**A MINIATURE ELECTRON PROBE FOR IN SITU ELEMENTAL MICROANALYSIS.** Lucy F. Lim[1], Adrian E. Southard[1,2], Stephanie A. Getty[1], Larry A. Hess[1], John G. Hagopian[1,3], [1]NASA Goddard Space Flight Center (lucy.f.lim@nasa.gov) [2]USRA [3]Sigma Space Corp

The Mini-EPMA will combine efficient microscale compositional mapping with a new light-element (C/N/O) capability to significantly advance our capability for remote *in situ* determination of the elemental composition of planetary, asteroidal, and cometary material. Composition provides key evidence about the processes by which rocks, soils, and ices were formed and altered (for example, accretion, differentiation, and hydrothermal alteration) thus recording past stages in solar system evolution. The capability for rapid basic elemental analysis will also contribute to the location of resources to support exploration. The instrument prototype discussed here would be a promising addition to the scientific payload of a future landed lunar, asteroid or comet mission.

The high spatial resolution achievable with a focused electron beam will permit sub-millimeter scale compositional mapping in a flight instrument. Modeling with SIMION [1] indicates that spot sizes under 100 μm are achievable in a flight instrument with microscale field emitters in an array, with focusing achieved by a compact electrostatic lens stack.

In the mini-electron probe ("EPMA") flight concept (Fig. 1), electrons are drawn out of an addressable-element carbon nanotube field emitter array [2, 3] by the cathode/grid extraction voltage, then accelerated by the lens stack (Fig. 2) into the planetary/asteroidal/cometary surface, exciting X-ray line emission characteristic of the elemental composition of the surface. The X-rays are then measured by a silicon drift detector similar to those used in laboratory energy-dispersive spectroscopy (EDS) and analyzed using standard EPMA techniques to give the surface composition of the region illuminated sequentially by each electron-beam spot (100 μm). In this way, a grid of e-beam spots activated in sequence will non-destructively produce a fine-scale map of elemental composition. Microfabrication techniques are used to define the growth regions for the CNT emitters, as well as the grid electrode required to individually address each element in the array.

**Science goals and sensitivity:** Laboratory electron microprobe analyses of mineral grains achieve precisions of 1% or less for the weight percentages of major-element oxides as well as measurements of minor-element oxides <0.5% by weight. Typical beam currents are ≊ 10–100 nA, accelerating voltages 15–20 kV, cm-scale working distances, and exposure times ≊ 20–30 s. These levels of current and voltage will be readily achievable with the miniature electron gun albeit at a larger spot size

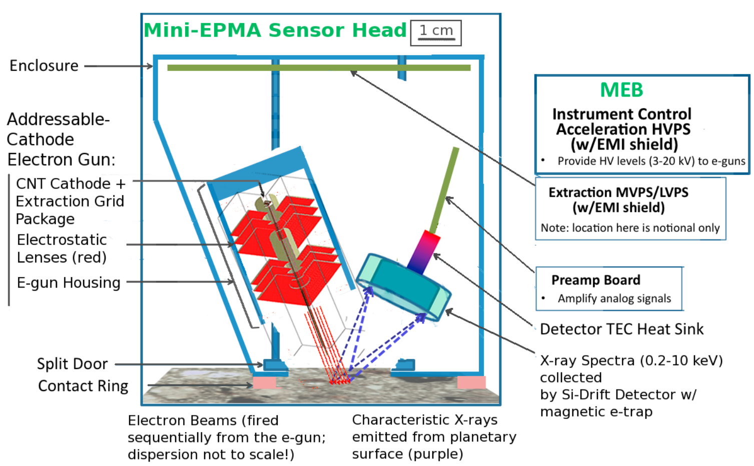


Figure 1: The electron gun will illuminate 100 μm spots on the natural surface, thus enabling *in situ* mapping of elemental composition on the scale of the beam diameter. The prototype will employ a 10x10 array of carbon nanotube "forest" emitters and cover a 3.1x3.1 mm field.

