Active Semiconductor Fibers and Devices

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Abstract: Unary and compound semiconductors have been deposited into microstructured optical fibers to make junction-based fiber devices, very high power infrared fibers, mid-infrared fiber lasers, and nonlinear hydrogenated amorphous silicon fibers.

High pressure chemical vapor deposition (HPCVD) has enable the fabrication of layers and void-free cores of both unary semiconductors such as crystalline silicon [1], germanium [2], and hydrogenated amorphous silicon [3, 4] and compound semiconductors such as zinc selenide [5] that are centimeters to meters long within the pores of microstructured optical fibers (Figure 1) [6, 7]. These semiconductor materials generally cannot be drawn into chemically pure micron to sub-micron size fiber cores or cannot be drawn at all. The semiconductor wires and fiber cores can have near atomically smooth exterior surfaces and guide light with optical losses of < 1 dB/cm. We have shown that this HPCVD capability can be used to fabricate Schottky and *p-i-n* junction-based fiber devices such as detectors with bandwidths up to 3 GHz [8] (Figure 2), modulators [7], and meter-long photovoltaic fibers [7]. In this way semiconductor optical and electronic functions that have traditionally been available only on chips can be integrated into optical fibers. These fiber devices are advantageous in integrating well with existing fiber infrastructure and in allowing for long light-matter interaction lengths [1], the full design geometric flexibility of microstructured optical fibers [9], which allows for designed guidance [10] and seamless light coupling schemes [8], polarization independent guidance, tapering, and very high power guidance [6].

Refractory zinc selenide fiber cores (Figure 3), for example, allow for guidance of light in the infrared at power densities within a factor of 3 of silica [6]. Non-linear fiber devices operating at powers much in excess of that possible with conventional chalcogenide glass fiber cores may thus be possible. Doping the fiber cores with transition metal ions to serve as gain media has also allowed for mid-infrared fiber lasers based on these crystalline compound semiconductor fiber cores.

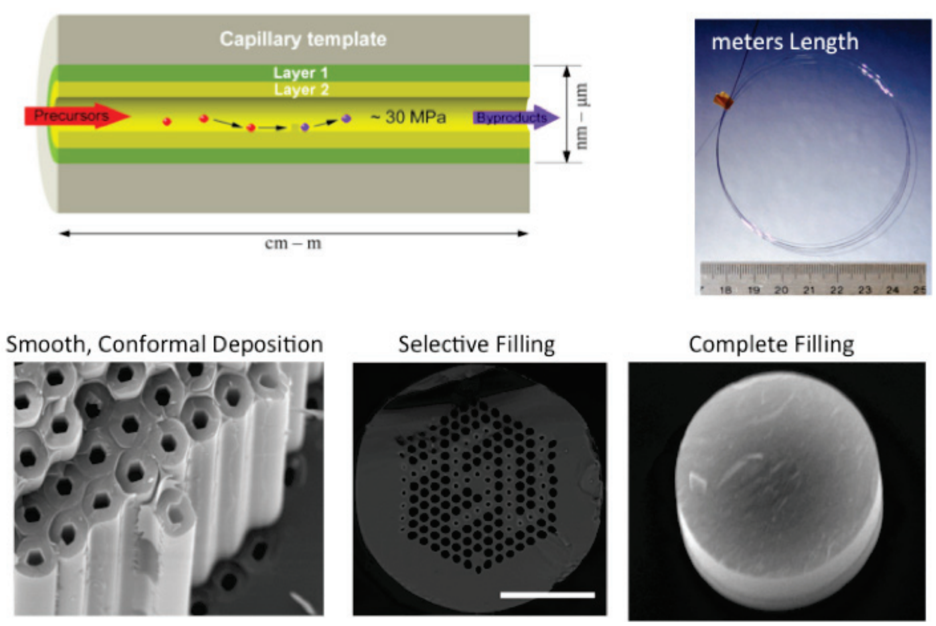

Figure 1. High pressure chemical vapor deposition allows for the deposition of conformal, well developed films of semiconductors, in this case, silicon, within the pores of microstructured optical fibers. Smooth silicon films that conformally coat a MOF template to form 2 μm diameter tubes are possible, along with selective filling of a template, and complete filling of the pores over distances of many centimeters, to form void-free atomically smooth fiber cores, long enough for many semiconductor fiber devices. Recent work shows that silicon films as long as 10 meters are possible, with prospects for much longer lengths in the future.

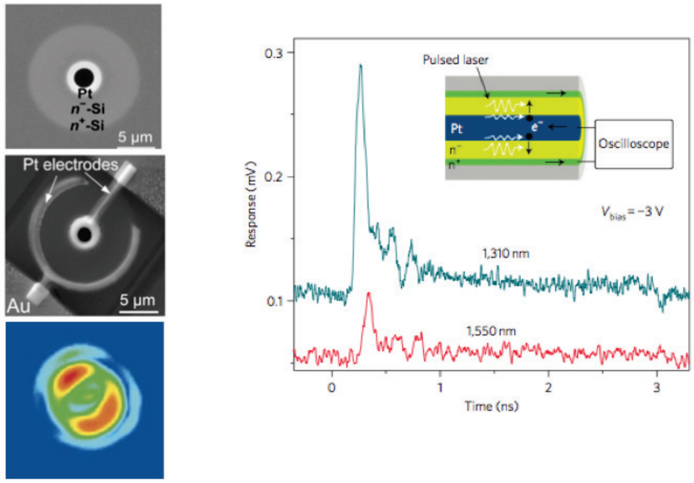

Figure 2. SEM micrograph of cross section of fiber integrated GHz Bandwidth silicon Schotty junction. These junctions guide light in the higher index undoped region, as shown in the far-field image of light exiting the junction. The junction functions with 3 GHz -3 dB bandwidth.

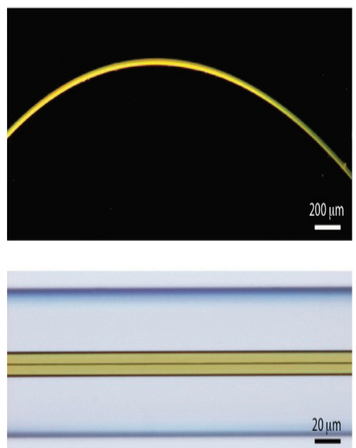

Figure 3. Optical micrographs of zinc selenide optical fibers fabricated by high pressure chemical vapor deposition, which have losses as low as 0.5 dB/cm, in the range of losses for many planar semiconductor waveguides.

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