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Materials at the Biological and Nanotechnology Interface

Materials at the biological and nanotechnology interface are at in interesting intersection of materials science, bioengineering, and informatics. Materials at this interface are essential in integrating biological systems with man-made materials including implants, prosthetics, and biosensors. When these man-made materials can properly interface with biological tissue, they allow for the improvement or fixing of a suboptimal or failed biological system. Production of materials at this interface must be handled from both a man-made and a biological context. For example, certain biosensors utilize a graphene field effect transistor. When target biological molecules bind to the graphene, the conductivity of the FET changes[1]. This change can be very accurately measured, and thus the presence of these target molecules can be assessed. In a different vein, implants into human tissue need to be able to integrate seamlessly, without risk of infection. Such seamless integration requires the implant to not trigger an immune response, which is only possible through the correct use materials at the bio / nano interface. These are only a couple of the many applications of materials at this interface, and continued engineering here will open new doors of innovation of man-made materials in biological systems.

Because biological systems can be so delicate, materials with very specific properties must be used. To cite some recent research at GEMSEC at UW, both graphene and the peptides that bind to it are very specifically chosen based on their electrical and biological properties. Measuring a material's efficacy in these metrics is a bit of a departure from the traditional material science metrics of density, shear weight, and tensile strength, but this specific application of material science put the focus on these properties. Unlike traditional silicon MOSFETs, the graphene layer in GFETs is only one carbon atom thick, which puts the entire

[1] Spasenovic, Marko. "Graphene Biosensors." *Graphenea*, 14 July 2018, https://www.graphenea.com/blogs/graphene-news/51855425-graphene-biosensors.

conductive channel right at the surface. This exposes all conductive material to any molecules present. Such molecules, like peptides specifically chosen through phage display to bind to the graphene, have electrical effects on the graphene[2]. The two-dimensional nature of the graphene gives the FET an increased sensitivity to changes in its electrical characteristics. This makes graphene FETs very useful in applications where detection of subtle changes is necessary, like the detection of varying patterns of peptide self-assembly on the surface of graphene.

One of the reasons that progress at the bio / nano interface is slow is because of the great variation in the biological systems into which human-engineered technologies must be integrated. This is one area of focus where computer science and informatics comes into play. While the selection of peptides through phage display in the aforementioned applications is useful, it is not as efficient as predictive analytics could be. To produce materials that properly interface with the molecules in a biological system, it would be very useful to have these materials work on a case by case basis. Specifically designing materials to work with individuals optimizes their efficacy, and using computational tools like artificial intelligence would allow engineers to predict which sequences and structures of peptides would optimally work in which cases. The future of medicine is in analytically driven tailoring of treatment, and at the bio / nano interface, material science, bioengineering, and informatics are coming together to drive the next generation of medical and nanotechnological innovation.

[2] Hayamizu, Y., So, C., Dag, S. *et al.* Bioelectronic interfaces by spontaneously organized peptides on 2D atomic single layer materials. *Sci Rep* **6,** 33778 (2016) doi:10.1038/srep33778