(≊100 μm instead of <1 μm). We will also evaluate the benefit to the light-element analyses of collecting a second spectral map at a lower beam voltage (3–5 kV) where the C/N/O cross-sections are higher.

**Preliminary mechanical concept for the mini-EPMA flight instrument:** A mechanical model produced by the GSFC Instrument Design Laboratory has a total instrument mass of 3.3–3.6 kg depending on whether the main electronics (including high-voltage power supply) are mounted on a deployment arm with the rest of the mini-EPMA instrument or on the main lander body (for a two-meter notional arm length). A rotating door protects the sensors from dust and particle intrusion during deployment and can also carry a calibration target. The model includes two electron guns and two X-ray detectors for reliability. Peak power is estimated at 12.7 W; average power at 5.7 W.

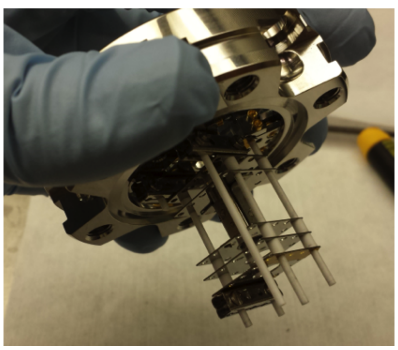

Figure 2: Prototype lens stack for EPMA electron gun

**Year 1–2 Work:** Preliminary design of the lens stack and cathode/grid package have been completed. Cathode/grid fabrication is in progress, with photomask layout having been completed. In parallel, CNT growth with two catalyst types is in testing in order to optimize forest emission properties. Prototype patterned 10x10 cathodes have been grown with both catalysts (Fig. 3).

**Acknowledgements:** We gratefully acknowledge the support of the NASA PICASSO program for this work. C. Kotecki (GSFC) and J. Gaskin (NASA/MSFC) also contributed as co-authors on the PICASSO proposal. This work depends on the ongoing efforts of N. Costen, A. Ewin, G. Hidrobo, C. Johnson, G. Manos, G. Ramu, and E. Young at GSFC.

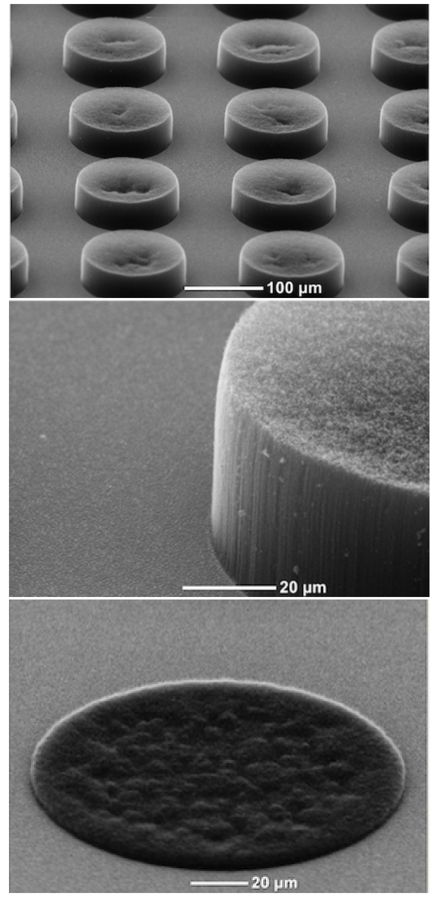


Figure 3: SEM micrographs of 10x10-element carbon nanotube forest cathode prototypes. Top and middle: Cathode grown with “Catalyst B”. Bottom: Single forest of “Catalyst A” cathode, grown to a lower height than “Catalyst B”. Each forest serves as a field emitter when addressed, providing electrons to the e-gun in order to stimulate characteristic X-ray emission from the target material.

## References

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