Silicon-Based Microevaporator Print Head for Direct-Write Vapor Deposition

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In order to realize the next generation of electronic devices, it is desirable to be able to create nano and mesoscale dimensioned patterns in three dimensions with scalability, robustness, and ease of fabrication. Current lithography techniques are inherently two-dimensional in approach, and subtractive in nature (i.e. involving the blocking out patterns then removal or addition of material on a wafer). As a result many successive steps of lithography and wafer processing are necessary for creating three-dimensional heterostructures on a wafer.

We present here our work towards modifying the traditional physical vapor deposition (PVD) and chemical vapor deposition (CVD) precursor delivery systems to utilize a micron to nanometer-scale aperture ("nozzle") to perform direct-write deposition of thin films onto any substrate. We have developed a silicon printhead device, illustrated in Figure 1, for the purpose of delivering gaseous precursor to a localized area on the substrate. The printhead features nozzle of diameters from 100µm to 100nm (and possibly as small as 10nm). Depositions are performed in high-vacuum (~10^{-7} Torr), and a piezo-driven three-axis nanopositioning stage is used to move the substrate relative to the nozzle.

To create a localized deposition spot, the nozzle must be positioned in close proximity to the substrate. We find that direct-write deposition is achievable when the source-to-substrate distance is on the order of the diameter of the nozzle and the linewidth of deposited features is closely dependent on source-to-substrate distance.

We will present proof-of-concept which was performed via PVD experiments, shown in Figure 2. Features such as lines, step-and-repeat dots, and single dots are demonstrated with source-to-substrate distances of around 500 nm for several organic molecules and zinc. Preliminary results from deposition of aluminum by CVD and comparison to the PVD experiments is also discussed.

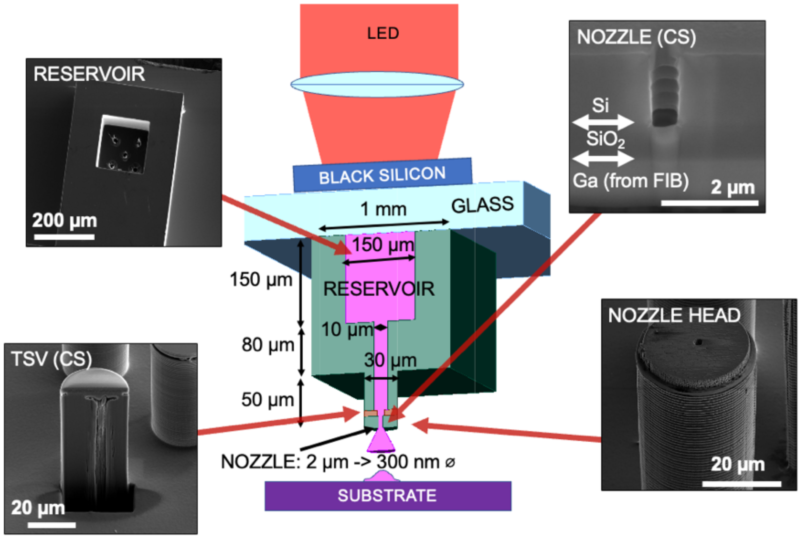

Figure 1: CAD sketch of microevaporator used for PVD and SEM images of key microevaporator features. Microevaporator consists of material reservoir, which holds material to be evaporated. When heated from the backside, evaporated material travels through the TSV to exit via the nozzle and deposit on a substrate.

Figure 2: (A) SEM of lines written by Coumarin. Lines were written by PVD of Coumarin from microevaporator containing 5 nozzles at 160° C, 5 nm/s translation speed, 23° C substrate. Nozzle diameters varied between 700nm – 300nm. (B) AFM scan of region on SEM indicated by the arrow. (C) Optical image of step and repeat Coumarin deposition from 5 nozzle microevaporator with 900 nm nozzle diameter at 160° C, 23° C substrate. Translation direction indicated by blue arrow. (D) Scanning laser confocal microscopy image of Coumarin deposition. Deposited from microevaporator with 900 nm diameter nozzle at 160° C, 23° C substrate.