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Functional Materials at the Biological Interface

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The construction and function of biological tissues are based on fundamental cell functions, such as proliferation, migration, differentiation, and death. These events are responses to local and temporal stimuli where ligands (senders) and receptors (receivers) relay signals to the intracellular signaling pathways. A vision for future tissue regeneration is to precisely control and sense the cell function in both space and time. In this talk, I will discuss two approaches we have done at the Center for Functional materials to control cell functions.

As a first approach we have developed a paper-based platform for studies on basic cell culture, material biocompatibility, and activity of pharmaceuticals in order to provide a reliable, robust and low-cost cell study platform [1]. It is based upon a paper or paperboard support, with a nanostructured latex coating to provide an enhanced cell growth and sufficient barrier properties. Wetting is limited to regions of interest using a flexographically printed hydrophobic polydimethylsiloxane layer with circular non-print areas. The nanostructured coating can be substituted for another coating of interest, or the regions of interest functionalized with a material to be studied. The platform is fully up-scalable, being produced with roll-to-roll rod coating, flexographic and inkjet printing methods. Results show that the platform efficiency is comparable to multi-well plates in colorimetric assays in three separate studies: a cell culture study, a biocompatibility study, and a drug screening study.

Secondly, we have employed organic bioelectronics using electrically responsive surfaces as an active way of controlling cell functions. We have chosen to work with the Notch signaling pathway, which is crucially involved in coordinating different cardiogenic processes [2]. Recent in vivo studies suggest that the Notch signaling pathway has a pivotal role in cardiac development and defects [3].

Our recent efforts to employ charged peptides mimicking Notch ligands anchored on the surface of the biofunctionalized electrode will be discussed. The conformation of Notch-mimetic peptides will switch from non-bonding (OFF) to binding (ON) conformation by applying a voltage to the electrode surface [4]. We have used the underwater contact angle to measure changes in the wetting property of a dichloromethane droplet under electrical stimuli. The observed changes can be understood as changes in the surface energy between the ON and OFF states. Molecular dynamics simulations in an electric field have been performed to verify the hypothesis of the orientational change of the charged peptides upon electrical stimulation.

In order to sense ligand-receptor interactions, we have developed a label-free and ultra-sensitive organic electrolyte gated transistor-based (EGOFET) sensor. We demonstrated the ability to sense even small changes by detecting dephosphorylated charged peptides among similar phosphorylated peptides at the physical limit [5].

References

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