The Study of Fatigue Mechanisms in a 3D Carbon-Carbon Composite

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This proposed research program will seek to learn the failure mechanisms of multidirectionally woven carbon-carbon composites when subjected to fatigue leading, and characterize this material's potential for use in internal prosthetic devices, e.g. hip and knee implants. Carbon-carbon composites are graphite fiber bundles embedded in a carbon matrix. Currently, implants are made of metals such as titanium and stainless steel which are cemented into the bone. In a hip implant, for instance, a portion of the bond can break down at the top of the femur resulting in high stresses at the base of the implant and a fatigue failure. It is also desirable to match the implant mechanical properties to those of the replaced bone — a difficult task with metals. Carbon-carbons have three potential advantages for this application: (i) Their strength and stiffness can be tailored by proper selection of fibers, fiber orientation, and fiber volume fraction; (ii) carbon is biocompatible; and (iii) carbon-carbon composites are porous, so anchoring may be achieved by tissue ingrowth.

Our major objectives in this Phase I program are:

1. To discover failure mechanisms and fatigue strengths of a typical fineweave 3D carbon-carbon to determine which parameters (density, matrix pocket shapes, etc.) bear most heavily on fatigue life. Where is the breakdown occurring and at what stress level, cycle, etc.?

2. To make a quantitative assessment on the suitability of multi-directional carbon-carbons for implants from a viewpoint of strength and fatigue properties.

To date, multidirectional carbon-carbons have been used primarily for high temperature aerospace applications such as missile nosetips and rocket nozzles. Since fatigue behavior is not a consideration for those applications, little work has been done in this area.

If this preliminary work shows a potential for carbon-carbon, follow-on effort will focus on all the design parameters for specific applications such as hip or knee implants.

Impedance Test for Intramedullary Anchored Femoral Prosthesis Loosening

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Bruce F. White,
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The use of intramedullary anchored femoral prosthesis for treatment of severe hip disorders is a relatively successful surgical procedure. However, many patients who receive such arthroplastic surgery must undergo revision surgery within a 10-year period following initial surgery. The need for such revision surgery is largely attributed to loosening of the stem of the prosthetic device. It has been suggested that early diagnosis of the prosthesis loosening may decrease the several associated risks such as infection and total failure of the prosthesis, and additionally allow prescription of limited weightbearing which would enhance the probability of bone regrowth and reestablishment of bone-cement/bone integrity. However, present diagnostic techniques using symptomatology and radiographic techniques are often not sensitive enough to detect early loosening.

The proposed approach is to use frequency-response testing (impedance testing) to detect system nonlinearities which would be characteristic of a mechanical system which has some degree of play. A program of experimental and analytical modeling and testing has been designed to investigate the feasibility of this concept.

A New Signal Processing Concept Applicable to Hearing

Time/Space Systems
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Principal Investigator

It is generally recognized that there has been slow progress in the treatment of hearing impairment relative to rapid advances in general technology. A large part of this can be traced to the lack of an adequate model of the ear's signal-processing functions. Present models interpret these functions as a form of Fourier spectral analysis, as evidenced by mechanical analysis of the basilar membrane in terms of "place theory." We suggest that these approaches have been too narrow in centering on the ear's internal functions, thereby neglecting the system constraints imposed by biological requirements for survival. This implies need for instantaneous responses to handle environmental sounds. Characterized by mixed epochs and short bursts, such signals are not amenable to spectral analysis. Rather, they require the use of temporal processing, using a low-dimensional signal representation. We have developed a system having the ability to identify epoch and periodicity of interleaved signals which could satisfy these requirements. Also, this technique appears to match data on both place and temporal observations. We propose a series of experiments to test a breadboard system embodying these principles. If successful, this concept could open new paths in treating hearing loss, as well as in efficient, robust speech rec-

ognition and bandwidth compression. The method could also be used for signal synthesis.

Biotechnical Multi-Electrode/ Neuronal Interface

EMV Associates, Inc.
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James H. McAlear, Principal Investigator, and John M. Wehrung, Co-Principal Investigator

Recent research conducted by EMV Associates, Inc., demonstrates the feasibility of fabricating arrays of biologically active materials with pattern densities approaching neuron densities in living nerve tissue. As a result, there appears to be an opportunity to develop a biologically linked probe which would offer very great advantages over probes presently available for the study of and communication with nervous systems.

Phase I of the planned research involves the demonstration of rat neuroblast attachment to spot-patterned arrays of a synthetic protein (polylysine). Phase II of the research involves development of an electrode system, ultimately a conventional microcircuit, to facilitate electrical contact with the neuroblasts. These neuroblast/electrode and neuroblast/microcircuit "interfaces" will be implanted in the central nervous systems (CNS) of rats, and tested for functionality. It is anticipated that the neuroblasts will make direct attachments within the CNS.

It is expected that this type of probe would greatly increase selectivity in communications with living nerve tissue, and that its benefits would accrue in the fields of biological and medical research, medical diagnosis and therapy, and prosthetic device development.

Natural Gum Substitute for Karaya Gum for Ostomy Products

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Arun K. Chatterji, Principal Investigator

We propose to study a family of natural gums with a view to find a suitable substitute for Karaya gum that is inexpensive, plentiful, and more acid-resistant than Karaya. These gums are uniquely analogous to Karaya and have good track record of performance in Ayurvedic medicine.

Our research plan consists of using a novel cryogenic grinding followed by our proprietary fabrication (under very controlled conditions) into ostomy discs for rheological and microbiological evaluation and cross comparison with the ostomy discs of Karaya and of synthetic polymer compositions. We will also correlate the structure-property-performance relations of the successful gums and the ostomy discs made of these gums, and apply for a generic patent.