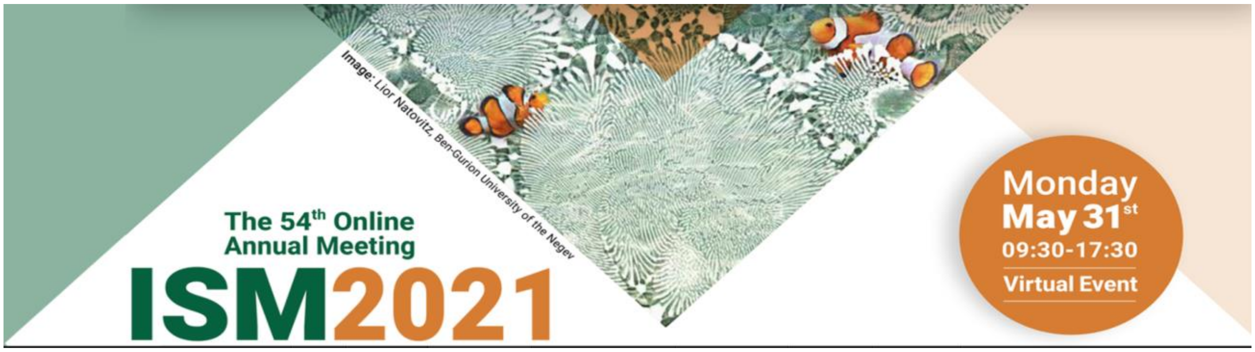

PUSHING THE LIMITS OF SPATIAL AND ENERGY RESOLUTION IN ENERGY-LOSS SPECTROSCOPY

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The functional properties of materials are increasingly controlled and tuned through structural or chemical architectures whose engineering takes place at the nano or even atomic level. This enables emergent properties relying on the interplay between charge, spin and local atomic-scale chemistry. A particularly powerful means of characterization of these physico-chemical effects lies within a combination of high-resolution scanning transmission electron microscopy and energy-loss spectroscopy (STEM-EELS). Recent instrumentation advances have pushed the energy resolution of these instruments below 10meV while maintaining atomic-sized probes, thus truly realizing the promise of placing a 'synchrotron in a microscope'.

As a result, it is now possible to fingerprint the functional chemistry of materials as diverse as organic grains in chondrites or metal organic framework glass blends at the nano-scale while simultaneously correlating it with their vibrational response in the sub 100meV energy range. This enables a direct comparison with bulk optical characterization at unprecedented length scales. Further methodological developments have demonstrated the ability to balance momentum and spatial resolution to either determine the electronic band structure of materials in momentum space from nanometre-sized volumes or carry out phonon spectroscopy at the atomic scale, culminating recently in the observation of a phonon signature localized at a single atom defect.

It is expected that building on these recent achievements, further improvements in energy resolution and the introduction of new direct/hybrid electron detectors will widen the range of chemistries that can be spectroscopically and spatially resolved, providing the ideal spectroscopic tool to understand the nanoscale organisation of organic and metal-organic bonding and complex interfacial structures in emerging hybrid composite materials.