

An Ultrathin Flexible Carbon Nanotube Microelectrode Array for Neural Recording and Stimulation

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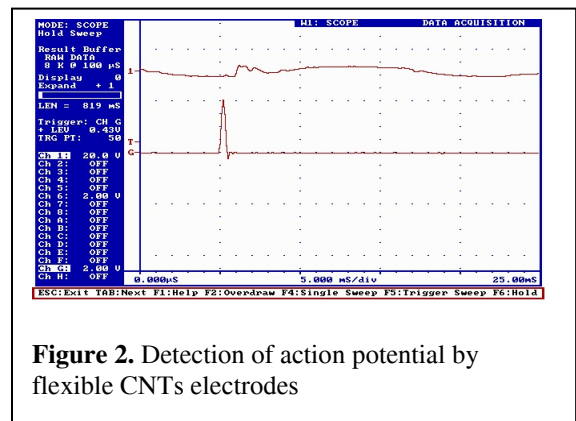
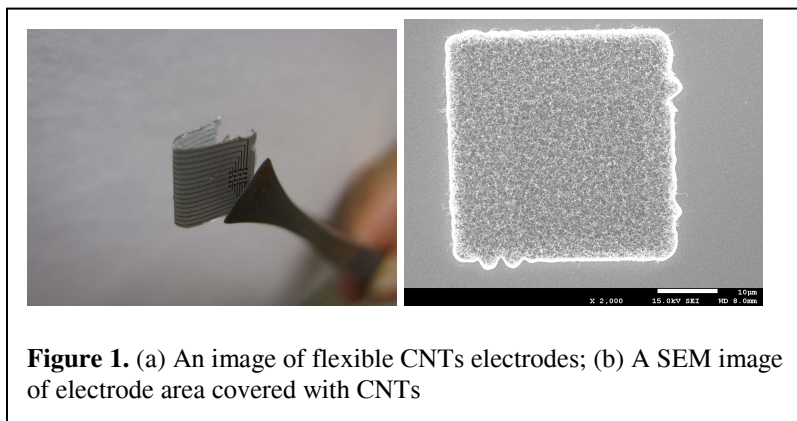
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Introduction: Carbon nanotubes (CNTs) have attracted many interests in the development of implantable electrodes because of their large surface areas, excellent electrical and mechanical properties, as well as biocompatibility to support neuronal cell adhesion. The integration CNTs electrode with flexible and biocompatible polymer is promising in the application of chronic neural stimulation and recording. The current techniques include (1) transfer of CNTs to polymer substrates or (2) direct growth of CNTs at low temperature on polymer substrates. However, the transfer process results in CNTs loss and poor adhesion. The low temperature growth leads to defective properties of CNTs. In this paper, we develop a new technique that combines a chemical vapor deposition (CVD) of parylene and xenon difluoride (XeF₂) etching in order to integrate hybrid CNT electrodes on a ultrathin (<10um) polymer substrate without the need for a transfer process or lowering the growth temperature. The CNT microelectrode arrays on a flexible polymer substrate have been tested in-vivo.

Materials and Methods: 10nm Ti/200nm Pt was deposited by e-beam evaporation on a silicon substrate coated with silicon nitride. Photolithography was used to pattern the metal, followed by a lift-off process to form electrode pads and interconnections. An array of holes was defined on Pt to serve as etching holes for the final release step. 2nm thick Fe was sputtered and patterned on top of the electrode to serve as a catalyst. CNTs were grown in a thermal CVD in a mixture of C₂H₄/NH₃ at 900°C. A 3 um thick parylene C layer was deposited by CVD, followed by an oxygen plasma etching to open etching holes. XeF₂ was used for isotropic etching of Si. The device was suspended because of the undercut of silicon. A second layer of parylene layer (~5um) was then grown to seal the etching holes. Finally the device was carefully removed from the Si substrate.

Results and Discussion: Fig 1(a) demonstrates the flexibility of the device, which could be bent easily with tweezers. Fig 1(b) is the SEM image of the electrode. CNTs were grown densely in the defined electrode area. The flexible CNT electrodes were employed to record the action potential of dorsal root ganglia neurons of rats. The flexible substrate made it easy for the electrodes to cover the surfaces of tissue for neural recording. Fig 2 shows the signals of neural firing. Integrating CNTs with flexible substrate also reduced electrode impedance and increased the charge transfer capacity.



Conclusions: A new technique was developed to integrate an ultrathin CNTs microelectrode array with flexible and biocompatible parylene C. We are in progress of testing the flexible electrodes in chronic neural recording and stimulation.