eSkin Energy Minimization via Multi-Scalar Architectures: From Cell Contractility to Sensing Materials to Adaptive Building Skins

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How might architecture respond to issues of ecology and sustainability whereby buildings behave more like organisms in their built environments? What role do humans play in response to changing conditions within the built environment? We are interested in probing the human body for design models that give rise to new ways of thinking about issues of adaptation, change and performance in architecture. The eSkin project starts with these fundamental questions and modes of design thinking, and applies them towards the design and engineering of passively responsive materials, and sensors and imagers. The goal of the eSkin project is to explore materiality from nano- to macroscales based upon understanding of non-linear, dynamic human cell behaviors on geometrically defined substrates. In contrast to a purely technical solution to problems of sustainability, we are specifically interested in the role of the human in response to changing conditions within the built environment using minimal energy consumption.

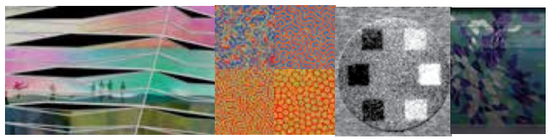
Buildings in the U.S. alone account for nearly 40% of the total national energy consumption. Therefore, the design and production of new energy efficient technologies is crucial to successfully meet goals such as the Net-Zero Energy Commercial Building Initiative put forward by the U.S. Department of Energy, which aims to achieve zero-energy commercial buildings by 2025. LEED (Leadership in Energy and Environmental Design) is a rating system launched by the U.S. Green Building Council for new construction and existing building renovations. The LEED green building certification program is the industry standard for accelerating global adoption of sustainable green building and development practices. While this certification program serves as a positive and productive report card for assessing a building's impact upon its environment, it ultimately enforces a short-term 'check box' mentality over long term and systemic ecological design thinking. Ecological design thinking requires a radical departure from traditional research and design models in architecture, art and science with a move towards hybrid, trans-disciplinary concepts and models for collaborating. Although there have been tremendous innovations in design, material sciences, bio- and information technologies, direct interactions and collaborations between scientists and architects are rare. All of this is regardless of the fact that science, engineering, and architecture all share the need to comprehend key social, environmental and technological issues. One approach is to couple architectural designers with engineers and biologists within a research-based laboratory-studio in order to develop new ways of thinking, seeing and doing in each of our fields.

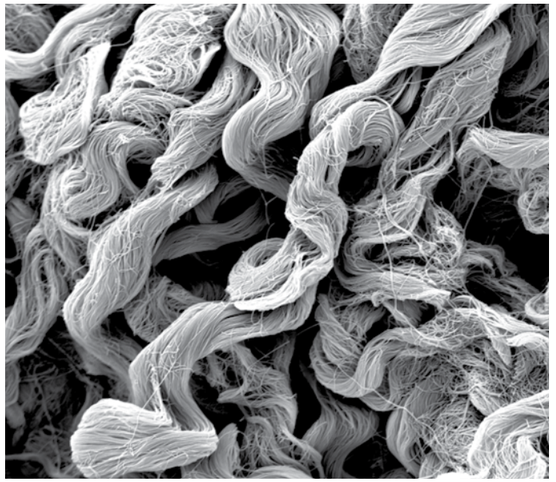
Since the official public launch in the fall of 2010 of our National Science Foundation (NSF) Emerging Frontiers in Research and Innovation (EFRI) Science in Energy and Environmental Design (SEED) project titled, Energy Minimization via Multi-Scalar Architectures: From Cell Contractility to Sensing Materials to Adaptive Building Skins, Jenny Sabin (Co-PI) along with Andrew Lucia (Senior Personnel) have led a team of architects, graduate architecture students and researchers in the investigation of biologically-informed design through the visualization of complex data sets, digital fabrication and the production of experimental material systems for prototype speculations of adaptive building skins, designated eSkin, at the macro-building scale. The full team, led by Dr. Shu Yang (PI), is actively engaged in rigorous scientific research at the core of ecological building materials and design. Our project contributes to an area within architecture called adaptive architecture while also presenting a unique avant-garde model for sustainable design via the fusion of the architectural design studio with laboratory-based scientific research.

