Miniaturized Energy-Efficient Integrated Neural Interface

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***Abstract**:* Despite tremendous progress over the years, current brain-machine interface (BMI) systems are relatively bulky, highly invasive, and limited in their effectiveness except for highly constrained tasks such as moving a cursor on a computer screen. Applications of BMI to continuous monitoring and closed-loop treatment of neurological disorders have been relatively scant to date. To improve performance and clinical impact of current BMI systems, it is necessary to dramatically increase spatial resolution and coverage across the brain without constraining the mobility of the patient. This calls for innovative approaches to high-density integrated neural recording and stimulation using non-invasive or minimally invasive microelectrode and custom silicon integrated circuits at extreme energy and area efficiency.

To this end, my research aims at neurotechnology development and biomedical applications of energy-efficient fully integrated miniaturized implants for electrocortical recording and stimulation, and unobtrusive body-area networks systems for subcutaneous power delivery and data communication, as fundamental building blocks to next generation clinical-grade BMI. I will present a fully custom-integrated, fully wireless, encapsulated neural interface and acquisition chip (ENIAC) that condenses all functions of 16-channel neural recording and stimulation including integrated 4x4 electrode array, coil antenna, and wireless power transfer and data telemetry onto a completely self-contained silicon microcircuit confined within $3mm^3$ volume, suitable for minimally invasive surgical insertion as a versatile module on the cortical surface that can be tiled for high spatial resolution and wide coverage of recording and modulation of electrocorticography (ECoG) signals wirelessly transmitted through the skull. I will further highlight related work on an alternative approach to covering the cortical surface at sub-millimeter resolution in neural recording, offering record noise-energy efficiency and integration density in electrical recording and acquisition, with 16 channels integrated on a $1mm^2$ system-on-chip at 92 dB input dynamic range and $<1\mu$Vrms input-referred noise covering DC-500Hz signal bandwidth at 0.8μW power consumption per channel. Validation with *in vivo* recordings in frontal cortex of marmoset primates reveals infra-slow (<0.1 Hz) local-field potentials (LFP) indicative of subject arousal during a visual attention task alternating with periods of rest and feeding. Finally, I will present advances in systems-on-chip solutions for simultaneous high-efficiency wireless power delivery and data telemetry over a single inductive link, as well as space-aware transceivers for ultra-low power wireless non-line-of-sight body-area network communication, that support live streaming of thousands of recorded channels of electrocortical neural data. These technology advances combine to support further developments towards modular wireless, minimally invasive, whole-brain electrocortical recording and modulation at near-cellular resolution, and their application to electroceutical remediation of neurological disorders.

***Biography**:* Chul Kim is an assistant professor at the department of Bio and Brain Engineering and the program of Brain and Cognitive Engineering in KAIST, South Korea. He received the Ph.D. degree in 2017 from Bioengineering, UC San Diego, La Jolla, CA, USA. From 2009 to 2012, he was with SK HYNIX, Icheon, South Korea. Dr. Kim received Gold Prize in the 16th Human-Tech Thesis Prize Contest from Samsung Electronics, Suwon, South Korea, in 2010, and the 2017–2018 Shunichi Usami Ph.D. Thesis Design Award from the Bioengineering Department, UC San Diego. He was the recipient of the 2017–2018 IEEE Solid-State Circuits Society Predoctoral Achievement Award.