Additively Manufactured Plastic Top-Hat Electrostatic Analyzer

Design work and some testing was done at UAF's SSEP Lab, funded by Alaska Space Grant Program

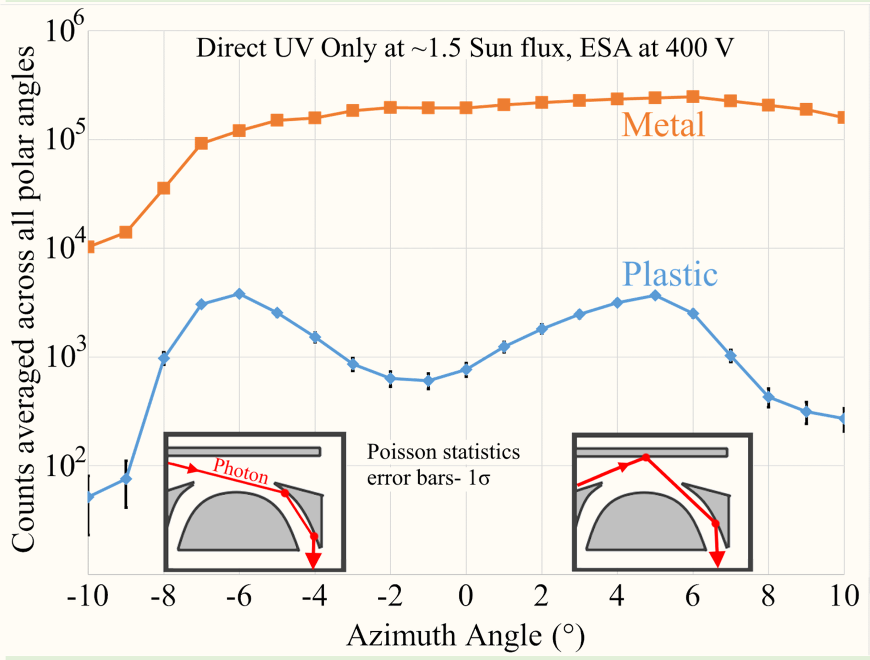
Additive Manufacturing and some testing was done in facilities at UAF's Geophysical Institute, including the Machine Shop and the Vacuum Lab.

SA13C-2505

Primarily funded by NASA H-TIDeS
Grant #19-HTIDS19-0030
Major testing was done at NASA Goddard's Geospace Physics Laboratory (673)

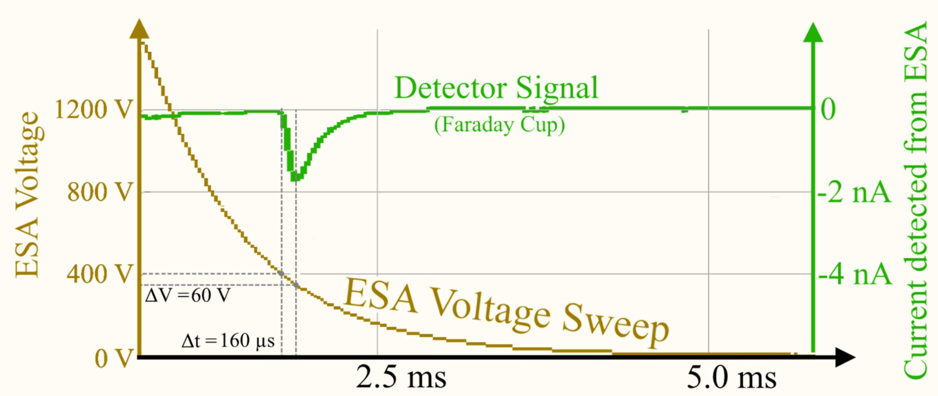
- Quetzal Larrick, University of Alaska Fairbanks
Space Systems Engineering Lab (uaf-ssep@alaska.edu or qaleubkelaroque@alaska.edu)
- Craig J Pollock, Denali Scientific
- Donald L Hampton, University of Alaska Fairbanks-Geophysical Institute
- Levon A Avanov, University of Maryland
- Daniel J Gershman, NASA Goddard-Geospace Physics Laboratory
- Denise Thorsen, University of Alaska Fairbanks-Alaska Space Grant

Plastic instrument shows improved rejection of ultraviolet light:



UV rejection is important because solar Lyman-Alpha (121 nm) causes false detections. Metal requires black coatings and serrations, but printed plastic may not require those.

