Cyborg insects, neural interfaces and other things:

building interfaces between the synthetic and the multicellular

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INTRODUCTION

AS the computation and communication circuits we build radically miniaturize (i.e. become so low power that 1 pJ is sufficient to bang out a bit of information over a wireless transceiver; become so small that 500 μm^2 of thinned CMOS can hold a reasonable sensor front-end and digital engine), the barrier to introducing all sorts of interfaces and control loops into organisms will lower radically. Put another way, the rapid pace of computation and communication miniaturization is swiftly blurring the line between the technological base that created us and the technological based we've created. This talk will provide an overview of recent work in the Maharbiz lab that touches on this concern. Some of this will cover our ongoing exploration of the remote control of insects in free flight via implantable radio-equipped miniature neural stimulating systems and more recent work in next generation mammalian neural interfaces for brain machine interface (BMI) applications.

MATERIALS AND METHODS

We have recently demonstrated a number of miniaturized neural interfaces and systems. We demonstrated the first example of the remote control of insects in free flight via an implantable radio-equipped miniature neural stimulating system [1-4]. The pronotum mounted system consisted of neural stimulators, muscular stimulators, a radio transceiver-equipped microcontroller and a microbattery. Subsequently, we have focused on systems for interfacing to insect sensory organs [7]; I will present this and newer developments.

More recently, we've demonstrated flexible multielectrode arrays for applications ranging from high density electrophysiology on insect sensory organs [7] to mammalian microelectrocorticography [5-6]. These designs include flexible 256-electrode arrays for micro-electrocorticography (µECoG) with an electrode pitch of 500 µm. Our µECoG grid is a flexible five-layer parylene MEMS device (two layers of platinum insulated by three layers of parylene) featuring plasma-etched vias and a monolithically integrated parylene cable which is compression-bonded to a fan-out board using anisotropic conductive film (ACF) technology. Additionally, indium tin oxide (ITO) µECoG's were developed for use in simultaneous neural recording and optical interfacing/imaging [5]. Lastly, I will discuss more recent work on high density implantable neural probes.

RESULTS

In the original demonstration of insect flight control [2,4], flight initiation, cessation and elevation control were accomplished through neural stimulus of the brain which elicited, suppressed or modulated wing oscillation. Turns were triggered through the direct muscular stimulus of either of the basalar muscles. We characterized the response times, success rates, and free-flight trajectories elicited by our neural control systems in remotely controlled beetles.

We will present data on device characterization by electrochemical impedance spectroscopy in artificial cerebrospinal fluid (aCSF), recorded acoustic evoked potentials in vivo from the rat primary auditory cortex, optogenetic stimulation during µECoG recording and our latest work in implantable probes.

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