Bio-Interface of Electron Devices

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Electron devices have fueled the revolution in computing, communication, and AI in the last 70 years. The market size in electronics in terms of gross income percentage has arguably saturated, and further revenue growth will rely on the technical innovation that can enable new domains of applications. On the other hand, our society has faced dire challenges from aging population and next pandemic, where in-depth engineering efforts have the potential to augment the present healthcare infrastructure. Unlike computing and communication markets, biological and biomedical products are much fragmented with heavy regulation. Taiwan's economics has three major pillars that excel in global competition: electronics, information and medicine. Therefore, it is both advantageous and *necessary* for electronic engineers to look deeper into technical adaptation and innovation to biomedical applications. In comparison with optical and acoustic devices, electronics has unique advantages in spatial/temporal resolution, wireless multiplexing, information handling, efficient manufacturing, and low cost. Technology fusion of all energy forms on the same CMOS platform is also possible to bring forth new capabilities.

In this survey talk, we will explore four areas where electron devices can interface with the biomedical applications, and present the inherent key advantages and critical future challenges:

(1) Coupling to internal organs and tissues: Similar to ultrasound, electromagnetic energy can be coupled to the internal organs and tissues in motion to retrieve physiological, pathological, emotional and personal features. The broad spectrum can cover the impedance, near-field, and radar operational modes. Multiple-input-multiple-output (MIMO) through mature multiplexing can readily achieve high observation diversity to achieve high-resolution recording. Reliable imaging remains very difficult due to the high dielectric complexity inside the living body.

(2) Biomolecular recognition: Biomolecules and ions can interface with CMOS through the field effect of hybridization and surface binding or through the amperical effect of local redox. Nano-scale transistors can enable single-molecule and femto-mol sensitivity, but specificity will need electronic intelligence instead of sole reliance on chemistry.

(3) Neural recording: Implanted electrode arrays with > 10,000 electrodes and > 10,000 sampling per second demands ultra-low-power signal processing in a high data bandwidth, but the recording capability remains highly invasive and far away from the brain complexity.

(4) Cure/care infrastructures: Medical care infrastructures, especially for long-term senior care, have many needs for automation to reduce the caregiver load, especially for diagnostics, living independence, and logistics where accumulation and processing of private information on vital signs and activities plays an important role.

For global sustainability, medicine, happiness, energy and environment are the four important areas that the next-generation engineers need to make continuous improvement. Especially for the next-generation electronic engineers, our past achievement can critically transition into bio-interface for medicine, human-computer interaction, long-term senior care, and so on. These forthcoming technology innovations can contribute to a better tomorrow for our society.