Correlative microscopy combining Electron Microscopy and Secondary Ion Mass Spectrometry

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Investigation of materials using multiple characterization techniques are often needed to precisely correlate structures, properties and underlying physical and biological mechanisms. Advanced microscopy techniques play an important role to unravel spatial correlation across complementary imaging modes. Transmission Electron Microscopy (TEM) is a well-known technique for high resolution imaging down to atomic resolution. The typical analytical techniques associated with TEM such as EDX and EELS are extremely powerful methods to obtain local chemical information about the investigated object. However, the sensitivity of those techniques is limited (> 0.1 at. %) and hence not suitable for the analysis of trace elements. Furthermore, those techniques do not have isotope selectivity which is needed in certain materials and life science research topics. Secondary Ion Mass Spectrometry (SIMS) is well-known for high sensitivity chemical analysis (down to ppm or micromole range) and it also allows isotope specific analysis. However, the resolution of SIMS images is fundamentally limited to ~ 10 nm due to the ion-solid interaction volume. To combine the advantages of TEM and SIMS in a single instrument, we have developed a correlative microscopy method combining the two techniques in-situ (Fig. 1). The proof of concept demonstration was performed using isotopically labelled lithium carbonate nanoparticles. The TEM images of the nanoparticles were correlated to ^{7}Li and ^{6}Li SIMS images [1].

As the image contrast mechanisms are different in the different imaging modalities, correlative imaging requires the development and adaptation of suitable data visualization protocols. To this end, we have quantitatively evaluated both pixel-domain and frequency-domain image fusion protocols specifically for EM-SIMS correlative data visualization using case-studies (ex-situ) from life science research [2].

One of the limitations of SIMS is the matrix effect (i.e. strong variation in signal intensity as a function of matrix elements). Hence, quantification of SIMS data is difficult. Recently we have demonstrated the possibility to quantify SIMS intensity of trace concentrations by extrapolating EDX quantification. Ongoing work focuses on the possibility to obtain quantitative SIMS images for correlation with high-resolution TEM images such that high-resolution high-sensitivity characterization can be accomplished quantitatively. In this presentation, we will highlight the exciting new characterization possibilities that emerge by using in-situ and ex-situ EM-SIMS correlative microscopy with examples from our work on frontier topics in materials [3] as well as life science research [4].

References

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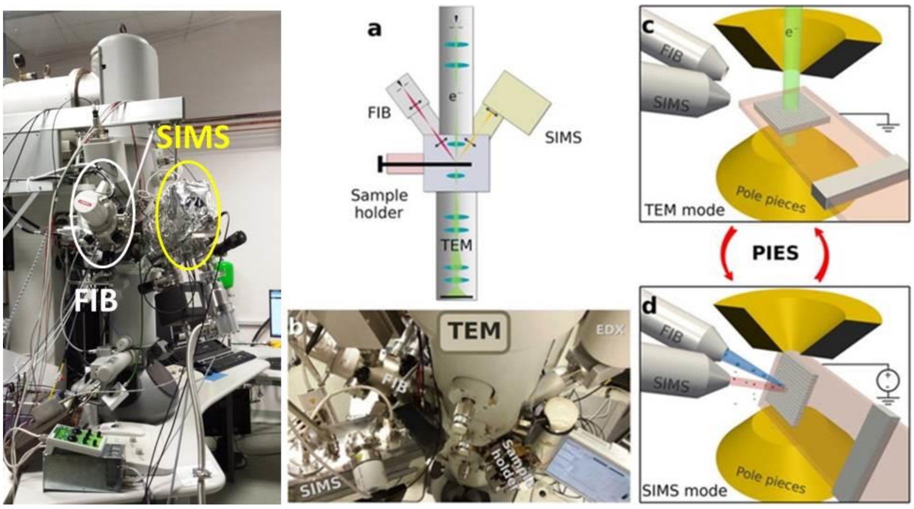

Figure 1: Schematic illustrations and a photo of the in-situ TEM-SIMS instrument. (adapted from [1]).

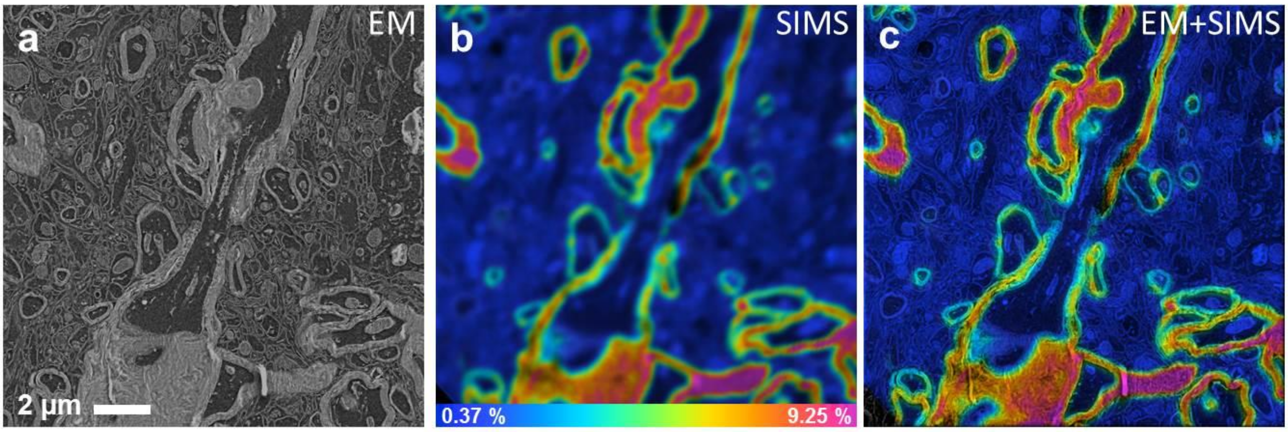

Figure 2: Correlative image fusion of (a) EM and (b) SIMS images of the same ROI obtained by ex-situ method. The frequency domain image fusion resulted in robust results with only minimal imaging artifacts. Quantitative metrics to evaluate the images are discussed elsewhere (adapted from [2]).