Ultra-thin flexible electronics and hybrid solutions for smart neural interfaces

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The cerebral cortex remains an experimental scenario with a huge level of complexity: indeed, human cortex contains approximately $5x10^4$ neurons in 1 mm^2 of space with a total number of cells that can achieves 25 billion according to the last estimation. The mechanisms by which the neural networks communicate and the understanding of these processes represent the fundamental issue of neuroscience.

Long-term brain activity registration and stimulation is a main ally to analyze and interpret data coming from the brain. In this framework, brain computer interfaces (BCIs) gather great interest for their capability of acquiring brain signals, process data and activate proper feedback. Although many efforts have been spent to obtain valuable probes to interface the brain many challenges remain unsolved in terms of local signal amplification, recording accuracy, tissue reaction, stiffness of the devices, etc.

Flexible electronics represent a unique solution to manufacture innovative and implantable BCIs that can guarantee advances brain signal sampling and closed loop tasks for people disabled by neuromuscular disorders or even to enhance specific functionalities of healthy subjects. In fact, the engineering of soft materials and the integration of ad hoc electronics in polymeric substrates can be used to create a long lasting connection between the biological world and the electronics. In particular, low Young's Modulus materials such as PDMS or ultra-thin polymer substrate like Polyimide provide a low mechanical friction, due to a softer response to the natural internal brain movement regulated by blood flow and respiration. Moreover, high charge transfer nanostructures like PEDOT composites and stable materials such as glassy carbon can guarantee high resolution and accuracy even in those less-invasive probes like the epicortical ones.

In this work, we present a bundle of technologies based on flexible electronics that enable the fabrication of ultra-compact BCIs to be used in different applications like neurorehabilitation, electrophysiology, electromyography, etc. The implantable system can be remotely powered and communicate through radio frequency to permit full operation in real life.