AI-enhanced correlative microscopy: a multi-modal approach to automotive coating evaluation

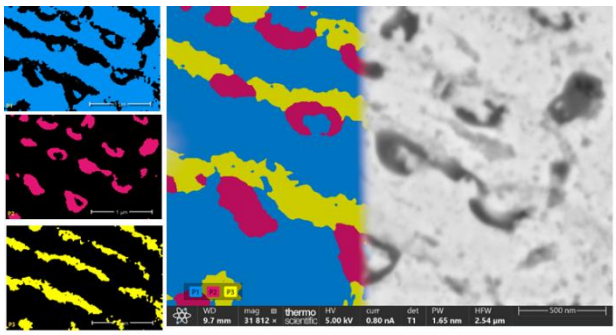
The automotive industry extensively employs zinc-based coatings to enhance corrosion resistance and extend the lifespan of steel components exposed to harsh atmospheric conditions. These protective layers, applied through hot-dip galvanizing and electroplating, prevent oxidation of the underlying steel. The effectiveness of these coatings depends on thorough material quality assessment, adhesion evaluation, and stringent final product control.

Scanning electron microscopy (SEM), along with other advanced analytical characterization techniques, is crucial for detailed evaluation of zinc-based coatings. SEM supports correlative microscopy (CM) workflows, integrating imaging, analytical solutions, and AI-assisted image analysis to provide a multi-modal and multi-dimensional view of the materials under investigation. The site-specific use of Plasma Focused Ion Beam-SEM (PFIB-SEM) cross-sections enables highly targeted analysis, revealing detailed microstructural features and providing comprehensive compositional and crystallographic information.

The Apreo ChemiSEM exemplifies this approach by enabling comprehensive surface and cross-sectional analysis of both coatings and steel substrates. Its correlative capabilities combine imaging, energy dispersive X-ray spectroscopy (EDS) via ChemiSEM Technology, and electron backscatter diffraction (EBSD) with the TruePix detector. Cross-sectional analysis is performed on both metallographically prepared sections and PFIB-prepared cross-sections, providing detailed insights and accelerating the characterization of coating morphology and defect identification.

Integrating imaging with ChemiSEM Technology allows for detailed investigation of surface oxidation, inclusions, and inhibition layers within the coatings. The TruePix detector identifies areas of high dislocation density and other crystalline defects, offering a deeper understanding of material weaknesses that may correlate with reduced adhesion or other issues.

AI-assisted image analysis enhances the characterization process by significantly reducing the time required to interpret complex datasets. Deep learning models integrated into the workflow provide accurate, large-scale analysis of data collected at both micro- and nanoscale levels, enabling validation over millimeter-scale regions. This synergy between advanced microscopy and AI ensures a robust and comprehensive evaluation of zinc-based coatings, linking structure, processing, property, and performance in automotive applications.



Element	Atomic % (Zn-rich) P1	Atomic % (pink) P2	Atomic % (yellow) P3
Zn	90.4	49.1	72.5
Al	7.2	47.3	18.5
Mg	2.4	3.6	9.0