# Snowmass2021 - Letter of Interest

## [Micro- and Nano- Machined Vacuum Photodetectors]

**Instrumentation Frontier Topical Groups:** (check all that apply □/■)

□ (IF1) Quantum Sensors
■ (IF2) Photon Detectors
□ (IF3) Solid State Detectors and Tracking
□ (IF4) Trigger and DAQ
□ (IF5) Micro Pattern Gas Detectors (MPGDs)
■ (IF6) Calorimetry
□ (IF7) Electronics/ASICs
□ (IF8) Noble Elements
■ (IF9) Cross Cutting and Systems Integration

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**Abstract:** We survey developed techniques in MEMS/NEMS and silicon foundaries used to form vacuum micromachined photodetectors, with gain from dynodes or silicon nanomachined microchannel plates, and to form high quantum efficiency photocathodes because of geometric field or topological areal enhancements. Examples and properties of recent devices from Japan, USA, and Europe will be shown. Prospects for novel materials such as GaAs MCP and diamond SE dynodes are discussed. Some allied applications of micromachining in all solid state detectors such as APD or integration with readout electronics will be presented. Benefits for high energy physics include fully channelized no-cross-talk pixels, high gain-bandwidths, thickness to the beam of a few mm, tileablility/low dead area, low areal mass, and high magnetic field operation. Because the technologies are amenable to standard wafer fab practice, lower costs may result. Potential applications in selected HEP experiments will be surveyed, varying between very large photodetectors for astroparticle physics, and fiber array detectors.

# Micro- and Nano- Machined Vacuum Photodetectors

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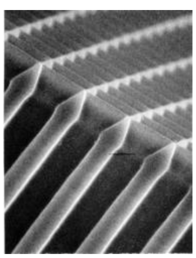
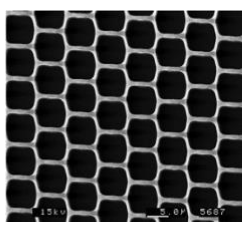
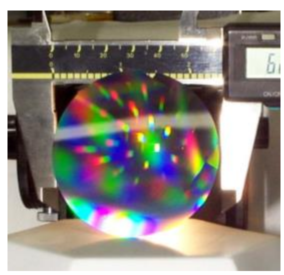
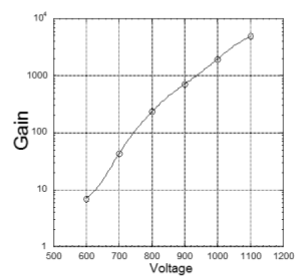
ABSTRACT: We survey developed techniques in MEMS/NEMS and silicon foundaries used to form vacuum micromachined photodetectors, with gain from dynodes or silicon nanomachined microchannel plates, and to form high quantum efficiency photocathodes because of geometric field or topological areal enhancements. Examples and properties of recent devices from Japan, USA, and Europe will be shown. Prospects for novel materials such as GaAs MCP and diamond SE dynodes are discussed. Some allied applications of micromachining in all solid state detectors such as APD or integration with readout electronics will be presented. Benefits for high energy physics include fully channelized no-cross-talk pixels, high gain-bandwidths, thickness to the beam of a few mm, tileablility/low dead area, low areal mass, and high magnetic field operation. Because the technologies are amenable to standard wafer fab practice, lower costs may result. Potential applications in selected HEP experiments will be surveyed, varying between very large photodetectors for astroparticle physics, and fiber array detectors.

