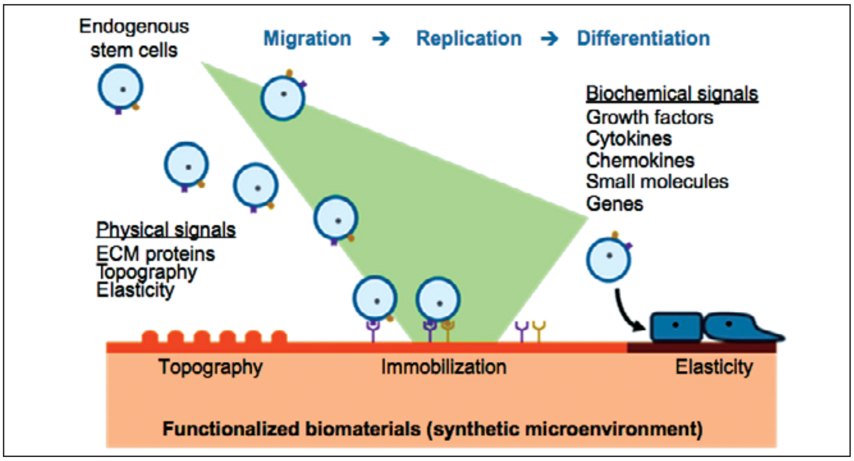
An ideal tissue-sculpting biomaterial would be able to mimic natural environmental niches that can coax stem cells into an appropriate series of responses along their tissue formation trajectory. These responses include adhesion, migration, proliferation, and differentiation (see Figure). In practice, designing the right environment is highly challenging, as native niches exhibit chemical, biological, and mechanical elements (e.g., small-molecule growth factors, signaling proteins, and extracellular matrix polymers) that contribute in concerted ways to direct stem cell fate. Progress, however, is being made, and Chandra and Lee survey this progressive research landscape.

Specifically, Chandra and Lee's review overviews and analyzes the results from more than 90 studies in which synthetic biomaterials have been applied to influence stem cell behavior. The authors discuss the roles of salient properties that affect a biomaterial's performance as an artificial niche, including biocompatibility, drug release behavior, mechanical elasticity, surface chemistry, and surface topography. Current favored materials show promise, but require further optimization. For example, electrospun polymers—such as poly(lactic-*co*-glycolide)—can be fabricated with tunable growth factor release kinetics, but the nanoscale morphological features of such materials are difficult to control reliably (thus hampering simultaneous control over the role of surface topography on stem cell response).



Schematic illustration of interactions between endogenous stem cells and synthetic microenvironment. Stem cells' fate in a particular microenvironment is regulated by intricate reciprocal molecular interactions with its surroundings. Credit: *Biomarker Insights*.

Due to the extensive combinatorial factors that influence stem cell proliferation and differentiation, the authors call for increased high throughput and computational studies as the field works toward a better understanding of extracellular matrix signals and their roles in controlling stem cell fate. However, despite the many lessons that remain ahead, the union of stem cells and engineered biomaterials holds great promise. Chandra and Lee emphasize this fact as they close their report by highlighting a variety of biomaterial-cell products that are currently under clinical development.

Lukmaan Bawazer

Nano Focus

Large-scale graphene gas barrier sets new record

Graphene has been widely heralded as a revolutionary material for making thin barrier membranes among various other applications, but the experimental realization of graphene as a gas barrier has been limited. Although many research articles make reference to graphene's high barrier capabilities, very few experimental studies have verified this. "Everyone talks about it [graphene barriers], and nobody really questions the result. However, when you try to do it on a large scale, it doesn't really work at all," says researcher Christian Wirtz of Trinity College. That is, until now.

