New perspective on mechanoluminescence:

increasing the signal visibility through recovery

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Monitoring the health of structures for the prevention and detection of early-stage damages requires easy-to-use and non-invasive stress sensing devices. Elastico-mechanoluminescent (EML) stress sensors consisting of a phosphor powder embedded in a polymer matrix are gaining a lot of interest in this area, allowing repetitive full field visualization of the stress distribution present in the material under loading conditions [1]. Many phosphors, including $SrAl_2O_4:Eu^{2+}$(, Dy^{3+}) [1, 2], $ZnS:Mn^{2+}$ [3] and $BaSi_2O_2N_2:Eu^{2+}$ [4], have been found to be eligible for use in EML sensors, exhibiting a linear relation between the mechanoluminescence intensity and the applied load in addition to wide pressure ranges and sensitivity to a variety of mechanical stresses and deformations: compression, tension, friction, impact, ultrasound, … [5-7].

The practical implementation of these EML sensors however is currently obstructed by relatively low signal visibility, the restriction to real-time measurements and the need for dark conditions [8]. Efforts to eliminate these drawbacks have mainly concentrated on reducing the unwanted persistent luminescent behavior or afterglow, for instance by using long delay times between the excitation and mechanical stimulation of the phosphor [9]. In this discussion, the ML behavior of the phosphor $BaSi_2O_2N_2:Eu^{2+}$ is investigated in depth, elucidating the underlying mechanism and the trap depth distribution of the phosphor through a combination of ML, thermoluminescence and optically stimulated luminescence. The obtained results indicate an alternative to the previously proposed solutions, namely the recovery of the ML signal. In our approach, signal acquisitioning can take place at a chosen time long after the initial loading of the material, eliminating the undesired afterglow and improving the ML signal visibility. A working mechanism is derived and extensively tested. From this, it became clear several other phosphors possess the possibility of displaying this behavior, increasing the potential of exploiting this phenomena for use in ML based applications.

[1] C.-N. Xu, T. Watanabe, M. Akiyama, X.-G. Zheng, Applied Physics Letters 74 (1999) 2414-2416.
[2] S. Timilsina, R. Bashnet, S. H. Kim, K. H. Lee, J. S. Kim, International Journal of Fatigue 101 (2017) 75-79.
[3] X. Wang, H. Zhang, R. Yu, L. Dong, D. Peng, A. Zhang, et al., Advanced Materials 27 (2015) 2324-2331.
[4] J. Botterman, K. Van den Eeckhout, I. De Baere, D. Poelman, et al., Acta Materialia 60 (2012) 5494-5500.
[5] J.-C. G. Bünzli, K.-L. Wong, Journal of Rare Earths 36 (2018) 1-41.
[6] J.-C. Zhang, C.-N. Xu, S. Kamimura, Y. Terasawa, et al., Optics Express 21 (2013) 12976-12986.
[7] S. Timilsina, et al., International Journal of Precision Engineering and Manufacturing 17 (2016) 1237-1247.
[8] A. Yoshida, L. Liu, D. Tu, S. Kainuma, C.-N. Xu, Journal of Disaster Research 12 (2017) 506-514.
[9] J.-C. Zhang, X.-H. Fan, X. Yan, F. Xia, W. Kong, Y.-Z. Long, et al., Acta Materialia 152 (2018) 148-154.