A streamlined process for fabricating multi-channel neural probes on optical fiber substrates

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Neural probes are used to stimulate spiking activity within a target population of neurons and monitor how these electrical signals propagate through the brain. This paper describes a simple fabrication process for multi-electrode neural probes on optical fiber substrates. It relies on neutral particle lithography to achieve the required depth-of-field and freedom from charging artifacts but circumvents the complexity of membrane masks and on-fiber alignment.

Fig. 1 shows, conceptually, 4-channel thin-film sensors on each of four sides of a fiber. It requires two masks; the first for the interconnect traces. The other for vias in the dielectric overcoat where the metal lines contact the brain.

As shown in Fig. 2, optical fibers are held in V-grooves etched into the top surface of a (100) Si wafer by light wire springs. A second set of V-grooves, etched from the opposite side of the wafer, forms open windows at the bottom of the upper grooves. When this *mask* is illuminated by 50 keV He atoms, transmitted beamlets transfer the pattern to resist on the fibers. A negative-tone resist is used to mask the gold interconnects. The vias are similar, but require a tone-reversal step. Mechanical alignment achieves longitudinal and transverse positional errors of 1.0 ± 0.6 µm and 0.3 ± 0.15 µm, respectively. The single-interconnect mask can be printed multiple times to build the probe of Fig.1. The offset is produced by tilting the mask relative to the beam. Fig. 3 shows two lines printed on a 300 µm fiber with 21.5 and 29.5 µm offsets in the longitudinal and transverse directions, respectively.

Fig. 4 is an in-vitro recording from a brain slice (mouse) after a battery of bench tests, including a) a 3-week soak in warm phosphate buffered saline, b) repeated insertion in agar and a stainless steel cannula, d) disinfection in MetriCide-2.6% glutaraldehyde, and a 6 hour implantation in mouse brain). Impedance spectra were the same within the error of the impedance bridge before and after these bench tests.

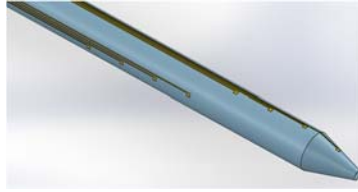

Fig. 1: Concept of a multi-contact neural probe on an optical fiber substrate: 4-channel tetrodes are printed on each of 4 sides of a fiber.

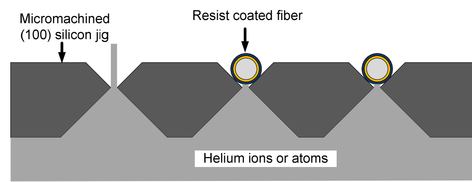

Fig 2: Exposure jig for metallization lines running the length of the fiber formed by two intersecting families of V-grooves on opposite sides of a (100) silicon wafer.

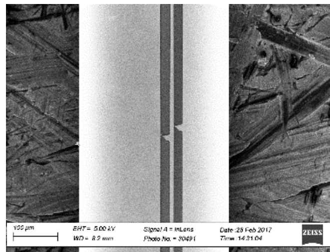

Fig 3: Resist (dark) image of 2 offset prints of a 20.0 μm wide mask opening in negative tone resist on a gold-coated optical fiber, 300 μm in diameter. The image on the left has been shifted up and to the right by 21.5 and 29.5 μm, respectively, by tilting the mask relative to the beam.

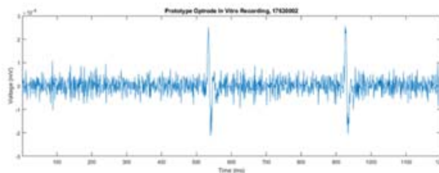

Fig 4: In-vitro recording of extracellular action potentials in a brain slice after a 3-week battery of bench tests including a) soaking in warm phosphate buffered saline with and without stimulation, b) repeated insertion in agar and a stainless steel cannula, d) disinfection in MetriCide-2.6% glutaraldehyde, and 6 hour implantation in mouse brain). Impedance spectra are the same before and after these bench tests.