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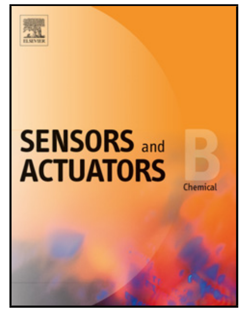

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Authors: Á.C. Horváth, Ö.C. Boros, S. Beleznai, Ö. Sepsi, P. Koppa, Z. Fekete

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A multimodal microtool for spatially controlled infrared neural stimulation in the deep brain tissue

Á C Horváth[1,2,3], Ö C Boros[4], S Beleznai[4], Ö Sepsi[4], P Koppa[4], Z Fekete[1,2*]

[1] Research Group for Implantable Microsystems, Faculty of Information Technology & Bionics, Pázmány Péter Catholic University, Budapest, Hungary
[2] Insitute for Technical Physics & Material Science, Centre for Energy Research, Hungarian Academy of Science, Budapest, Hungary
[3] Óbuda University Doctoral School on Materials Sciences and Technologies, Budapest, Hungary
[4] Department of Atomic Physics, Budapest University of Technology & Economics, Budapest, Hungary

Abstract

Infrared neural stimulation (INS) uses pulsed mid-infrared light to generate highly controlled temperature transients in neurons, leading them to fire action potentials. Stimulation of the superficial layer of the intact brain has been demonstrated, however, intervention in the deep neural tissue has larger potential in view of therapeutic use. To reveal the underlying mechanism of deep tissue stimulation properly, we present the design, the fabrication scheme and functional testing of a novel, multimodal optrode for future INS experiments in vivo. Three modalities – electrophysiological recording, thermal measurement and delivery of infrared light – were integrated using silicon MEMS technology. The average overall efficiency of the microoptical system delivering the infrared light at chip-scale is measured as 32.04 ± 4.10 %, while the max. efficiency in packaged form is 41.5 ± 3.29 %. The average beam spot size at the probe tip is 0.024 ± 0.006 mm^2. The temperature coefficient of resistance of the integrated thermal sensor monitoring the change in background temperature is 2636 ± 75 ppm/°C. The average impedance of the electrophysiological recording sites is 1031 ± 95 kΩ. Based on beam profile measurements and multiphysical modeling, the spatial extent of the thermally excited region and its temporal dynamics are estimated in case of both low (30 mW) and high (3 W) power excitation. Due to the monolithically integrated functionalities, a single probe is sufficient to determine safe stimulation parameters in vivo. As far as we know, this is the first planar, multimodal optrode designed for INS studies in the deep tissue.

Keywords: neural stimulation, infrared waveguide, optrode, silicon microelectrode

*Corresponding author. fekete.zoltan@itk.ppke.hu