Extended Abstracts of the 2002 International Conference on Solid State Devices and Materials, Nagoya, 2002, pp. 6-7

PL-3 (Plenary)

Microelectronics meets Molecular and Neurobiology

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Information processing in brains and computers relies on different charge carriers - ions and electrons. Due to the different mobility of ions in water (1/1000 cm2/Vs) and electrons in silicon (1000 cm2/Vs) the architecture of the two systems must be different. It is an intellectual and technological challenge to join neuronal networks and computer chips on a microscopic electrical level with the goal to get better insight into brain dynamics, to built neuroelectronic information processors and to lay the basis for biomedical neuroprosthetics. The research has two directions: (A) Elucidation of the electrical dynamics of the neuron-chip interface on a nanoscopic level. (B) Assembly of hybrid systems made of neuronal nets and electronic devices on a microscopic level.

In the first area we analyzed the structure of the neuron-chip contact using fluorescent dyes in the cell membrane: (i) Taking advantage of the optical microcavity effect in front of silicon we determined the distance of cells and chips. We found that the insulating core of cell membranes is separated from the insulating silicon dioxide by about 50 nm. (ii) Taking advantage of the electrochromic effect we measured the electrical response of membranes to ac stimuli at the chip and evaluated a sheet resistance around 10 megaohm-square. I.e. cell and chip are separated by conductive gap that suppresses direct electrical polarisation.

Electrical interfacing is achieved by current: Ionic and capacitive current through the attached cell membrane gives rise to a voltage in the gap that affects the electron channel of a field-effect transistor in the chip. Capacitive current through the silicon/electrolyte interface gives rise to a voltage in the gap that affects voltage-gated ion channels of the nerve cell. We are optimizing the cell-silicon junction by lowering the conductance of the gap, by enhancing the current through the membrane with ion channels using recombinant methods and by enhancing the current through the silicon/electrolyte interface using high-k materials.

In the second area we proceed in two directions: (i) Using large identified neurons from snails, we build elementary neuroelectronic devices. A signal loop was assembled with capacitive stimulation from a chip to a neuron, with a synapse in a grown neuronal net and with transistor recording of the second neuron. A reciprocal loop was created with transistor recording of neuronal excitation, with signal recognition and amplification on the chip and with capacitive stimulation of a second disconnected neuron. The outgrowth of neuronal nets on the chips is guided by chemical, electrical and mechanical cues. (ii) Using organotypic slices cut from brain we study the electronic interfacing of neuronal tissue. With a linear transistor array, onedimensional activity maps were recorded in slices from rat hippocampus.

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