From Atoms to Architecture:
Emerging Electron Microscopy for Quantum and Neuromorphic Materials

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Abstract:

Quantum and neuromorphic technologies promise transformative gains in energy-efficient computing and related applications. However, their performance is often governed by localized noise events or extremes of distributions rather than "averaged" information. Here, unlike "*conventional*" microstructure that is governed by average and often amplitude-based information, *quantum* microstructure represents perturbation to the *phase* of the wavefunction relevant in quantum systems. Such a *quantum* microstructure represents sparse, structurally severe defects, interfaces, strain fields, chemical heterogeneity, and dynamic disorder that control coherence, charge/spin/heat transport, switching, and thus, reliability.

In this context, advanced electron microscopy has therefore moved beyond supplying an illustrative "Figure 3" micrograph. Multimodal imaging, spectroscopy, nD-STEM, and some *in situ* and cryogenic methods can now extract quantitative, distribution-resolved variables—including defect density, curvature, strain variance, correlation length, and interface topology—that are directly relevant to decoherence and transport. I will introduce a *prescriptor formalism*, $\Pi_j = \rho_j G_j$. Unlike conventional descriptors that report what is present, prescriptors connect microscopy observables to device performance through falsifiable structure–property relations, enabling attribution, inverse design, and AI-guided adaptive measurement.

The talk will conclude with opportunities for U.S.–Korea collaboration in shared instrumentation, data infrastructure, and translation from atoms to functional architectures.