2012 EFRI Topics

1) Flexible Bioelectronics Systems (BioFlex)

Key Idea: Explore the fundamental science and engineering necessary to integrate new materials, sensors, electronic circuits, and devices for the development of biomedical technologies. With the spread of electronic functionality everywhere and the emergence of new materials systems, device architectures, and fabrication processes to create new types of electronic circuits, there is a trend towards designing electronic circuits and systems on flexible substrates: Flexible Hybrid Electronics. At the heart of this trend is the functional integration of many types of materials – inorganic, organic, and biological materials. Such integration permits new functionality and enhanced performance relative to currently existing devices.

The focus of this EFRI topic will be on the fundamental science and engineering that is required for developing biomedical technologies using flexible electronics. This EFRI topic will identify the fundamental science challenges related to electronic materials, biomaterials, sensor technologies, devices systems, and systems integration. The knowledge generated in researching development of such sensors for biomedical applications is applicable to sensors for all kinds of other applications such as structural, infrastructure, homeland security etc. Some examples of applications that could have huge impact include smart bandage for wound healing/monitoring/treatment, sensors for monitoring of people with Alzheimer's, monitoring of elderly people who are otherwise healthy, ophthalmic sensors for monitoring of retinopathy caused by pre-diabetic conditions, and sensors for detection and possibly drug delivery for skin conditions. Other areas where BioFlex can have huge impact include in-vivo sensors for mapping of electrical activities of brain and heart as well as implantable neural prostheses. Applications also exist for neonatal patients and pregnant women. The major advantage of flexible electronics sensors is that the sensors are lightweight, bendable, conformal, potentially disposable, relatively low cost, and useful for in-vivo and ex-vivo applications. The program would strongly encourage formation of interdisciplinary teams comprising of chemical, manufacturing, electrical engineers along with materials scientists. The participation of small businesses will be encouraged.

2) Origami Design for the Integration of Self-assembling Systems for Engineering Innovation (ODISSEI)

Key Idea: Identify and address the gaps in current knowledge that present obstacles to the application of origami to enable folding across scales for design of engineered systems such as materials, compliant mechanisms with fewer and foldable parts, and structures. Application opportunities include manufacturing, biotechnology, energy, complex engineered systems, and other areas of national priority.

Adaptive Morphing Systems (AMS) are self-assembling, multifunctional, compliant structures that are enabled through the integration of active materials, design theory, compliant

mechanisms, mathematics, and artistic expression. Fundamental understanding of how materials at different scales can be designed to be folded and unfolded through matter reorientation at creases and the relation of such folding to self-assembly can transform present design and manufacturing practice. In this context, there are intriguing opportunities to explore nonlinearities and time or rate-dependency for folding/unfolding mechanisms in micro- and macro-scales, which can be integrated with associated scaling laws. Understanding the key factors contributing to structural compliance and its interaction to material properties provides numerous research challenges (e.g. through the use of tensegrity structures or any other basic concepts or constructs). In order to rigorously design products with fewer and foldable parts, an understanding of the mathematical challenges and uncertainties associated with creases and folds must be achieved and modeled at different scales and, as appropriate, across scales. Insights from origami mathematics, artistic expression, topology optimization and complex systems will provide inspiration for AMS.

3) Photosynthetic Biorefineries (PhotoBio)

Key Idea: Establish the scaling and control principles which unify molecular, cellular, and bio-manufacturing processes to efficiently deliver light and carbon dioxide to photosynthetic microorganisms in scalable cultivation platforms, coupled to the engineering of primary and secondary metabolic processes that harness photosynthesis to flexibly generate complex and/or energy-dense molecules (biofuels, commodity and specialty chemicals, and bio-products), taking into consideration the environmental and life cycle impacts of these processes.

Achieving the sustainable production of chemicals and transportation fuels will be one of the grand challenges of the 21st century. Towards this end, one route is to harness the unique biocatalytic capacities of phototropic microorganisms that use sunlight as the energy source to convert atmospheric CO_2 and water into complex and/or energy-dense compounds, including biofuels, commodity or specialty chemicals, or bio-products. Upscaling these photobiological processes is a multi-scale systems challenge that embraces the fundamentals of biology, chemistry, and engineering. The scaling and control principles that unify molecular, cellular, and bio-manufacturing processes underlying the efficient delivery of light and carbon dioxide to photosynthetic organisms in scalable cultivation systems are poorly understood, and there is no theoretical framework to support the rational development of this emerging technology. Furthermore, novel molecular and bioprocess strategies are needed to tailor primary and secondary pathways that harness photosynthesis to flexibly make complex and/or energy-dense compounds, and facilitate their separation. Finally, new approaches to the management and control of large-scale bio-manufacturing processes that utilize sunlight as a primary energy source, combined with the assessment of the environmental, ecological, and life cycle impacts of these processes, are needed to synergistically advance the science of sustainable bio-manufacturing processes that will enable the photosynthetic bio-refineries of the future bio-economy.