SEEING DAMAGE OF COMPOSITES BY MECHANOLUMINESCENCE

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Abstract

Elasticoluminescence (ESL) is a kind of mechanoluminescence (ML). ESL materials are novel functional materials that can convert elastic deformation energy into visible light directly. Utilizing the materials, novel sensing devices and various applications are now under development. These materials can allow direct viewing of stress distribution.

Introduction

ESL materials are novel multi-functional materials that can convert deformation energy into visible light directly. Utilizing these materials, novel sensing devices and various applications are now under development. These materials can allow direct viewing of stress distribution. The direct visualization and monitoring of stress distribution can be achieved using the materials. It would help to health monitoring structures, such as buildings, bridges and aircrafts, to maintain safe and secure [1] ~ [6].

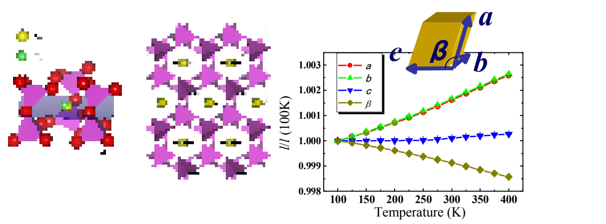
Experimental

ESL materials of ceramics powders have been developed with certain structure of aluminates [7], silicates [8], and phosphates. The ceramics fine powders have been then to disperse in certain polymer develop the smart paint of ESL. The paint can be coated on various target structures and the emission intensity of which under the application of mechanical stress has been evaluated using the ML measurement system.

Results and Discussion

Figure 1 shows the example of developed ESL material of strontium aluminates $SrAl_2O_4:Eu^{2+}$. Among ESL materials, $SrAl_2O_4$: Eu^{2+} (SAOE) has the strongest ESL, it shows green emission even under a weak elastic deformation.

The ESL intensity increases with the increase of deformation energy (Fig. 2).



(1) (2) (3)

Fig. 1 Structural features of ESL material of SAOE
(1)The luminescent center locates at non-inversion site
(2) A flexible framework structure
(3) Anisotropic thermal expansions

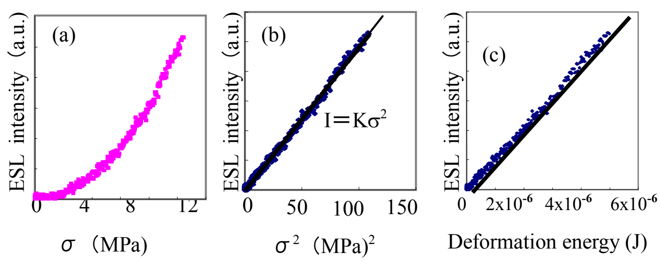


Fig. 2 (a) Relationship between ESL intensity and mechanical stress
(b) Relationship between ESL intensity and square of mechanical stress
(c) Relationship between ESL intensity and deformation energy

Figure 3 shows the TEM image of nano-particles of SAOE [9]. Each nano-particle of SAOE gave ESL pulse (green line) under the application of mechanical load (yellow line).
Figure 4 illustrates the ESL materials, and the luminescence image in pseudo-color displays the stress distribution on steel plate with a circle hole [10].

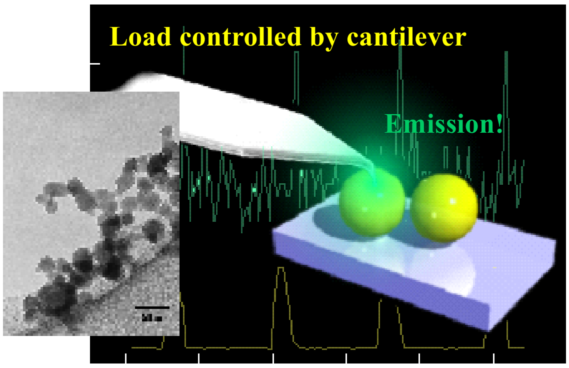


Fig. 3 TEM image of nano-particles and evaluation device for stress-induced luminescence (load/light emission controlled by cantilever)