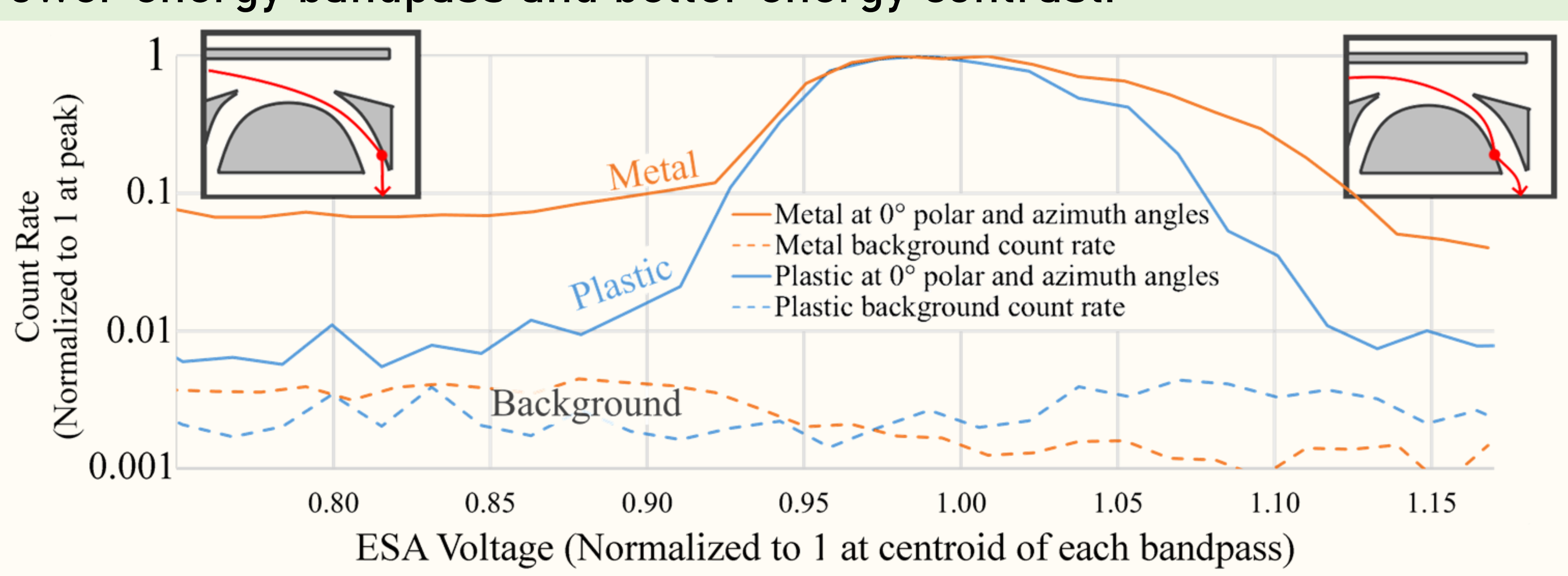
Plastic instrument is able to sweep through voltages rapidly, like metal:



