A Feasibility Study of Laser-based Concrete Stress Measurement Technique

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ABSTRACT: In this paper, a feasibility study for a laser-based concrete stress measurement technique has been conducted and experimentally validated with uniaxial compression tests. Photoluminescence piezospectroscopy (PLPS) method is widely used for measuring residual stresses in thermal barrier coating, and the technique is being researched in civil engineering field recently thanks to its laser-based non-contact and non-destructive features. In this paper, non-contact and non-destructive PLPS technique is firstly applied to a concrete material for measuring stress induced by external force. To do that, a piezospectroscopic material has been mixed with cement powder, and a cubic specimen has been fabricated for uniaxial compression tests. Based on the results of uniaxial compression tests, it has been experimentally proved that the applied compressive stresses into the specimen and its spectral peak shifts have a linear relationship.

1 INTRODUCTION

There are various studies looking for practically applicable nondestructive and noncontact techniques for the concrete stress measurement, but the techniques are still unproved to be practically applied in the field. Photoluminescence piezospectroscopy (PLPS) is a potential nondestructive testing technique that can measure the concrete stress induced by external force. Here, photoluminescence (PL) is a result of light emission process from any form of matter after the absorption of photons, and it can be generated when a sample is irradiated by a laser. Using the spectrum, the molecular structure of a material can be identified. In addition, the stress state of the material can be also determined particularly for α-Al_2O_3 (alumina). It is known as PLPS technique and widely used to determine the residual stress in thermal barrier coating (D.M. Lipkin et al. (1996)). As shown in Figure 1, a typical PL spectrum has two distinguishable peaks of R1 and R2 lines at the wavenumbers of 14,403 cm^{-1} and 14,433 cm^{-1}, and the R1 and R2 lines are shifted to the left or right side from the stress-free spectrum when compressive or tensile stress is applied into the sample, respectively. Based on the phenomena, the current stress level in a parent material can be calculated.

In this study, a feasibility study has been therefore performed to use the alumina particles in cement cubes as an in-situ passive stress sensor using PLPS technique. Uniaxial compression tests have been conducted to a cement cube specimen to investigate the piezospectroscopic effect of alumina in cement structure.

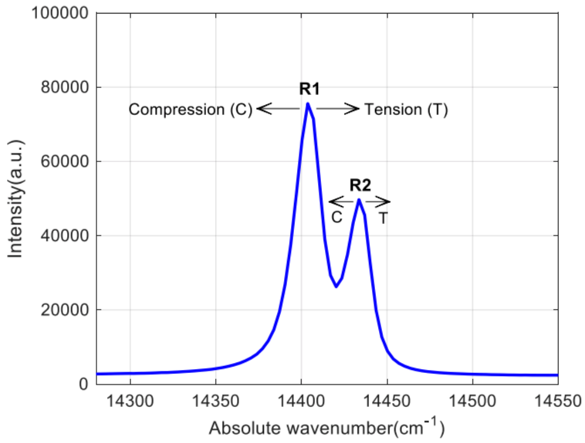

Figure 1. Typical PL spectrum (Namgyu et al. (2018))

2 PIEZOSPECTROSCOPY-BASED STRESS MEASUREMENT IN CEMENT

2.1 Compression test setup

To investigate the feasibility of a piezospectroscopy-based cement stress measurement technique, a cement cube specimen was prepared by mixing the alumina powder with cement powder. Here, alumina is a sensitive piezospectroscopic material. The prepared cement cube specimen was then put into a universal testing machine, and uniaxial compression tests were performed on it up to 15.2 MPa. To generate PL signals in each load step, the excitation source was produced by a diode laser having a wavelength of 532nm, in this study. The laser was transmitted along a fiber optic probe and then irradiated for 3 seconds onto the surface of the cement cube specimen. Finally, PL spectra were collected using a dispersive Raman spectrometer as shown in Figure 2.

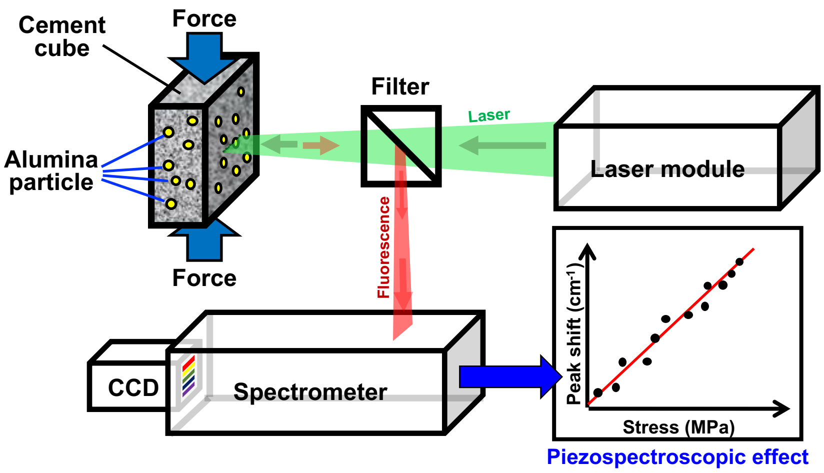

Figure 2. Schematic drawing of PLPS technique for stress measurement in cement structure.

2.2 Compression test results

Figure 3 shows the PL spectra under states of stress-free (0 MPa) and compression (15.2 MPa). Here, x-axis and y-axis indicate the absolute wavenumber and normalized intensity of PL spectra, respectively. As it was expected, the PL spectrum obtained under a state of compression (red solid line) was shifted to left hand from the stress-free PL spectrum (blue solid line). It was also found that the peak shift and stress level have a linear relationship.

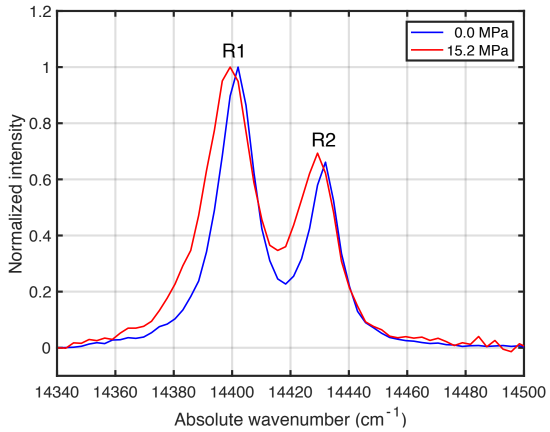

Figure 3. R1 and R2 lines under 15.2 MPa compressive stress.

3 CONCLUSIONS

In order to determine the feasibility of using alumina particles as a passive in-situ stress sensor to measure concrete stress induced by external forces, experimental tests were performed in this research. To investigate the relationship between peak shift and stress level, a cement cube was prepared by mixing cement powder with alumina powder, and a uniaxial compression test was performed on it. Finally, it was found that the PL spectrum obtained under a state of compression was shifted to left hand from the stress-free PL spectrum. Also, it was found that the peak shift and stress level have a linear relationship. Therefore, it has a strong possibility to use the alumina particles in cement structure as a passive stress sensor for measuring a current stress level in cement structure.

4 ACKNOWLEDGMENTS

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5 REFERENCES

D. M. Lipkin and D. R. Clarke, 1996, Measurement of the stress in oxide scales formed by oxidation of alumina-forming alloys, *Oxidation of Metals*, 45(3/4), 267–280.

Namgyu Kim and Hae-Bum Yun, 2018, Noncontact mobile sensing for absolute stress in rail using photoluminescence piezospectroscopy, *Structural Health Monitoring*, 17(5), 1213-1224