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Inherently Adaptive Structural Systems

We propose to develop bio-inspired structural systems capable of adapting to altering and unpredictable service environments. Structural biomaterials such as bones, shells and teeth occur as composite materials with outstanding properties embraced by a complex structure which evolves in response to external stimuli. Conventional composite processing schemes cannot reproduce the exquisite ultra-structure of biomaterials. In an approach inspired by the development of bone structure, we propose to use a high-performance cellular (e.g., micro-cellular carbon) structure as the framework for controlled deposition of various structural and functional mono-layers in an aqueous processing environment. We will employ the ionically self-assembled mono-layer (ISAM) technique to develop a complex, multi-layer architecture with detailed molecular level control over its composition and micro-structure. The functional layers built into the system convert the mechanical energy input of service environment to electrical energy by employing either the piezoelectric effect to generate electrolytic cells or the stress-induced phase transformation to generate galvanic cells. These cells drive electrolysis processes within a solid electrolyte which eliminate locally elevated stresses by mobilizing finite material resources to best meet the structural demands of altering and unpredictable service environments. Besides novel self-adaptation qualities, our envisioned system also offers major advantages in terms of structural efficiency, economy and geometric/compositional versatility, and provides tremendous control over the load paths within the system at local and global levels, with material resources strategically positioned along these paths for optimum structural performance. The proposed Phase I research will verify the viability of our approach towards development of efficient structural systems with intrinsic adaptation attributes. We will accomplish the following objectives in Phase I research: (1) develop design methodologies for hybrid, multi-layer systems of high structural efficiency with intrinsic adaptation qualities which are amenable to ISAM processing; (2) establish processing schemes for building the hybrid, multi-layer architecture into an open-cell foam structure; and (3) experimentally verify the structural and self-adaptation features of the new system, and assess the prospects of the technology emphasizing development of autonomous and evolvable structures which perform optimally during long periods in unknown harsh and/or changing environments. Technova Corporation will join forces with Michigan State University (Composite Materials and Structures Center), Auburn University, Dupont and Airmar Technology to implement the proposed project.