High Density Silicon Electrode Arrays

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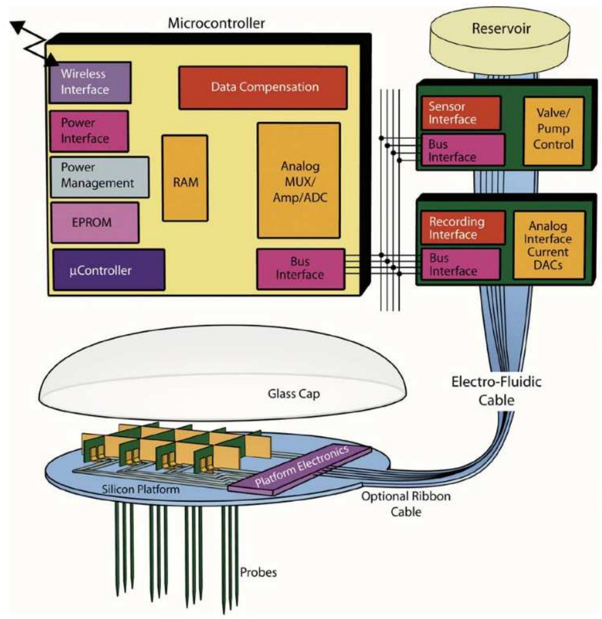
Traditional cortical electrical measurements are taken with electrolytically sharpened wires, which are usually around 25 to 50 μm in diameter. These microwires are insulated in order to define a exposed measurement site at the tip. Cortical electrodes are able to record the voltage associated with ionic current flow around a neuron when it fires an action potential in response to inputs received from other neurons. The electrode sites are capacitive, meaning they exhibit low pass characteristics, with an impedance on the order of a megohm at 1 kHz. Recorded signals have a bandwidth of 10 kHz. Their recording bandwidths are limited by the input capacitance of tip which can be increased by the Miller effect (capacitive multiplying seen in gain stages). Unlike the discrete approach, typical thin-film probes allow for the integration of mulltiple electrodes onto a single substrate, on chip amplification, and signal processing, as well as other applications such as drug delivery. On the silicon, all dimensions can be controlled using lithography, to the sub micron level. An array of recording or stimulating sites is connected to VLSI circuitry at the rear of the structure via thin-film conductors that are insulated above and below by deposited dielectrics. The performance of these probes is directly determined by the substrate and how it is shaped, the recording sites, the interconnects, and the isolating dielectrics. The shank substrate is formed using boron-stop reactive ion etching, after a boron predeposition and drive-in. Once the boron diffusion defines the shank dimensions the amplification and signal processing electronics are deposited. The CMOS circuit is built on an epitaxially grown n-type substrate. Once the circuitry has been deposited down a silicon oxide or nitride dielectric is grown, usually through a low temperature chemical vapor deposition (such as PECVD). Once a conductor is deposited onto the wafer three final LPCVDs are performed (oxide layer, nitride layer, and a second oxide layer). Finally the device is encased in a polymer, this is essential since small ions will diffuse to the silicon-silicon oxide interface and create states in the bandgap effecting the electrical properties of the material, and ions such as sodium and potassium will destabilize glass. Channels for drug delivery can be easily incorporated into the shank, by depositing impurities into a desired channel location, epitaxially growing silicon, deposition the same impurities into windows on the epitaxial layer to leak the fluid out of the channel, and etching the impurity, exposing the channel location.



One of the critical factors that determines the performance of these electrode arrays is biocompatibility. Norman et al. 2005 tested the biocompatiblity of silicon, silicon nitride, silicon dioxide, platinum, titanium, and tungsten for vision studies. The position of a light source was changed and the response of the CNS was determined. It was shown that a signal to noise ratio of 1.5 or more is needed to detect the position of th light. One of the critical factors they noted was the importance of the surgical implantation to the performance of the electrode array.

References

[1] K. Wise, *Wireless Implantable Microsystems: High-Density Electronic Interfaces to the Nervous System*, Proceedings of the IEEE, Vol 92 No. 1, Jan. 2004.

[2] R. Normann, *A Neural Interface for Cortical Vision Prosthesis*, Human Mutation, Oct. 2005.