Material Dynamics Analysis with Deep Generative Model

Duc-Anh Dao,[1] Tien-Sinh Vu,[1] Yoshifumi Oshima,[1] Masahiko Tomitori,[1] Yukio Takahashi,[2] Hieu-Chi Dam,[1,2,3†]

[1] *Japan Advanced Institute of Science and Technology, 1-1 Asahidai, Nomi, Ishikawa 923-1292, Japan*

[2] *International Center for Synchrotron Radiation Innovation Smart (SRIS), Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan*

[3] *ESICMM, National Institute for Materials Science, 1-2-1 Sengen, Tsukuba, Ibaraki 305-0047, Japan*

Email: dam@jaist.ac.jp

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Studying material dynamics is essential for predicting degradation, failure, and specific behaviors under various conditions, enabling efficient material design, enhanced performance, and driving innovation in materials science. Microscopic techniques have advanced significantly to document the dynamic evolution of materials during experimental progression. However, experimental observations from microscopy images are inherently bias to drive subsequent analysis to observable behaviors and excluding those in unobserved scenarios. To address this issue, we designed an analysis framework integrating a deep generative model to synthesize hypothetical material states that could emerge under realistic experimental conditions. This approach enables Monte Carlo simulations of material state variations driven by dynamic progression, reflecting more generalized and predictive dynamic behaviors. Applied to various microscopy image datasets, our framework effectively uncovers hidden physical phenomena in materials science experiments. Furthermore, this research supports a shift towards data-driven methodologies, advocating the adoption of deep learning technologies to foster innovative research practices in materials science.

Keywords: material dynamics, data analysis, microscopy images, deep generative model