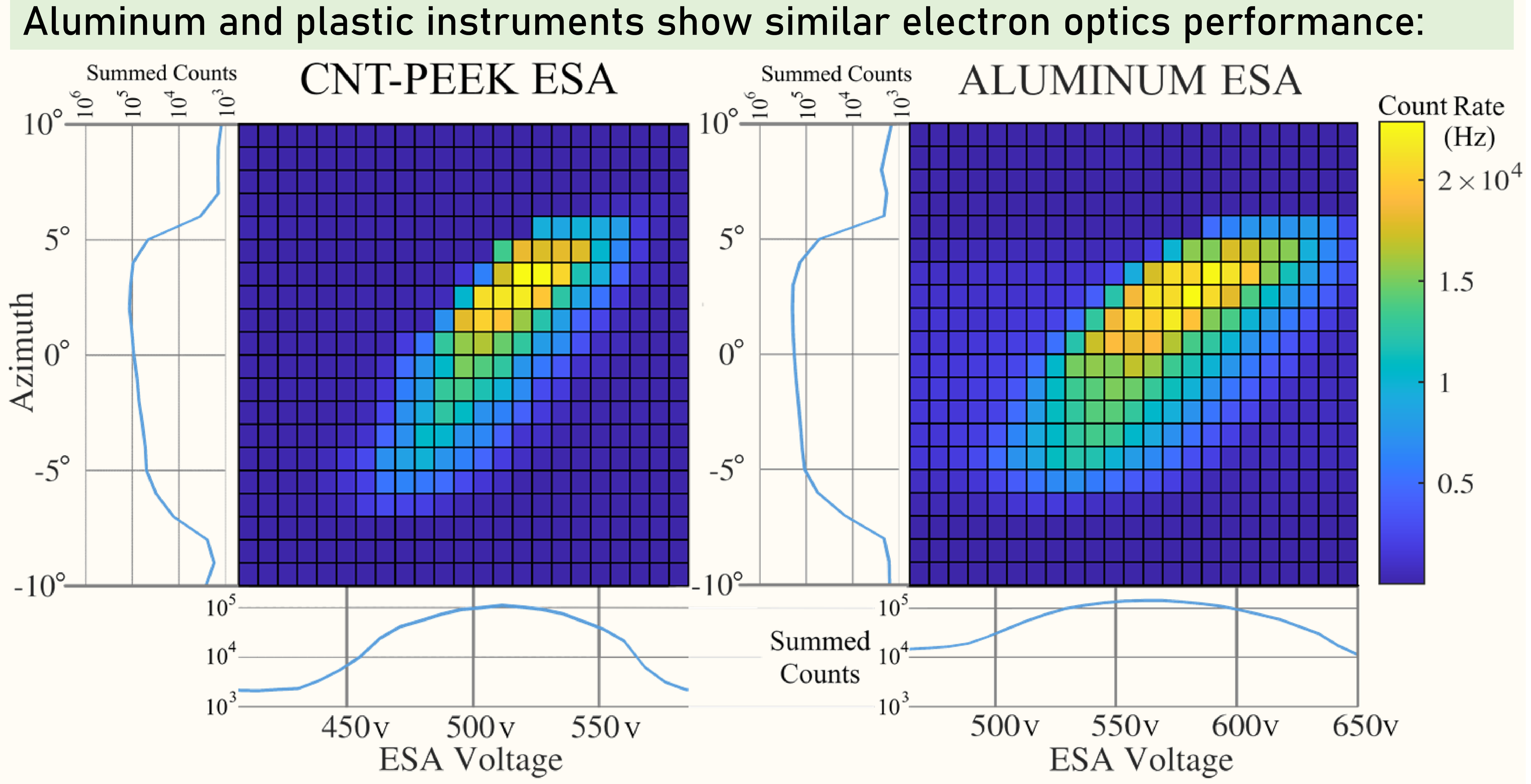
Rapid sweeping ability is important because these instruments may acquire an entire energy spectrum in only 10 ms, with only ~300 µs at each energy step.

This printed plastic instrument has a resistance-capacitance (R*C) time constant of <10 µs.
The voltage sweep shown above has a time constant of about 1000 µs, so the plastic's R*C is not a significant source of error.

Plastic instrument shows reduced out-of band electron detection, providing a narrower energy bandpass and better energy contrast:



Aluminum and plastic instruments show similar electron optics performance:



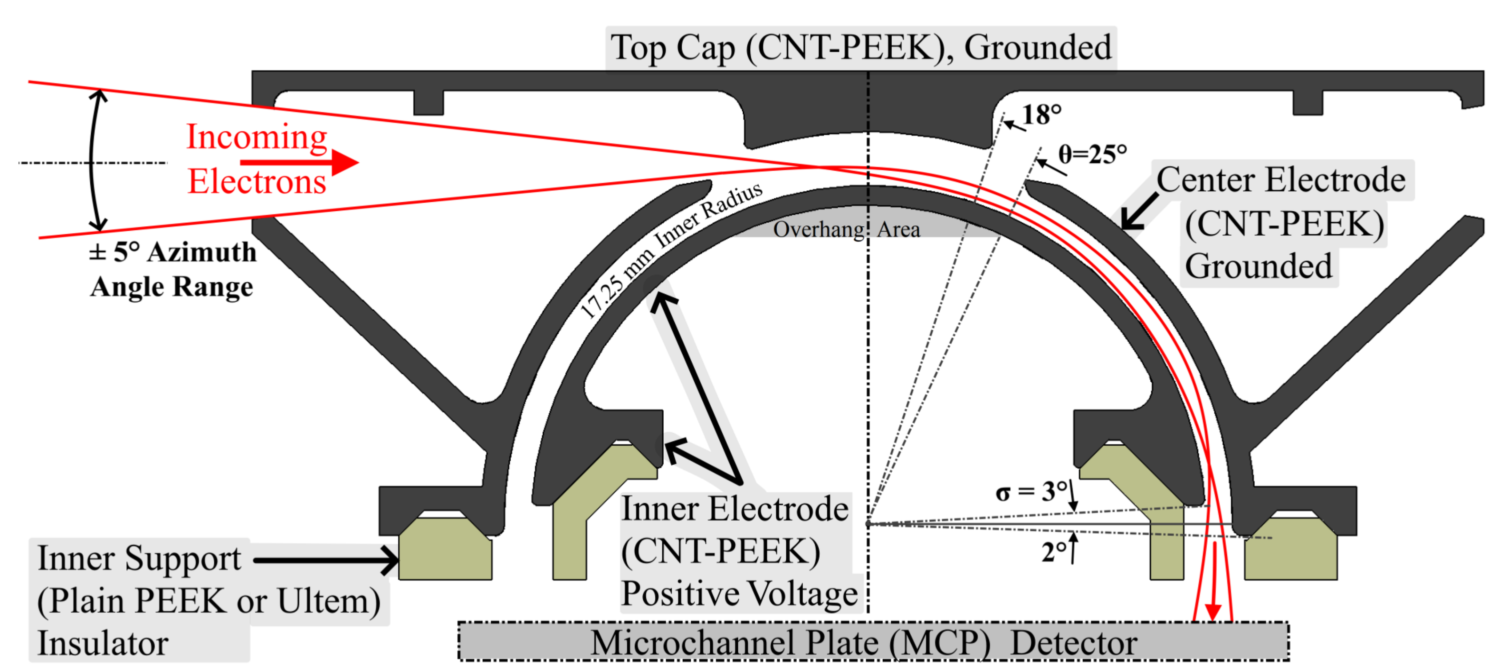
Can 3D-printed plastics be useful for plasma instruments?

