optiXphere Sensor Development

CNF Project Number: 3101-23
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Primary CNF Tools Used: CHA Evaporators, ABM Contact Aligner, Heidelberg DWL2000, YES Polyimide Oven

Abstract:

The optiXphere project aims to develop an omnidirectional UV-C detector. This report summarizes the progress made in substrate development, coating methods, and photolithographic techniques over the past year. Key advancements include refining the aluminum evaporation process, developing a wax resist etching technique, and constructing a projection lithographic system. These efforts have significantly improved the uniformity of photocurrent response across the substrate, moving closer to achieving a nearly flat detection curve.

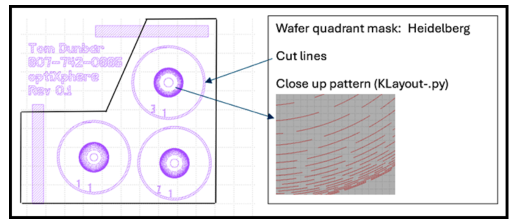

Figure 1: Quadrant mask design used for initial pattern transfer attempts.

Summary of Research, 2023-2024 Progress:

Substrate Development. Initial substrates were received from a Vermont Lampworker. A contract for substrate molding production was undertaken, resulting in near production-quality components. The refinement in the lampworker's process has ensured that the substrates are of high quality and suitable for subsequent experimental phases. The ability to produce substrates that meet the desired specifications has been a critical step in advancing the project.

Coating Methods. Various coating methods and CHA evaporations were evaluated, reducing UV-C photocurrent non-uniformity from four to two orders of magnitude. This significant improvement highlights the effectiveness of the refined coating techniques, paving the way for consistent and reliable substrate performance in future experiments. The evaluation of different methods has allowed for optimization of the coating process, ensuring that the substrates meet the necessary quality standards.

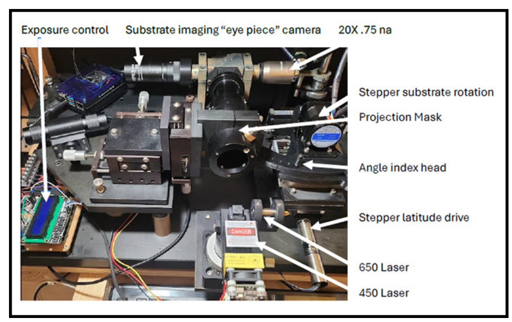

Figure 2: Custom-built projection photolithographic stepper system.

Nanoimprint Pattern Transfer Attempts. Initial attempts using SU-8 photoresist and Sylgard 185 molds for pattern transfer were abandoned due to mold press issues and limitations in feature size. The process aimed to create diffractive patterns, Figure 1, on the substrate but faced challenges in achieving the desired precision and resolution. Despite these challenges, valuable insights were gained, leading to the development of alternative approaches for pattern transfer.

New Approach 1, Projection Photolithography. Aluminum evaporation over the full substrate using the ODD-hour evaporator and a custom-built projection photolithographic stepper was pursued. A simplistic rotator system was developed as an accessory for the CHA Thermal evaporator to improve substrate coating uniformity.

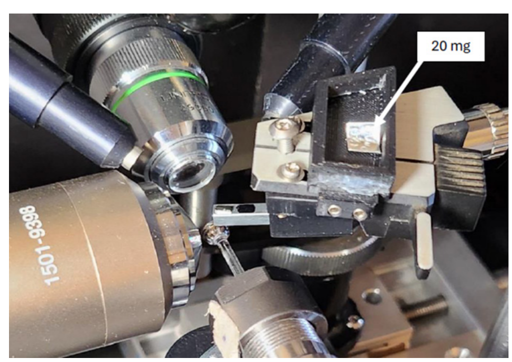

Figure 3: Custom-built wax scribing system.

This new approach addressed the limitations of previous methods, allowing for more precise control over the coating process and resulting in better substrate uniformity. The ability to achieve uniform coatings has been crucial in improving the overall performance of the substrates.

System Construction, Figure 2. A projection system with on-axis imaging was constructed to evaluate focus on spherical substrates. Exposures were made using a Young's double slit pattern, revealing resolution limitations. The system included a 650 nm dimmable diode laser for focusing and a 450 nm laser for exposure, controlled by an Arduino microcontroller. This setup enabled detailed examination of the substrate surface and the quality of the photolithographic process, providing critical insights for further refinements. The construction of this system has been a key development, allowing for precise control and evaluation of the photolithographic process. Resolution limitations using the current system components have shelved this approach for now.

New Approach 2, Wax Resist Etching. Inspired by Renaissance glassmaking techniques, wax-coated substrates were scribed and etched, creating thin horizontal features. Initial experiments using atomic force microscope probes were unsuccessful, leading to the planned use of microtome blades for more robust scribing. This wax resist technique, dubbed "Plow Lithography," involved detailed scribing of the wax layer followed by etching to expose the underlying aluminum, creating the desired patterns. The development of this technique should provide a reliable method for creating the necessary patterns on the substrates, Figure 3.

Funding and Collaboration:

Supplemental funding was secured through the NYS Advanced Materials Initiative Grant with MEP partnership with the Alliance for Manufacturing and Technology. Collaboration with Glassomer for substrate development is ongoing, with the first prototypes expected soon. The grant supplies in part CNF experiment expenses. These collaborations have provided essential resources and expertise, enabling significant progress and ensuring that the project stays on track. The funding and collaborative efforts have been instrumental in advancing the project and overcoming various challenges.

Experimental Results:

The first set of suitably coated substrates provided promising photocurrent results, showing a significant reduction in non-uniformity, Figure 4. The raw uncoated substrate had a four orders of magnitude non-uniformity, which was reduced to two orders with aluminum coating. This marked improvement validates the new coating and patterning techniques and demonstrates their potential for producing high-quality detectors. The experimental results have been encouraging, providing a strong foundation for further development.

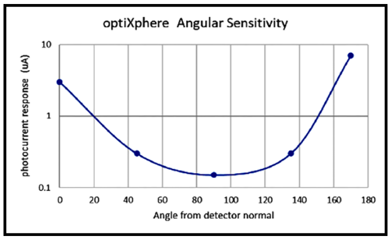

Figure 4: Photocurrent response versus latitude location on the substrate.

Process Challenges:

The initial pattern transfer approach faced challenges with mold pressing and achieving sub-micron feature sizes. The wax resist etching process also encountered difficulties, particularly with the surface roughness and speed limitations using atomic force microscope probes. These issues prompted the development of a more robust scribing technique using microtome blades. Addressing these challenges is crucial for achieving the desired precision and consistency in the substrate features, ensuring the final product meets the stringent requirements for UV-C detection. The challenges encountered have highlighted the need for continuous refinement and adaptation of the techniques used.

Conclusions and Future Steps:

The optiXphere project has made significant strides in substrate coating and patterning techniques. However, challenges remain in achieving the desired feature sizes and uniformity. Future efforts will focus on refining the wax resist etching process, developing stronger scribing tools, and exploring reflow transfer techniques for conformal 3D microprinting. Continued collaboration with CNF and external partners will be crucial in advancing the project towards a commercial-ready detector. Achieving a nearly flat photocurrent response across the substrate remains the ultimate goal, ensuring consistent and reliable detection of UV-C light, which is essential for practical applications in various fields. The future steps outlined will build on the progress made and address the remaining challenges to achieve the project's goals.

References:

[1] Zabow, G. (2022). Reflow Transfer for conformal 3-dimensional microprinting. NIST patent pending.