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# Ultrasonic wave induced mechanoluminescence

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## 1. Introduction

A practical material that is mechanoluminescent (ML) in the elastic deformation region has been developed in our laboratory for the first time.[1−6] The ML material can continuously emit high-intensity visible light under the application of mechanical stress such as deformation, friction, or impact (Fig. 1). In previous studies, we were able to achieve the following: high mechano-optical conversion efficiency, linearity of ML intensity against load, synthesis of ML microparticles and nanoparticles, etc. By using the ML material, two-dimensional stress distributions in plants, structures, and living bodies can be observed from the viewpoints of safety and reliability against mechanical stress. At high values of ML conversion efficiency, the mechanoluminescence exhibited even under the application of a small mechanical stress such as that generated by scratching the material with a finger can be easily observed with a naked eye. Thus, by increasing the ML conversion efficiency, ML materials can be used as light sources.[7−9]

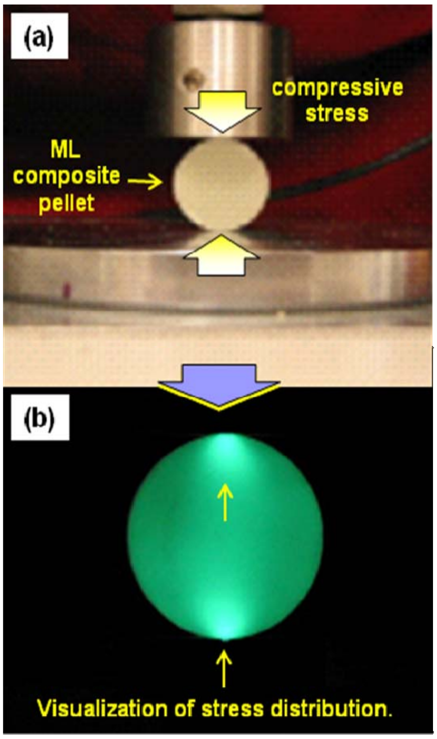


**Fig. 1.** Picture of ML experiment (a), and ML during the application of compressive stress on cylindrical structure (b).

The ML materials are powder of ceramics, and as the characters one by one particle itself is stress sensor and emitting material. In addition, recently, we succeeded to synthesize the ML nanoparticle with the size of 10 nm, and it is enough small to inject and use in bio-body. From these viewpoints, we believe that our ML nano- or micro-particle can be used as an ubiquitous light source even in the dark bio-tissue and cell.

For the purpose, we have investigated mechanoluminescence induced by ultrasonic wave, non-destructive and non-inventive stimulation for bio-tissue, and we successfully detect the mechanoluminescence.

## 2. Experimental

### *Material*

We succeeded in developing ML materials with various emission colors, ultraviolet, blue, yellow and red.[1-6, 10, 11] In this time, europium doped strontium aluminate (denoted as $SrAl_2O_4$:Eu, or SAOE) was used as the ML material, because SAOE is one of the most efficient ML material at this time. The emission peak is located at around 520 nm, produced by the transition of $Eu^{2+}$ ions between $4f^7$ and $4f^6 5d^1$ in SAOE. From the SEM images, the size of the SAOE ceramic particles was estimated to be ca. 3–5 µm (Fig. 2).

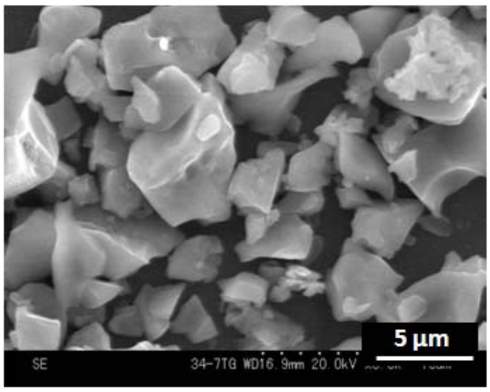


**Fig. 2.** SEM image of SAOE microparticles.

### *Experimental setup*

The experimental setting is shown in figure 3. The SAOE ML particle was blended into adhesion matrix, and immobilized at the bottom of the sample tube with the depth of 2 mm. The SAOE immobilized sample tube was set at the center of the water bath (300×240×85 mm) of ultrasonic cleaner, with immersing 2 mm from the bottom.

The frequency of ultrasonic wave was 37 kHz. The irradiated power of the ultrasonic wave was measured by sound pressure meter (HUS-5, HONDA ELECTRONICS Co.). Emissive light from the ML sample tube was detected by using a photomultiplier and photoncounter (C-8855, Hamamatsu Photonics).

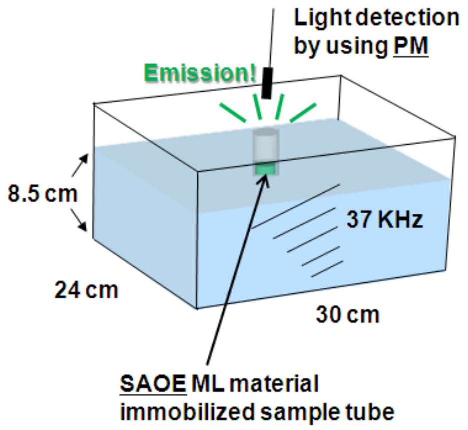


**Fig. 3.** Experimental setup and picture of SAOE ML particle immobilized sample tube.

### 3. Results and Discussions

The response of ultrasonic wave on emission light is shown in figure 4. We can easily find clear emission repeatedly from the ML sample tube dur-ing the ultrasonic wave irradiation. The emission intensity during the ultrasonic wave irradiation was maintained at least within 5 min.

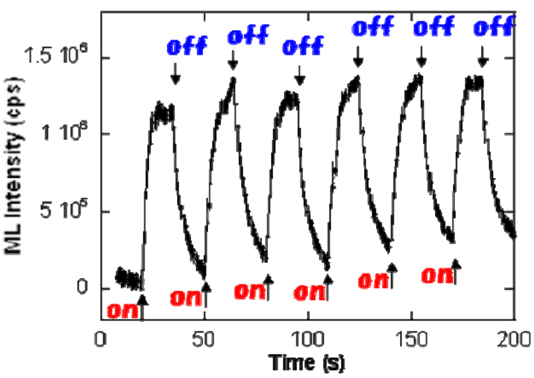


**Fig. 4.** Response of ultrasonic wave on emission light from SAOE ML particle immobilized sample tube. Frequency: 37 kHz

Further, it was found that the emission intensity from the ML sample tube was intentional to the power of irradiated ultrasonic wave. These results clearly indicated that the ultrasonic wave is efficient stimulation for the generation of mechanoluminescence.

### 4. Conclusions

In this study, we have investigated mechanoluminescence induced by ultrasonic wave, and we successfully detected the mechanoluminescence that depend on irradiated power of ultrasonic wave. From the viewpoint of utilizing an ML material as an ubiquitous light source, we can recognize that the ultrasonic wave, non-destructive and non-inventive stimulation for bio-tissue, should be suitable candidate of mechanical stimulation for mechanoluminescence.


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