PROJECT SUMMARY

Under this NASA Phase II SBIR project, Physical Optics Corporation (POC) developed technologies that allow fabrication of a new Silicon Microchannel-Plate-based Large-Area UV detector (UV-Si-MCP). POC, working in close cooperation with Technology and Devices International (TDI, Inc.) demonstrated technologies for the fabrication of large-size (2 in. diameter) silicon microchannel plates (MCPs) with the AlGaN ultraviolet (UV)-sensitive photocathode deposited on the front surface and the microchannel walls. The developed hydride vapor phase epitaxy (HPVE) process for growing the AlGaN layer within microchannels allows use of this layer both as a UV-sensitive photocathode with high quantum efficiency (QE) and as an effective emitter of secondary electrons with large secondary electron emission (SEE) coefficient. The demonstrated photocathodes showed a sharp cutoff at wavelengths longer than 280 nm, – rendering the UV photocathode solar blind.

POC designed and developed major manufacturing technologies for a new UV-Si-MCP with a highly efficient, negative electron affinity (NEA) AlGaN photocathode fabricated directly on the surface of a silicon microchannel substrate. This development was based on POC technology of light-assisted electrochemical anisotropic etching (ECANE) of large-area Si-MCPs, in which the photolithographic mask defines the microchannels, plus the utilization of technologies established by our subcontractor, TDI, Inc., of Silver Spring, Maryland—the HVPE process for the growth of photocathodes, and SEE layers on the surfaces of silicon MCPs. The fabrication of these large-area photodetectors with an AlGaN photocathode deposited directly on the surface of Si-MCPs and into MCP microchannels is possible because of the high processing temperature permitted by the silicon substrate. First, POC designed a 2-in.-diameter Si-MCP for the UV region with 5 μm × 5 μm microchannels inclined at 15° to the surface with AlGaN photocathode deposited on the front surface and into microchannels to provide SEE. Then we developed the required sequence of technological operations required for the fabrication of the UV-Si-MCP as well as determination of the requirements for each step, available vendors, and methods for quality control. We developed new equipment for the etching of 6-in.-diameter silicon wafers, including new etching reactors, installed a new semi-automatic etching station, and optimized the etching procedure for wafers with 15° inclination to the [100] crystal plane. Together with TDI, we developed the innovative technology and equipment for the growth of the p-doped $Al_xGa_{1-x}N$ photocathode and a SEE layer on the front surface and on the microchannel walls of the Si-MCP in a single HVPE process. POC designed and assembled a turbo-pumped vacuum chamber with a UV-transparent window for activation of the p-doped $Al_xGa_{1-x}N$ ($x \cong 0.15$) photocathode and SEE layer by Cs vapor and estimation of the photocathode's quantum efficiency (QE). The same chamber may be used for the SEE gain measurement as well. Finally, we fabricated UV-Si-MCP prototypes, initially developed the activation procedure, and delivered the prototypes to the Goddard Space Flight Center (GSFC) for activation and QE measurements in a special high-vacuum chamber with calibrated UV light sources.

The UV-Si-MCP photodetectors offer higher sensitivity, lower background noise (lower probability of interaction with gamma rays), larger size, and better spatial resolution. The developed technology will benefit future NASA missions within Explorers, Discovery, Origins, and Beyond Einstein Programs. Non-NASA applications of UV-Si-MCP include missile plume detection, non-line-of-sight covert communication, atmospheric research, biosensors, machine vision, and semiconductor industries.