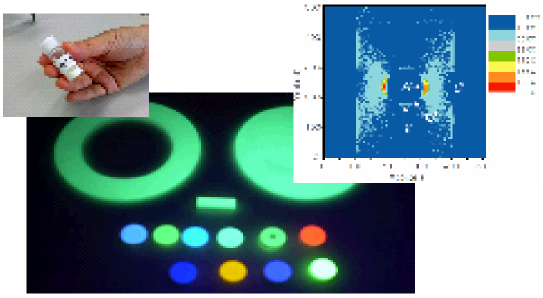


Fig. 4 ESL materials and the luminescence image in pseudo-color displays the stress distribution on steel plate with a circle hole

Summary

We demonstrate that ESL materials developed possess the following features.

- Fine powders of ESL have high luminosity upon stress-stimulation, and the intensity of light is proportional to the deformation energy.
- Paint of ESL can coat various objects and make it possible to direct visualization of stress distribution.
- The light emitted from ESL can be controlled with a wavelength from ultraviolet to near infrared range.
- Each nano particle of these materials is able to work as a stress sensor individually, such as 20 nm force sensor available.

Utilizing these features, dynamical stress distribution can be visualized directly and easily. These materials can realize both wide area and high resolution stress distribution sensing. Various applications are now under developing, such as on-field visualization of stress distribution, novel mechanical sensors, nano-micro stress sensing, product proto-type evaluation, stress-sensitive displays with multi-colors, amusements, etc.

Acknowledgements

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References

[1]http://unit.aist.go.jp/msrc/ci/organization/ouryoku.html, National Institute of Advanced Industrial Science and Technology, Measurement Solution Research Center

[2] C.N. Xu, “Sensing Technology with Elasticoluminescence – Visualizing ‘Invisible’ Defects in Structures” Bull. Ceram. Soc. Japan, Vol. 44, No.2, pp.154－160, 2009

[3] C.N. Xu, Encyclopedia of Smart Materials: John Wiley & Sons, Vol.1, 2002

[4] C.N. Xu, T. Watanabe, M. Akiyama and X. G. Zheng, “Artificial skin to sense mechanical stress by visible light emission” Appl. Phys. Lett., Vol. 74, No.9, pp.1236-1238, 1999

[5] C.N. Xu, T. Watanabe, M. Akiyama and X.G. Zheng, “Direct view of stress distribution by mechanoluminescence” Appl. Phys. Lett., Vol.74, No.17, pp.2414-2416, 1999

[6] C.N. Xu, X.G. Zheng, M. Akiyama, K. Nonaka and T. Watanabe, “Dynamic visualization of stress distribution by mechanoluminescence image” Appl. Phys. Lett., Vol.76, No.2, pp.179-181, 2000

[7] C.N. Xu, H. Yamada, X.S. Wang, X.G. Zheng, “Strong elasticoluminescence from monoclinic-structure $SrAl_2O_4$” Appl. Phys. Lett., Vol.84, No.16, pp.3040-3042, 2004

[8] L. Zhang, H. Yamada, Y. Imai, C.N. Xu, Observation of elasticoluminescence from $CaAl_2Si_2O_8$:Eu^{2+} and its water resistance behavior” J. Electrochem. Soc., Vol.155, No.3, J63-65, 2008

[9] C.Z. Li, Y. Imai, Y. Adachi, H. Yamada, K. Nishikubo, C.N. Xu, “One-step synthesis of luminescent nanoparticles of complex oxide, strontium aluminate” J. Am. Ceram. Soc., Vol.90, No.7, pp.2273-2275, 2007

[10] C.S. Li, C.N. Xu, Y. Imai, W-X. Wang, L. Zhang, H. Yamada, “Real-time monitoring of dynamic stress concentration by mechanoluminescent sensing film” Appl. Mechanics and Materials, Vol.13-14, pp.247-250, 2008