Frontiers in Mechanoluminescent Materials: Innovation, Mechanisms, and Applications

Chao-Nan Xu#, Tomoki Uchiyama, Xu-Guang Zheng

Department of Material Science and Engineering, Tohoku University, Sendai, 980-8579, Japan

Mechanoluminescence (ML), the light emission induced by mechanical stimuli, has emerged as a promising phenomenon for visualizing mechanical responses and energy conversion in materials. In 1999, we established reproducible ML from defect-controlled phosphors such as $ZnS:Mn^{2+}$ and $SrAl_2O_4:Eu^{2+}$, and developed hybrid inorganic/organic ML composites and coatings for real-time stress and strain visualization. These innovations opened a new avenue for mechano-optical sensing and structural health monitoring.

In recent years, material design strategies have advanced significantly, enabling precise control of defects, crystal structures, and interfaces to enhance mechano-optical sensitivity. Building on these developments, we have introduced multipiezo materials, a new class that combines strong piezoluminescence and piezoelectricity. These materials exhibit high sensitivity and stability under elastic deformation without a stress threshold. By finely tuning the morphotropic phase boundary (MPB) and crystalline symmetry, both piezoluminescence and piezoelectricity have been enhanced by more than an order of magnitude.

This presentation highlights innovative approaches in the design and mechanism of ML and multipiezo materials and explores their potential applications in nano/micro sensing, damage diagnosis, energy conversion, and multifunctional optoelectronic systems. Future research directions and challenges for real-world implementation will also be discussed.

This research was partially supported by JSPS Grant Nos. 19H00835, 22H00269, 25H00790 and JST-CREST Grand No.2025JPMICR25S3.

corresponding author: chao-nan.xu.c8@tohoku.ac.jp