Dielectrophoretic assembly of carbon nanotube devices

The purpose of this project has been to assemble single-walled carbon nanotubes on electrodes at the tip of a biocompatible cantilever and use these for chemical species sensing in air and liquid, for example in order to measure the local activity from ion channels in the cell membrane. The electrical resistance of carbon nanotubes has been shown to be extremely sensitive to gas molecules. Dielectrophoresis is a method capable of quickly attracting nanotubes on microelectrodes by using an electric field, thus enabling nanotube integration in microsystems. Dielectrophoresis offers also the potential of distinguishing between nanotubes of different electrical properties, which is very important for the optimisation of the properties of the carbon nanotube sensors. Various cantilever and planar structures were designed, fabricated and tested both with multi-walled and single-walled carbon nanotubes dispersed in a number of different liquids. As a result of these test experiments a cantilever probe was designed specifically for the dielectrophoretic assembly of carbon nanotubes and a prototype was fabricated in the MIC (now Danchip) cleanroom. The prototype is not yet fully operational. A model for the dielectrophoretic assembly of carbon nanotubes on microelectrodes was developed and several simulations were conducted using values from the available literature for the various key parameters. The model can give qualitative results regarding the parameters dominating the dielectrophoretic process and assist in the design of future experiments. Based on the literature and the simulation results, several of the parameters governing the dielectrophoretic assembly of carbon nanotubes were investigated and the results generally agree with the theory. During heating and cooling of the nanotube networks their resistance changes following a pattern that could be explained by oxygen desorption and adsorption. Moreover, the resistance of the networks is generally unstable, which could indicate that the networks are responding to normal changes in the environmental conditions. The response of the assembled carbon nanotube networks to heat, nitrogen, humidity and light was also investigated and the results point once again to oxygen desorption and adsorption as important factors in determining the conductance of a nanotube. Finally an attempt was made to sort carbon nanotubes into metallic and semiconducting. Raman spectra taken from samples assembled at different frequencies directly contradicted theoretical predictions as well as previously published experimental results.