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Insulated Gate Field Effect Transistors For Biomedical Applications

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INTRODUCTION

Networks of neurons producing meaningful patterns of neural activity leads to behaviour in an organism. Neurons in culture reorganize themselves into two-dimensional networks whose activity can change over time spontaneously or as a result of chemical or physical stimuli. The neurons in culture are a promising tool for the study of the auto-organization properties of populations of neurons under controlled physiochemical conditions. Networks of neurons in culture can be considered to be new rudimentary biological systems. Solid state microelectronic technology can be utilized to design and fabricate a chip which would allow the user to simulate a living neural network and observe the induced effects by various biologically meaningful synaptic contacts on the living neural network.

This abstract describes the design, fabrication and investigation of the Insulated Gate Field Effect Transistors (IGFET) for biomedical applications. This included the effects of sodium [Na+], hydrogen [H+] ion concentration and the interaction of Leech neurons with the IGFET. An IGFET fabrication process using 4 masks was designed using AutoCAD was developed. N-channel IGFETs with dimensions (L x W) 5 um x 100 um, 10 um x 100 um, 16 um x 30 um and 20 um x 100um were fabricated.

EXPERIMENTAL

A protocol for the isolation of neurons from the ganglia of the leech hirudo medicinalis was developed. The medicinal leech, *Hirudo Medicinalis*, obtained from Leeches USA. Anaesthetized leeches were dissected under a stereo microscope. Exposed ganglia were isolated in pairs and placed in supplemented L-15 medium. The ganglia were opened using a fine forceps. The cells were centrifuged and re-suspended in Leech Ringer for testing.

Current Voltage characteristics were investigated for all devices using a salt bridge reference electrode (Ag/AgCl electrode with 3 M KCl solution) as the gate electrode. The contact pads for the source and drain of the IGFETs where bonded to gold wires using a conductive epoxy and encapsulated using Sylgard. The fabricated devices had their gate regions exposed to NaCl solution of decreasing concentrations. In addition the devices were exposed to Leech Ringer solution of increasing pH in addition to standard pH buffer solutions, Dubelcco's Modified Eagle Medium (DMEM) and Leibovitz's L-15 medium. The current voltage characteristics of the IGFETs were investigated to study the influence of leech neurons on the transistors.

RESULTS

The drain current of the IGFETs was found to decrease with increasing pH [H+] concentration. The drain current of the 10 um x 100 um IGFET was found to decrease by 22.75 uA (pH buffer solutions), 13.75 uA (DMEM) and 12.5 uA (L-15 medium) per decade of [H+] concentration.

The drain current of the 10 um x 100 um IGFET was found to decrease by 28.5 uA (Leech Ringer) per decade of [H+] concentration. For an applied drain source voltage (Vds) from 0 V to 5V the drain current of the 16 um x 30 um IGFET was found to vary from 0 uA to 199 uA at an applied gate voltage (Vgs) of 2 V in Leech Ringer solution (pH = 7.4). In the presence of freshly isolated leech neurons in Leech Ringer solution (pH=7.4) the drain current (Ids) of the 16 um x 30 um IGFET varied from 0 uA to 205 uA for an applied drain source voltage (Vds) from 0 V to 5 V. A kink was observed in the drain current curve at Vds = 3.0 V. The I-V curve for the Leech Neurons @ V_{GS} = 2 V is shown in Figure 1.

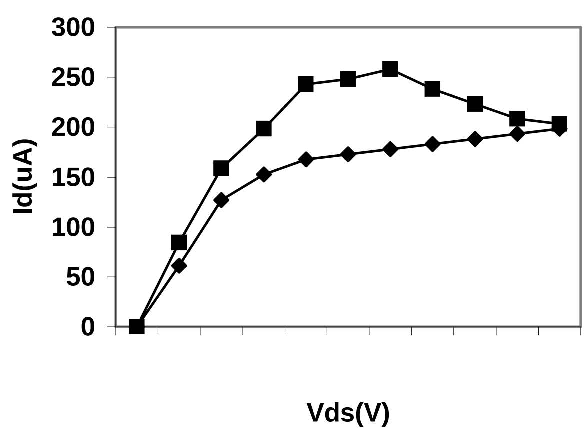

Figure 1

CONCLUSIONS

Solid state microelectronic technology can be utilized to design and fabricate a chip, which would allow the user to study a living neural network. The current voltage characteristics may provide a method of estimating the electrical properties of the Leech Neurons located on the gate electrode of the IGFETs. The material on the gate of an IGFET affects its electrical properties such as the threshold voltage, current voltage characteristics through the influence of electric charge and thus the electric field on the gate electrode. The observed electrical phenomena suggest that IGFETs may be useful as bioelectronic devices for the study of living neural networks.