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Inherently Adaptive Structural Systems

Novel material compositions and architectures, enabled by recent advances in nano-technology, are employed towards development of structural systems with inherent self-healing and adaptive qualities. The new system mimics the simple, but powerful, control mechanism of the skeletal system to eliminate stress gradients and concentrations, yielding a normalized stress distribution which makes optimum use of available structural materials. This biomimetic system converts the input mechanical energy of service loads to electrical energy. The resulting electrical potential guides adaptive phenomena which relieve critical stress conditions within the system. Implementation of this strategy in the context of our material system involves: (1) generation of electric potentials in response to stress gradients; and (2) redistribution of material resources through electrolysis processes (within solid electrolyte) driven and guided by the generated electrical energy. The process is self-controlling and terminates when the stress gradient/concentration and thus the generated electric potential diminish; this occurs when concentration of mass along optimum load paths is completed. The structural embodiment of these adaptive principles comprises hybrid structural/functional nano-layers built onto an open-cell precursor. This efficient system is formed using simple and versatile membrane-mimetic processes; broad selections of structural and functional nano-layers can be used to meet diverse service requirements. The integrated analytical/experimental research undertaken in Phase I accomplished the following objectives: (1) theoretical modeling of the structural and adaptive aspects of system behavior; (2) design of representative systems embodying our adaptive principles, and establishment of the viable ranges of design variables; (3) experimental research underlying principles of the approach, emphasizing piezo-driven electrolysis within solid electrolytes; and (4) design, fabrication and experimental verification of basic integrated systems embodying the adaptive principles. The proposed Phase II research will: (1) develop a thorough analytical basis for design and optimization of adaptive systems at material and structural levels; (2) refine the membrane-mimetic process to fully exploit its potentials in terms of efficiency, the array of constituting materials, and system architecture; (3) design and experimentally validate basic structural components with adaptive and self-healing qualities; (4) demonstrate the technology at structural level through design and experimental validation of integrated structural systems with adaptive and self-healing qualities; (5) determine the benefits of adaptive structural systems in terms of performance, cost and reliability; and (6) develop elaborate plans for integrating adaptive structures into future NASA missions, and introduce the concept to scientific and industrial communities to facilitate further development and implementation of the technology.

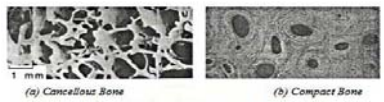

Figure 1. Cancellous and Compact Bones.

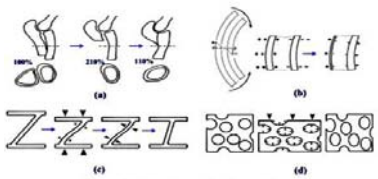
Figure 2. Adaptive Mechanisms of Bone.