Wafer-scale Manufacturing of Nanoporous Membranes by Mean of Nanosphere Lithography

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We report on the manufacturing of nanoporous membranes used as highly selective, high flowrate filters for a CNT detection device. The main objective of this work was to decrease manufacturing costs, streamline the process flow used for membrane fabrication by using nanosphere lithography. With this approach, the size and distribution of the pores was defined by using nanoparticle monolayers as a template for the manufacturing of ultrathin silicon nitride nanoporous membranes. This represents a cost-effective alternative to standard lithography techniques for this case study. In this project, we mainly focused on the upscale and automation of the nanosphere lithography process to 100mm wafers and investigated different characterization means to improve quality control during the membrane fabrication.

During the past 10 years, CSEM has been manufacturing a broad range of micro and nanoporous membranes using silicon-based materials for various applications. Specific microporous membranes have for instance been developed to fabricate Fabry-Perot optical filter [1]. Membranes presenting sub-micro-meter pores were manufactured and over-molded in a plastic cell-culture insert to investigate the growth of biological barrier cells using TEER measurement [2]. Nanoporous membranes have also been developed and optimized to achieve selective molecular filtration [3] and were also found to improve the kinetics of a bioassay [4].

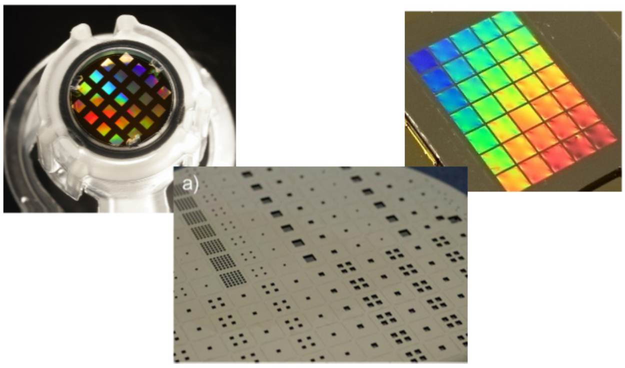

Figure 1: Examples of micro, submicro and nanoporous membranes manufactured at CSEM.

On a process standpoint, the manufacturing of micro and sub-microporous membrane relies on well-established microfabrication steps. However, in the case of nanoporous membranes, existing lithography techniques are either too expensive (DUV, E-beam) or do not have sufficient resolution to fabricate nanopores. For that, CSEM has been developing cost-effective alternatives for surface-nanopatterning by means of polymer self-assembly and nanosphere lithography. These nanopatterns have been successfully used as templates in standard clean room process-flows to generate sub-100nm pores in ultrathin silicon nitride membranes.

The main task of this project was to streamline the process flow for nanoporous membrane fabrication by focusing on nanoshpere lithography. For that, a specific process was developed to deposit monolayers of commercially available nanoparticles at a wafer scale. The process was automated to improve the quality of the deposition and wafer-to-wafer process reproducibility.

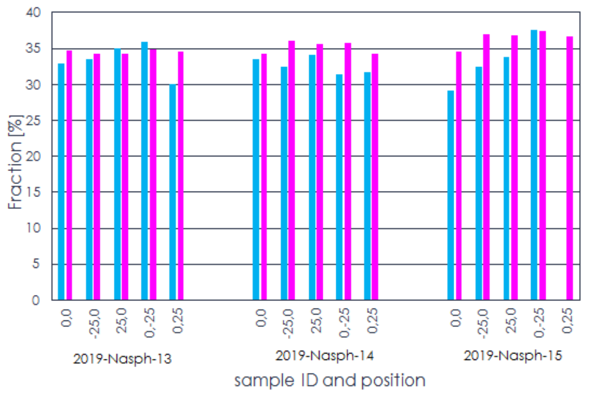

Figure 2: Comparison of quality control for membrane porosity (homogeneity and reproducibility). SEM characterization (blue) and ellipsometry (pink)

On a quality-control point of view, ellipsometry was evaluated to characterize the monolayers with a high-throughput and compared with standard SEM characterization. Membranes are currently manufacture using 100 mm wafers. However, the objective is to further decrease manufacturing costs by uspcaling this process to 150 mm wafers.

One application of such nanoporous membranes is their use in a highly sensitive carbon nanotube (CNTs) detection device [5]. In this system, which was developed in collaboration with the company Statpeel, the porous membrane is a key element acting both as a filter to collect CNTs and as a sensing element for their detection among other dusts.

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