Title: *High-Resolution Chemical Imaging and Depth Profiling of Hybrid and Organic Materials with Gas Cluster and Water Cluster Secondary Ion Mass Spectrometry (Cluster SIMS) at Cryogenic Temperatures*

Session: Industrial Highlights

Gas Cluster Ion Beam (GCIB) SIMS is a high-sensitivity secondary ion mass spectrometry imaging (MSI) technique for imaging complex materials without matrix. Utilizing GCIB as the analysis beam significantly reduces molecular fragmentation compared with traditional monoatomic beam SIMS, vastly improving sensitivity of the technique to higher mass analytes.

However, volatile species within both biological samples or hybrid materials are sensitive to the high vacuum environment used in SIMS instrumentation, and prone to migration, meaning that the resulting 2D and 3D images may not be representative of the native samples when analysed at room temperature (RT).

Unlike other MSI techniques, SIMS may be performed at cryogenic temperatures. However, complex cryogenic sample handling requirements and high cryogen consumption have meant that such experiments have hitherto been expensive and complicated. Utilising Ionoptika's J Series III instrument with Cryo stage, we show that long-term Cryogenic studies may be carried out on both hard and soft materials, with demonstrable improvements in results compared to RT analysis.

Firstly, we demonstrate imaging of sex steroid hormones in zebrafish (an ideal vertebrate model organism) with GCIB SIMS at Cryo temperatures. An adult female zebrafish was embedded while fresh in 0.75% HPMC and 0.25% PVP embedding media, flash-frozen, and sectioned to 20 μm at -25 °C . Analysis was performed with the J series III SIMS (Ionoptika Ltd), using a 70 keV (H_2O)n beam, where n is in the range of 15,000-35,000, and also separately with a 40 keV C_{60} beam. High-resolution images were acquired with a pixel size of < 1 micron.

Secondly, we demonstrate 3D depth profiling of layered industrial materials, such as perovskites, and show that the precision of the depth profile is increased at Cryo temperatures when compared with RT analysis. Furthermore, this latter work is carried out with small gas clusters at high beam energy, demonstrating the suitability and lack of preferential sputtering, of such small clusters for hard and mixed materials including metals and organics.

We conclude that analysis of both biological and inorganic samples results in superior data when conducted at Cryogenic temperatures.

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