REMOTE MONITORING OF AIRBORNE ASBESTOS PARTICLES USING LASER-INDUCED FLUORESCENCE IMAGING

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ABSTRACT

We have demonstrated that asbestos particles in air can be visualized with laser-induced fluorescence emitted from asbestos. A ultra-violet (266 nm) laser pulse is used to excite asbestos particles suspended in a closed vessel. The fluorescence emitted from the asbestos in the region where the laser beam passes through is detected with a low-pass optical filter and an image intensified CCD camera with ultra-fast gate shutter. Many asbestos particles in the region are separately visualized on an image. It is possible to derive from the image the number and size of asbestos particles through image data processing. The method described in this study is expected to be useful in real-time monitoring of the concentration of asbestos particle.

1. INTRODUCTION

Asbestos is one of the most hazardous environmental pollutants because inhalation of asbestos fibers can cause serious disease such as lung cancer and asbestosis, etc.[1]. In recent years, concern has been raised about diffusion of the asbestos used on exposed surfaces as fireproofing and thermal-isolation materials in the old buildings to an ambient environment. It has promoted study of real-time monitoring of asbestos particle in air from the standpoint of the health hazard because conventional methods for monitoring airborne asbestos particle cannot provide the concentration of asbestos on real-time basis.

The normal method of determining the concentration is to collect asbestos particles on a filter via air sampling and then to count with visual observation the total number of fibrous particle on a phase-contrast optical microscope. It takes at least a few hours to obtain the concentration. Therefore, several real-time monitoring methods using laser light-scattering had been developed [2]. As well as the conventional methods, those methods draw airborne asbestos particles into the device together with air and then detect fibrous particles separately by using the characteristic spatial scattering profiles or polarization dependence of light scattered from a fibrous spherical particle. However, although those methods are capable of counting fibrous particles in real-time, they have not been widely employed yet for airborne asbestos particle.

As an alternative real-time monitoring method, we propose a novel method to measure the concentration of airborne asbestos particle with laser-induced fluorescence emitted from asbestos particle. This method enables to derive the number of asbestos from an image that airborne asbestos in a limited volume are visualized separately.

So far, Raman, mid-infrared, and near-infrared spectroscopic studies, in terms of multiple excitation wavelength (from visible to infrared region) and various kinds of asbestos materials [3], had been extensively conducted. On the other hand, published data on the laser-induced fluorescence emitted from asbestos are limited. A previous study on the fluorescence of chrysotile-asbestos crystals reported that laser light with a wavelength of 330 nm induced the fluorescence spectrum, a wide band with a maximum near 530 nm, whose intensity enhances as the excitation wavelength decreased [4].

On the basis of the results of the previous work, we have examined the fluorescence with a laser light with wavelength of 266 nm and developed a monitoring system for visualizing the individual fluorescence from airborne asbestos particles. The present study provides information on the fluorescence spectrum and the system.

2. EXPERIMENTAL SETUP

Fig. 1 shows a schematic diagram of the experimental setup using the monitoring system. The system is made of (a) a Q-switched Nd:YAG laser device, (b) a CCD camera, and (c) a personal computer for system control. The laser device produces a short laser pulse (wavelength: 266 nm, pulse energy: ~8 mJ, duration: < ~4 ns, diameter: ~5 mm) with a repetition rate of 20 Hz. The CCD camera coupled with a highly sensitive image intensifier employs a zoom lens and (e) a low-pass optical filter to reject laser-scattered light and background optical noise. The image intensifier has a fast gate shutter speed (exposure time: ~5 ns). The timing of the gate shutter is synchronized with the laser pulse, and controlled with a delay pulse generator. (d) A transparent (acrylic resin) closed vessel (size: 20 x 20 x 20 cm, thickness: 2 mm) in which a few tens g of chrysotile-asbestos is enclosed, is used to visualize (f) asbestos fibers suspended in air. The laser device and the CCD camera are located near by the vessel.