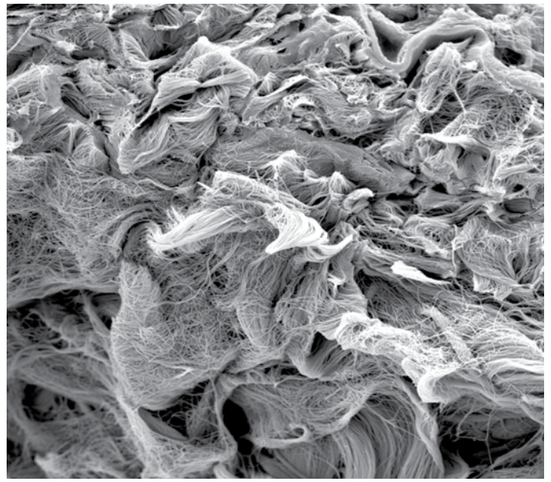
Our emphasis rests heavily upon the study of natural and artificial ecology and design, especially in observing how cells interacting with pre-designed geometric patterns alter these patterns to generate new surface effects. These tools and modes of design thinking, are then applied towards the design and engineering of passively responsive materials, and sensors and imagers. Our role as architects, involves generating tools to visualize and simulate cell attraction forces and cell behavior such as forces distributed via a virtual extracellular matrix environment, over multiple time-states while also incorporating micro-scale material constraints. Beyond visualization, we also direct the architectural intent of the project by constantly speculating on how results at the nano and micro-level will potentially look, feel, and assemble at a building scale. Based upon these nonlinear and dynamic responses that human cells generate, we are redesigning and re-engineering interfaces between living and engineered systems with the ultimate goal of implementing some of the key features and functions revealed by cells on a chip for sensing and control at the building scale.

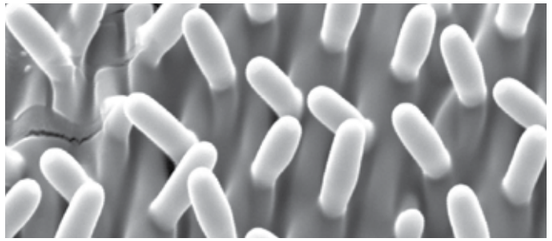
Comprised of a field of low cost sensors and passively responsive materials, eSkin is conceived to be generic and homogenously structured upon installation (i.e. laden with the full potential) but readily adaptable to local heterogeneous spatiotemporal conditions, thereby reducing the overall functioning demands upon it and ultimately lowering overall energy consumption. In this regard a "learning" and adaptive second skin would forgo the need for lengthy, costly, and one-time site analysis relegating ever changing environmental analysis and response of the local and global spatiotemporal environments to its own internal/local functionality. This manner of operation not only maximizes immediate performative efficiency, but also allows for ongoing contextual adaptation.

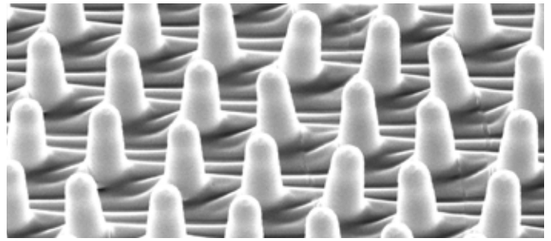
The synergistic, bottom-up approach across diverse disciplines, including cell-matrix biology, materials science & engineering, electrical & systems engineering, and architecture brings about a new paradigm to construct intelligent and sustainable building skins that engage users at an aesthetic level with minimal energy consumption. eSkin cultivates active ecologies from the micro to the macro, where code, context, matter, geometry and perception are integrated into responsive material systems. eSkin is also about breaking pedagogical boundaries through shared collaborations in design and science to generate context-driven tools, models and modes of 'seeing' within an ever-increasing information context. We hope that our interdisciplinary work and modes of ecological design thinking not only redefine definitions of research and design, but will also address pressing topics in each of our fields concerning key social, environmental and technological issues that ultimately impact all humans in our built environments.



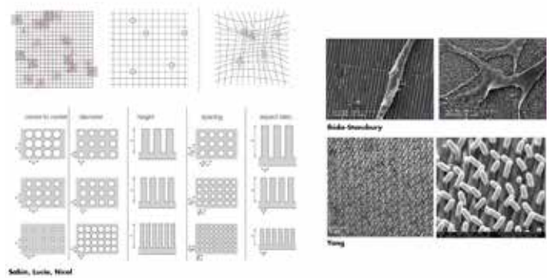








Bio-inspired Substrates: Passively Responsive Material Systems



Contextual Analysis and Computational Design
Schematic Framework