To find out, we made an Electrostatic Analyzer of PEEK plastic, infused with carbon nanotubes for conductivity.

The results are promising.

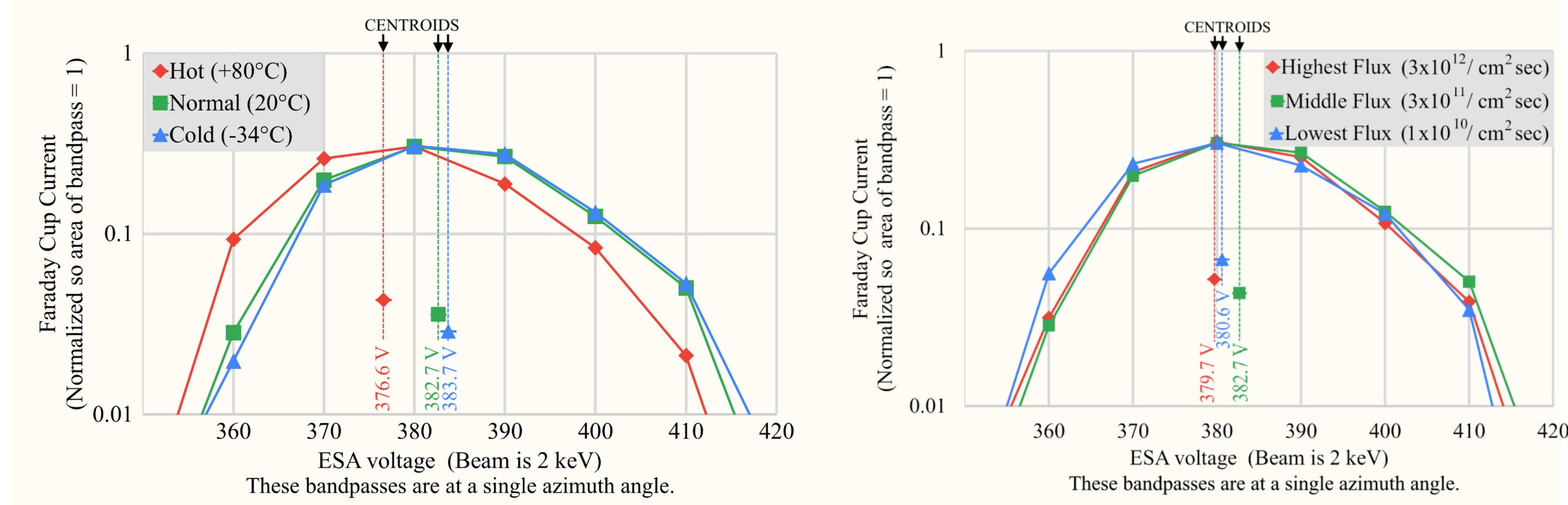
Potential benefits:

- Easier manufacturing/assembly
- Convenient ultraviolet rejection
- Reduced electron scattering
- New geometries become possible
- Reduced mass



