radioactive materials were identified with low LODs. Therefore, the present work not only establishes LIBS database but demonstrates the feasibility of identifying radioactive materials in urban areas when a dirty bomb terror occurs. This technique is anticipated to provide roadmap of in-situ analysis in a dirty bomb terror scene as handheld and telescope LIBS are developed which makes portable and remote detection by LIBS possible.

ACKNOWLEDGEMENT

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