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Raman Spectroscopy at the Core of Multi-Modal, Scale-Bridging Analytics: Driving Insight and Innovation Across Materials and Life Sciences

Abstract

Understanding the complex interplay between structure, composition, and function in modern materials and devices requires more than isolated measurements—it demands integrated, correlative analytics across scales and modalities. **Raman spectroscopy**, with its intrinsic sensitivity to chemical bonds, crystallinity, and strain, offers a uniquely rich source of molecular and structural information. When embedded in **scale-bridging, multi-modal workflows**, Raman becomes a central pillar for the advanced characterization of heterogeneous systems across disciplines.

In this talk, we will showcase how Raman spectroscopy, both spontaneous and stimulated, is synergistically combined with electron, ion, optical, and x-ray microscopies, as well as complementary spectroscopic methods (IR, mass spectrometry), all precisely co-registered using **nanoGPS technology[1]**. The result is a truly correlative approach to data integration, enabling 2D and 3D co-visualization and interpretation of morphology, topography, composition, and function.

We will present **case studies** from:

- **Battery research**, where Raman helps monitor phase evolution, degradation, and e.g. solid-electrolyte interfaces post mortem and in operando, enhancing material design for improved cycle life and safety.
- **Semiconductor device analytics**, where strain mapping and defect localization via Raman are coupled with FIB cross-sectioning and high-resolution imaging to detect failure mechanisms.
- **Biomedical research**, where Raman is used to track molecular changes in bone and soft tissues, revealing the biochemical pathways behind diseases such as osteoporosis or pollution-related inflammation.

Central to our approach is the **Correlyze data platform[2]**, which facilitates high-throughput, AI-enhanced data mining across heterogeneous datasets. By combining Raman maps with other analytical layers, we uncover emergent properties not visible in single-modality analysis—transforming data into actionable insight.

This talk will explore how Raman spectroscopy, when placed at the heart of correlative, multi-scale analytics, acts as a key enabler of predictive material modeling, precision diagnostics, and sustainable innovation across domains. We propose a vision of Raman not as a standalone tool, but as an integrative force in the data-driven materials and life sciences of the future.

References

[1] https://www.horiba.com/int/scientific/products/detail/action/show/Product/nanogps-navyx-4959/
[2] https://correlyze.org/

Figures

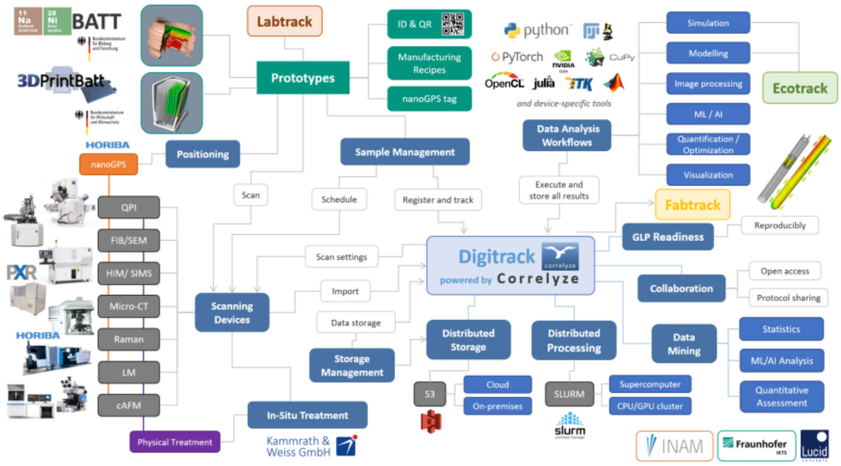

Figure 1: Correlize multi-modal data management platform to assess data with statistical and machine learning methods[2].