The process of the visualization is as follows. (g) The laser beam is set to pass through near around the center of the vessel as shown in Fig. 1. Concurrently with the laser incidence, (i) laser-scattered light and (h) fluorescence are induced from asbestos particles in the volume where the laser beam propagates in the vessel. The CCD camera synchronizing with the laser pulse can visualize only the fluorescence emitted from asbestos fibers in the volume through the optical filter to reject the laser-scattered light.

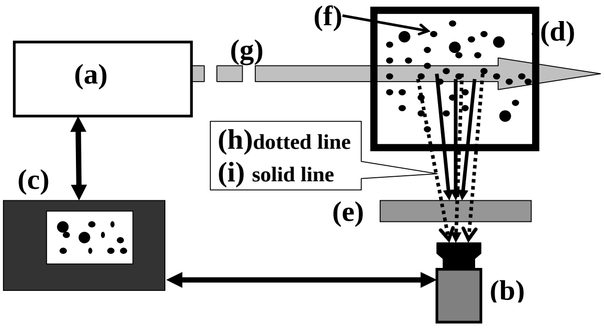

Fig. 1 A schematic diagram of the experimental setup. (a) laser device, (b) CCD camera, (c) control unit, (d) transparent closed vessel, (e) low-pass optical filter, (f) asbestos partiles suspended in vessel, (g) laser beam, (h) fluorescence emitted from asbestos, and (i) laser- scattered light from asbestos.

3. RESULTS AND DISCUSSION

The spectrum of the fluorescence emitted from chrysotile asbestos material was investigated when it was excited by a laser light with wavelength of 266 nm. As a result, fluorescence spectrum with broad band from 400 to 700 nm was clearly observed. The maximum of the spectrum appeared around 500 nm though it appeared around 530 nm in [4].

Taking the spectral characteristics into consideration, the fluorescence emitted from the asbestos was detected by the system with a low-pass optical filter of >450 nm. Fig. 2 shows an image that the asbestos particles suspended in the volume (~1 cm^{-3}) was separately visualized based on the fluorescence. A white speckled and inclined linear area from left to right side in the middle of the image in height is the region where the laser beam propagates. Within the region, many white spots which size is large or small can be seen definitely.

The number and brightness of the spot indicate the number and size of asbestos particle, respectively. If they could be derived with an image data processing used in [5], the number and size distribution of the asbestos particle is expected to be measured on real-time basis. Since the brightness depends on the laser intensity, it has to be compensated by the laser intensity at each position in the region when the size of asbestos particle was estimated from the brightness. Also, since the volume could be estimated, the concentration would be instantly obtained. If the diameter of the laser pulse is more magnified or a large sheet laser beam is used, the measurement volume in the vessel can be extended. In addition, when the laser device and the camera were arranged in the same manner of the remote particle counter described in [5], *in sit* remote-monitoring of airborne asbestos particle in an ambient environment could be realized. This method capable of visualizing asbestos particles with laser-induced fluorescence will be available for monitoring particle of asbestos fiber in air.

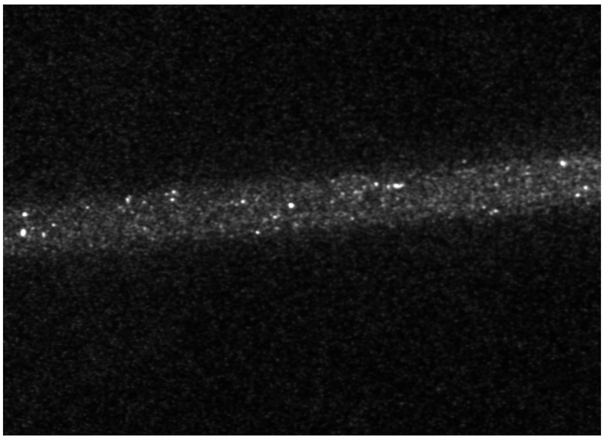

Fig. 2 A picture image of the fluorescence emitted from the asbestos particles suspended in the vessel.

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