[Energy Distinguished Lecture Series]

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Traceable TEM Nanometrology and AI-assisted Size Uncertainty Evaluation of Nanoparticles

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KRISS

Abstract

Nanoparticle size and size distribution are important parameters for understanding material properties and performance. Transmission electron microscopy (TEM) enables direct observation of individual particle morphology and size, but reliable quantitative analysis requires both metrological traceability and efficient image analysis. Conventional manual measurements are labor-intensive and time-consuming, limiting large-scale data processing and real-time feedback. This lecture presents the metrological foundations and AI-assisted analysis methods for quantitative nanoparticle size measurements using TEM.

First, we examine the traceability chain connecting the SI definition of the metre to silicon lattice spacing and TEM image calibration. We discuss how a calibrated image scale converts particle dimensions from pixels into physical lengths, and why measurement uncertainty must be evaluated and documented at each calibration step. We also consider how image focus, particle boundary identification, and the definition of particle size affect measurement results. These considerations establish the metrological basis that must be maintained when image analysis is automated using AI.

We then introduce a real-time analysis system that connects image acquisition, particle detection, individual particle segmentation, equivalent circular diameter calculation, and statistical analysis using lightweight deep-learning models. Detector designs with expanded receptive fields and U-Net-based segmentation are examined to balance analysis accuracy and processing speed. We present integration with live TEM image acquisition and illustrate large-scale size-distribution analysis using 26,780 particle measurements. Finally, we discuss how traceable length calibration and AI-assisted automation can be combined to support reliable and efficient nanoparticle size measurements, while preserving a clear distinction between the observed size distribution and measurement uncertainty.

Brief Bio



Sang-Hyeok Yang received his Ph.D. in Energy Science from Sungkyunkwan University in 2025. He continued his research at Sungkyunkwan University as a postdoctoral researcher and joined the Korea Research Institute of Standards and Science (KRISS) in January 2026 as a Senior Researcher in the division of chemical material metrology. His research interests include quantitative electron microscopy, deep learning for 4D-STEM and spectroscopic data analysis, and nanoscale materials characterization. He currently contributes to a KRISS strategic research project on cryogenic, low-dose TEM, developing AI-based methods for real-time data analysis and measurement automation.

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