Manipulating neurons and neuronal networks with micropatterned surfaces


Primary neurons cultured on a conventional coverslip grow neurites in random orientation and form a uniform network that covers the whole surface (~cm). Using micropatterned surface as a growth scaffold, direction of neurite outgrowth in single neurons or the region of network formation can be extrinsically controlled. Such micropatterned neurons and networks allow us, e.g., to study development of neurons and to investigate how structure of the network determines its function. Here we present our recent work on the application of surface nano/micro-modification techniques in manipulating neurons and their networks. (Yamamoto et al., Appl. Phys. Lett. 99 (2011) 163701; Yamamoto et al., J. Neurochem. 123 (2012) 904-910.)

Noninvasive real-time measurement of dopamine, action potentials, and postsynaptic potentials using carbon nanotube electrodes chip

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Multi-electrode arrays (MEAs) can be used for noninvasive, real-time, and long-term recording of electrophysiological activity, but it is still difficult to measure presynaptic activity, such as neurotransmitter release. In this study, we describe the development of planar carbon nanotube (CNT)-MEA chips that can measure both the release of the neurotransmitter dopamine as well as electrophysiological responses. Chronoamperometric measurements using these CNT-MEA chips detected dopamine at nanomolar concentrations and synaptic dopamine release from spontaneous firings. Our CNT-MEA chips made it possible to measure presynaptic activities, postsynaptic potentials, and action potentials, which have a central role in information processing in the neuronal network.

Laser-induced perturbation into living neuronal networks: Toward understanding neurodynamics

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Living neuronal networks have been widely studied to elucidate information processing in brain systems. In order to realize artificial control of spatio-temporal dynamics in neuronal activity, we propose and demonstrate laser-induced perturbation into living neurons. Optical tweezers were applied to manipulate synaptic vesicles and neural cell adhesion molecules labeled with quantum dots in neurons. The fluorescence analysis revealed that these were trapped and assembled at the focal spot, because the small assemblies were effectively trapped. Moreover, laser processing and stimulation of neurons was succeeded with a focused femtosecond laser. Our methods have potential in realizing regulation of neuronal networks without application of any drugs and genes.

Revealing Neuronal Dynamics through Advanced Electrophysiology and Chemical Sensing using CMOS Technology

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Measuring neuronal activity accurately and simultaneously is key for advancing our understanding of how the brain processes information. Microelectrode arrays (MEAs) are used for highly parallel, non-invasive, and long-term measurements from large assemblies of neurons in cell cultures, brain slices and retinal preparations. The use of CMOS technology for MEAs allows increasing the sensor count and spatial resolution drastically. We present our recent progress in advancing MEA technology and in integrating carbon nanotubes to sense the chemical microenvironment in the extracellular fluid. We discuss our research on Purkinje cell functional dynamics in acute cerebellar slices and our investigations on subcellular extracellular dynamics of neurons in vitro cultures.