Bringing neurons to light with novel materials

Yael Hanein
School of Electrical Engineering, Tel Aviv University, Tel Aviv

Stimulation of neurons in a localized and safe manner is important both as an investigative tool and as a therapeutic means. The motivation to develop improved understanding and better tools with better properties for electrical and optical stimulation of cells fueled recent studies involving carbon nanotubes, organic semiconducting polymers, semiconducting nanocrystals, and amorphous silicon to name just few examples. In this presentation our ongoing investigation into the biophysics of neuronal stimulation will be presented. First, in vitro experiments allowing us to directly visualize neuronal response to stimulation will be presented. These investigations reveal that (1) Electrical stimulation targets a very particular subset of cells. Most likely, cells with processes crossing close to the electrode. (2) Activation is statistical in nature with higher amplitudes/durations recruiting more elements – not necessarily more distant elements. (3) Those cells which are coupled successfully with an electrode appear to have pretty consistent voltage stimulation thresholds. Current thresholds appear to vary more considerably, reflecting variations in coupling in tissue impedance. It appears that undesired reversible and irreversible biological effects are occurring at charge injections values which we commonly considered as safe. Building on these insights, we also study novel materials for improved electrical interfacing. We have been able to demonstrate that CNT electrodes have the following properties which we believe make these electrodes very attractive for further development: (1) They are non-Fradaic (2) They have high specific capacitance (3) They are compatible with micro-fabrication of flexible devices (4) The support full integration with the tissue (retina). More recently we developed organic crystalline semiconductor p-n heterojunctions that in physiological conditions operate as photocapacitors, meeting the properties necessary for cellular stimulation: efficient photogeneration of charges, stability, minimal footprint, and lack of Faradaic processes.