A recent article from Georg Duesberg's (Trinity College) laboratory, of which Wirtz is lead author, describes a novel large-scale graphene barrier that outperforms previously reported graphene barriers by a factor of 5000. The work is published in *Advanced Materials Interfaces* (DOI:10.1002/admi.201500082). Duesberg, Wirtz, and colleague Nina Berner (Trinity College) describe a highly effective oxygen gas barrier using stacks of chemical-vapor-deposited (CVD) graphene. A stack of three graphene layers (~5 cm^2 surface area) transmitted just 1.10×10^{-17} cm^3 cm/cm^2 s (cm Hg) of oxygen, or 1.1×10^{-7} barrer, which is on par with most modern barriers, such as AlO_x or SiO_x. The oxygen and moisture barrier properties of graphene, coupled with its size and high conductivity, make it an ideal candidate for a wide variety of applications, including flexible electronic displays and microelectronics packaging.

The graphene barrier was prepared by stacking CVD-grown graphene onto a 150-µm polyethylene terephthalate (PET) substrate, a food packaging polymer that is known for good barrier properties. Unfortunately, "current CVD methods always have grain boundaries [defects] that give way to diffusion," Wirtz says. "We tried with just monolayer graphene and there was no improvement whatsoever. Then we started stacking it the right way. We got improvement, which was very exciting." The best barrier results came from a stack of three layers of CVD graphene, as shown in the graph.

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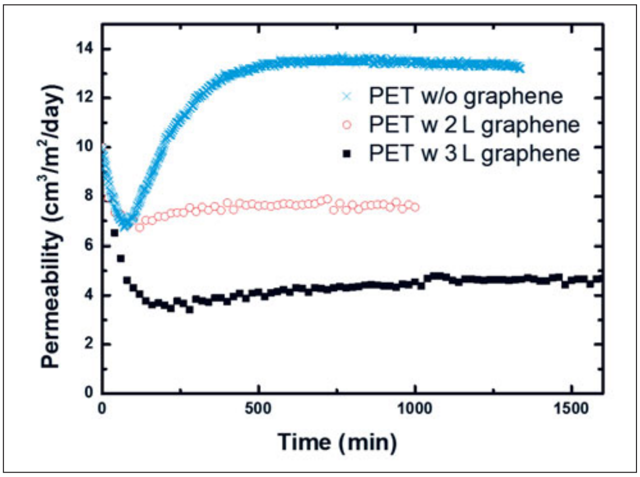
The researchers also introduced a modified polymer-assisted transfer method for transferring large-area (~5 cm^2) CVD graphene from its metallic growth substrate to the PET support used in this study. The conventional transfer method used by many groups leaves 1–2 nm of polymer residue on the surface of graphene, which dominates the oxygen diffusion pathway between stacks of graphene layers. The modified method, however, does not leave polymer residue on the graphene flakes, allowing airtight stacking of graphene sheets. The researchers point out a remarkable difference in oxygen permeability when comparing stacks of graphene prepared using each method, revealing that polymer residue acts as a diffusion pathway between stacked graphene layers.

Ho Bum Park (Hanyang University), an expert in graphene barriers who was not involved in this work, comments, "The importance of this work is the fact that they revisited the issue of how we can make oxygen- (or maybe water-) barriers by using large-area CVD graphene. The current modified transfer method they showed here is not perfect and should still be improved, but this work provides an insight into the importance of polymer residue-free CVD graphene transfer to achieve good oxygen-barrier graphene."



Oxygen permeability through 5 cm^2 chemical-vapor-deposited graphene barriers. Monolayer graphene is not shown because it did not enhance the permeability of the underlying polyethylene terephthalate substrate (PET). Photo courtesy of Christian Wirtz.

If perfected, a large-area, thin graphene barrier offers a set of properties unlike any other modern barrier material, including high electronic conductivity, optical transparency, and biocompatibility. Although this work only tested a maximum area of 5 cm^2, the limiting factor for scale-up is simply time and money, as CVD growth already enables roll-to-roll production of large-area graphene. With improved scale-up of the modified transfer method, graphene will be able to compete with modern barrier systems used in micro- and nanoelectronics.

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