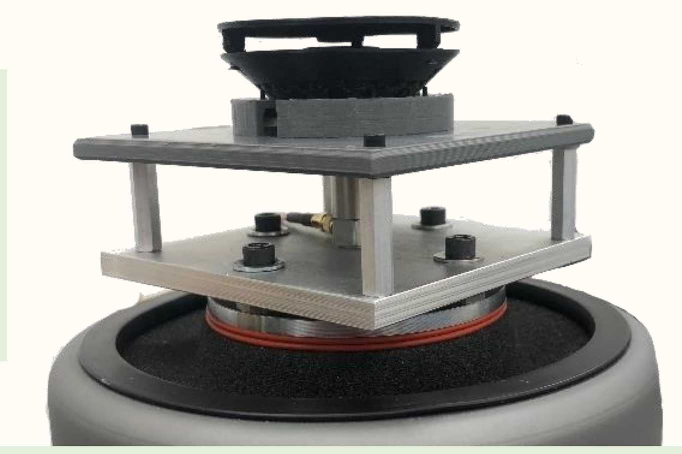
Temperature and Beam Flux:

The printed instrument was subjected to extreme temperatures and extremely high electron beam fluxes, with no ill effects seen. These graphs show only small shifts of the electron energy bandpass:



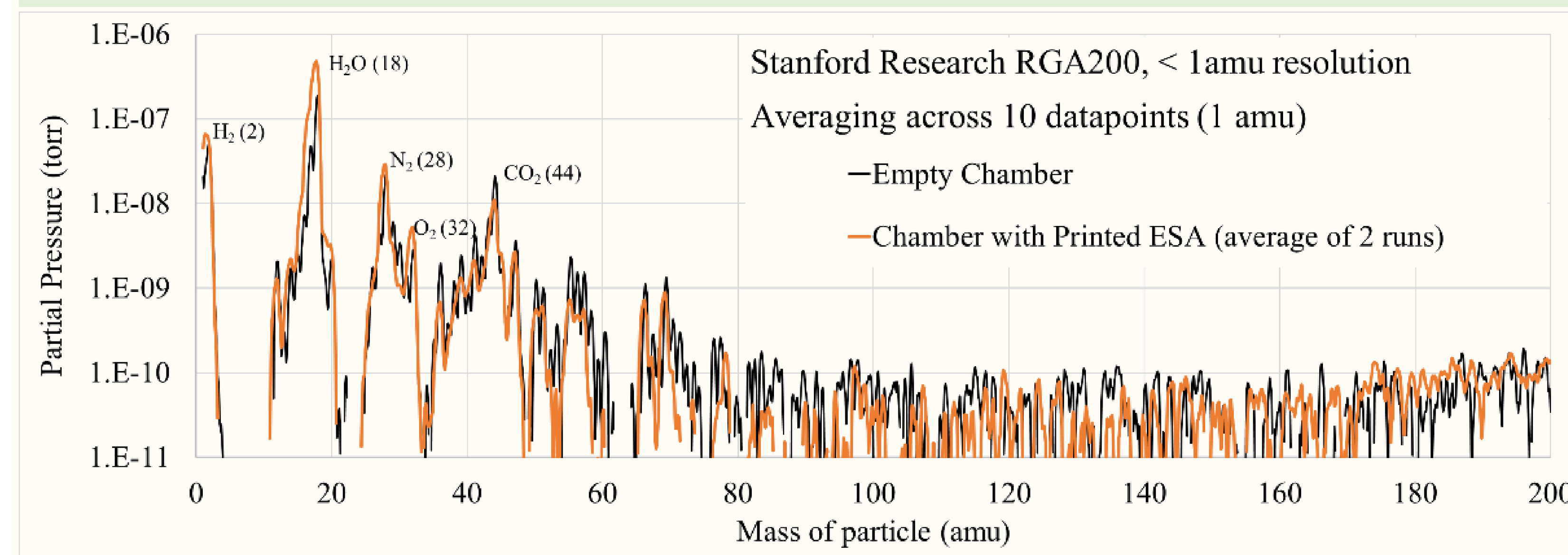
Vibration:

The printed instrument survived vibration testing at a 20 g RMS, well beyond the NASA GEVS qualification standard. Tests were done with the instrument in both orientations.



Vacuum Outgassing:

No abnormal outgassing was seen with a RGA (Residual Gas Analyzer):



Remaining Questions:

- Is it conductive enough?
  - At higher electron beam energies (>500eV), this plastic behaves like metal, but lower-energy electron or ion beam tests may reveal problems. Plastic with a higher fraction of carbon nanoparticles may be necessary.
- Will it survive exposure to space?
  - Atomic oxygen damage and radiation damage to the plastic have not yet been assessed. Plating the external surfaces may be necessary.
- Will there be detector contamination problems?
  - While the RGA data shows no significant outgassing, we are still concerned about surface contamination degrading microchannel plates. There is currently a separately funded experiment at UAF to study MCP degradation over time when exposed to this printed plastic.