## ***Silicon MCP***

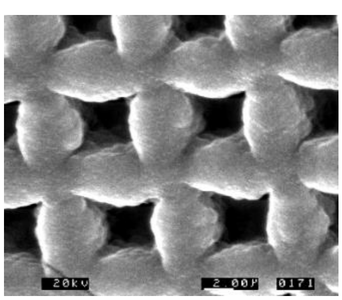
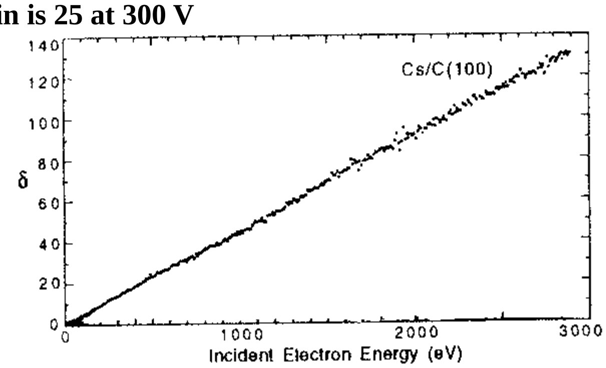
- Wafers up to 12” diameter
- Channels 1-10 microns wide, 200:1 long, off-axis up to 20 degrees
- Square, “Hex”, Round channel cross-sections
- Refractory; High Purity– CVD, PVD
- Convertible to Si- Nitride, Oxide, Carbide


Si MCP: L, ML oxidized, coated 6µm channels, 8µm centers, Aspect ratio 40-60
MR: 8” machined wafer; R: Gain ~8k Aspect ratio 40-60:1;
Gain Increases with operation - Opposite of glass MCP – no H, O, $H_2O$

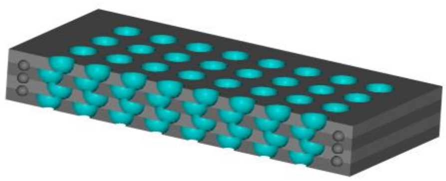
**• B-doped Diamond:Cs SE Film - Dynodes and MCP**

- Diamond nucleation ~200nm film/hour Flow through CVD - $CH_4$+$H_2$
- 500 nm Diamond Film on SiMCP in left figure above -> Diamond First Strike
- **Diamond SE Gain – At ~3000 V, 9% single p.e. resolution.**
- **With B-doping at $10^{19}$/cc, gain is 25 at 300 V**

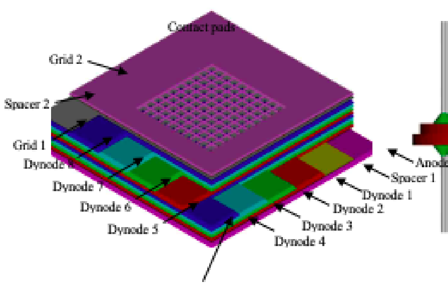



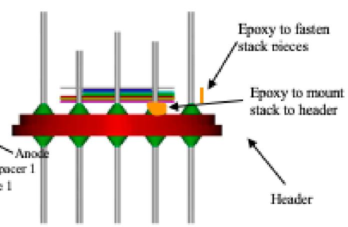
# Micro Machined MEMS PMT

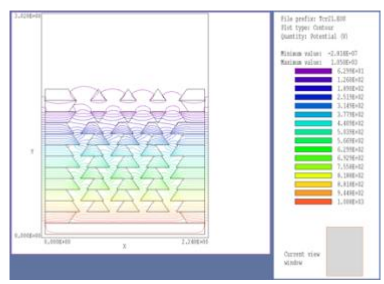
- Wafer-PMT: 2" diameter x 3-4 mm thick
- Edge PMT: 2-3 mm x 25 cm Photocathode
- Dinner PMT: 12" diameter x 6 mm thick
- MicroPMT: 1mm diameter x 3mm long
- Fully-Channelized Multianode PMT - photocathode on top dimple surface
- High-B PMT
- Dynode stages ~100-200 mm thick
- Self-Supporting, Self-Aligning
- No Separate Vacuum Envelope
- Standard MEMS, Fab Tooling, Economics
- Thickness for 10 Stage "PMT"<3 mm
- Channelized Photocathode, p.e. gain, and Anode
  - Essentially No Cross-Talk > High B-field operation



Silicon Micromachined Wafers Bonded Together to form a Channelized MicroPMT.



Engineering Test Design to test the micromachined PMT concepts: 3D CAD modeling of an 8 stage microPMT and mounting to a standard TO5 12pin header for electrical testing. The assembled stack is held together with UHV compatible Torr Seal. The stack is then mounted to a header. See photographs of these assemblies below.