Mechanoluminescence - smart visualization of dynamic mechanical behaviors toward innovative evaluation, design, and simulation

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Mechanoluminescent (ML) sensing materials are functional ceramic micro powders that emit intense light repeatedly under mechanical stimuli. This phenomenon is observed even within the region of elastic deformation. When dispersed onto the surface of a structure, individual ML particles function as sensitive mechanical sensors, and the two-dimensional (2D) ML pattern reflects the dynamic strain distribution. The ML emission pattern consists of a mechanical simulation of the strain distribution (Fig. 1).

ML sensors have been applied to visualize two-dimensional (2D) and three-dimensional (3D) dynamic mechanical behaviors in elastic, plastic, and destruction processes using coupon test specimens comprising recent advanced lightweight structural materials (e.g., high-tensile strength steel, aluminum, carbon fiber-reinforced plastic: CFRP), the adhesive joint for damage tolerance design and components of products (e.g., gear, flexible electronics file for foldable phone and complicated adhesive and/or welding joints used for validating computer-aided engineering (CAE) results in laboratory-level testing. Additionally, ML sensors have been successfully applied in practical applications such as structural health monitoring (SHM) of buildings and bridges for detecting crack propagation or probability of strain concentration leading to structural degradation, monitoring of the inner crack propagation in interlaminar layer, prediction of the lifetime of high-pressure hydrogen vessels, impact tests of mobility for visualizing impact wave propagation or excitation of vibration mode1, and visual sensing of sports tools to determine appropriate physical settings for the win. In this presentation, I would like to introduce the ML material and basic properties of ML visual sensing at first, and then explain application of the smart visualization of dynamic mechanical behaviors using ML sensing toward innovative evaluation, design, and simulation.

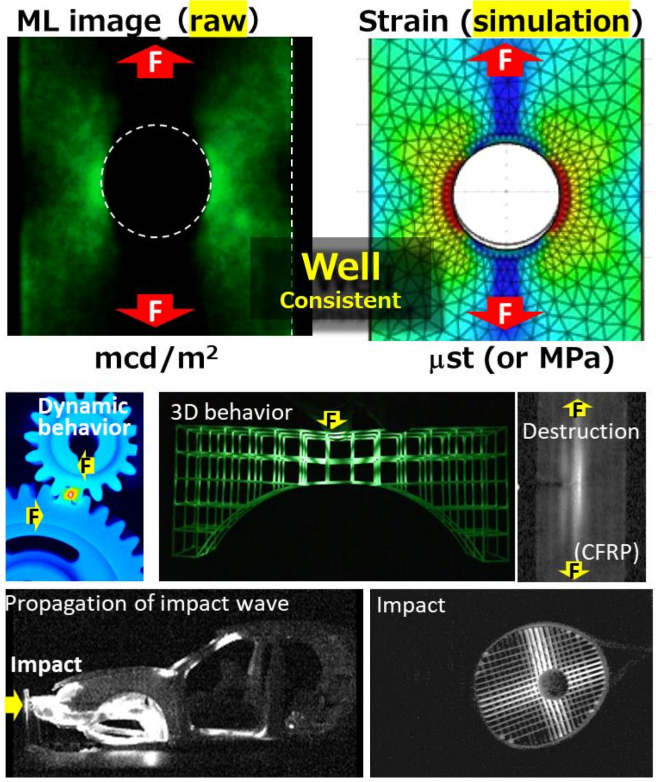

Fig. 1: Property of ML sensor. (**A**) Mechanoluminescence under tensile load for stainless steel plate with a hole and numerical analysis (simulation) of Mises strain distribution. (**B**) Examples of ML visual sensing to visualize dynamic 2D/3D mechanical behavior.

(ML movies)

- Mechanoluminescence paper cup, https://www.youtube.com/watch?v=ose3T1Gd2SU
- Mechanoluminescence under tensile load for perforated SUS631 supecimem, https://www.youtube.com/watch?v=PSzTvntGTM4
- Mechanoluminescence during front collision test, https://www.youtube.com/watch?v=JElP-4Zvl5w
- Protecting Infrastructure by Visualizing Stress (MHK world, Scince view), https://www3.nhk.or.jp/nhkworld/en/ondemand/video/2015274/

Nao TERASAKI, Ph.D is research team leader of 4D visual sensing team (4DVsens) in Sensing System Research Center (SSRC) in National Institute of Advanced Industrial Science and Technology (AIST), He received his PhD from Kyushu University. After joining into AIST in 2003, he has investigated on mechanoluminescent (ML) sensing material and ML visual sensing especially in application. In 2013, he was guest researcher in UC San Diego and developed printable and bio-degradable trillion sensors with Prof. Albert Pisano (Dean of Jacobs school). He has developed (1) ubiquitous ML light source, (2) structural health monitoring (SHM) in infrastructure, (3) sophistication of design and simulation on light weight material and structure through ML visualization, (4) ML inspection of weak-bond area, and (5) international standardization from the viewpoint of visualization of dynamic strain distribution.

(recent reserch project)

1. Structural Material for innovation (SIP project, JST)
2. Quality assurance of structural adhesive for composite in aircraft (ALTA)
3. Development of inovative structual adhesive (NEDO)
4. Development of international standardization in the field of energy saving
5. Long-term stabilization of automotive adhesion and the interfacial design (NEDO)