Biosignature detection using the Analyzer of Nanoscale Textures for Objects in Near-surface Ice on Europa (ANTONIE)

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Introduction: In the search for life on icy and ocean worlds, the most robust conclusions will be drawn from gathering information from multiple lines of scientific inquiry. One of the Europa Lander Science Definition Team science objectives was to identify and characterize morphological, textural, or other indicators of life. Atomic Force Microscopy (AFM; Binnig et al. 1986) is a powerful technique for mapping topographic and mechanical properties on the nanoscale that we propose would be an invaluable addition to the payload of any landed mission to an ocean world.

Optical resolution may not be sufficient for bio-signature identification: Extremophilic and oceanic microbes on Earth tend to be sub-micron in size. For example, -13 ºC Lake Vida brines were dominated by 0.2 um ultramicrobacteria (Kuhn et al. 2014). Particulate organic material – the byproducts of life – co-occurs wherever microbial life is found. This limits the ability of optical microscopy to successfully visualize small cells or other potential bio-particles (e.g. viruses or vesicles). AFMs on the other hand, are routinely capable of resolving sub-nm features, even in relatively soft materials. Fig 1a provides an example of AFM topographic imaging of Lake Vida brine.

Nanomechanics: Since the AFM tip “touches” the sample, it is intrinsically a mechanical measurement. Mechanical property resolution, similar to topography, is routinely sub-nm. Properties that are commonly measured include modulus (stiffness), viscosity (dissipated energy) and tip-sample adhesion. These are strong indicators of terrestrial biotic materials including extremophiles and may indeed be universal biosignatures.

Partitioning of biogenic, fabricated, and other engineering materials (Fig. 1) can be discerned by (a) topography measured by AFM, (b) ideal structure and (c) loss tangent, (a mechanical property related to stiffness), such that materials with different mechanical properties can be discerned into biosignature and abiotic zones (d).

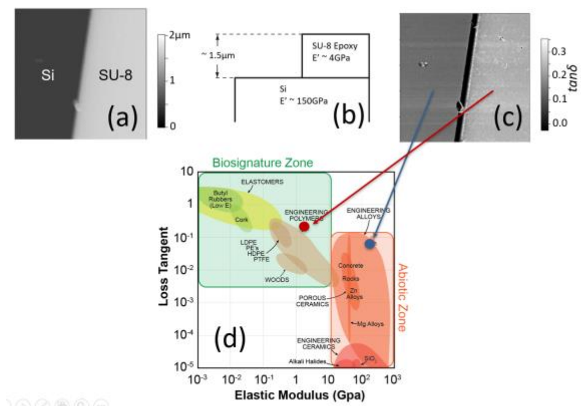

Fig. 1. Mechanical properties of biosignatures can be distinguished from abiotic materials (Proksch et al. 2016) where stiffness properties define biotic particles (modulus increases for abiotic samples, and loss tangent increases and modulus decreases with soft materials.

ANTONIE: We have developed an integrated sample processing, optical and atomic force microscope instrument concept that addresses the need for technology to characterize morphological, textural and in this case, mechanical indicators of sub-micron scale life. ANTONIE builds on earlier AFM designs that were parts of the Phoenix Mission to Mars and Rosetta missions to Comet 67P/Churyumov–Gerasimenko.

Key design features: Reliable high sensitivity probe readout sensors and electronics, redundant design; resilient operations on unknown, complex particles, image analysis, feasibility of multimodal analysis.

*Remote operation*s: Limited operational control and data download bandwidth imply that an analytical approach where machine learning algorithms and data analytic techniques for identifying ROIs is needed. Machine learning approaches allow semi-autonomous characterization of particles and nanomechanical features that may separate them on the spectrum from abiotic to potentially biological in nature.

References:

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