Sensorized Biomimetic Scaffolds: Toward Universal Bionic Interfaces

Introduction

Long term biointegration of prosthetic devices is a goal that heretofore has not been achieved. One envisioned strategy would utilize a permanently implanted device that interfaces prosthetic modules with intact tissues such as bone. This Universal Bionic Interface (UBI) would provide for a stable and comfortable attachment of smart prosthetics to the body and electrical feed-through for signal and power interconnections to implanted sensory systems. The UBI includes (i) a bone tacnic which includes embedded biomechanical sensors, (ii) RF communication to peripheral nerves, (iii) a telemetry system, which would provide for wireless transmission of energy and data to either a base station fixed to the UBI or an external reader, would eliminate practical proble

2. Bioplastics Scaffolds

A complementary technology is our biodegradable protein-based plastic scaffold, which can be used to interface bone with UBI components. These native protein biopolymers can be engineered to have a range of initial biomechanical properties (elastic, in rubber, to hard). Due to low processing temperature (~0°C), hormones and other biologics can be incorporated. Sublimation degrades and nanoscale particulate calcium phosphate (CaP) can be included to provide porosity and osteoconductivity, respectively. Biopolymer degradation is in response to cellular proteolytic processes and that degradation occurs in concert with the growth and healing of bone and tissue integration. Natural polymer biopolymers are biocompatible and biodegradable. As with other plastics, biopolymers can be post processed by a wide variety of manufacturing techniques including extrusion, molding, and machining.

3. Growth factor gradients

To provide persistent spatial hormonal cues to direct tissue in-growth and improve the fusion/implant interface we have developed an in situ bioprinting technology capable of the manufacture of both 2D and 3D spatial patterns of immobilized hormones to direct cell behavior. By example, the 3D printing shown here is capable of coating complex, interesting hormonal gradients that can then be shaped (e.g., by stamping or molding) into 2D spatial patterns. Stacked or rolled layers of native ECM biopolymers could be grown in situ and cast or printed into preformed molds to provide a range of fabrication techniques for both rigid and soft tissues.

4. Microbarb fasteners

In addition, microbarb connectors, which we are developing using novel micro-milling techniques to shape our prototype-based plastic biopolymers, could be used in conjunction with 2D or plastic biopolymer scaffolds to facilitate attachment and integration of bone and soft tissue. The micro-milling can be done for other materials as well.

5. Ti/ceramics interfaces

Bone integration with titanium alloys (e.g., the housing materials for UBI) is achieved with the use of our novel solid gel processing methods to coat titanium with controlled morphology and microstructure of bioactive biomaterials to promote favorable tissue responses.

1. Wireless Bone Implantable Sensor

Enabled by our advances in CMOS-MEMS technology, we are also developing an ultraminiature (2 mm x 2 mm x 0.5 mm) wireless sensor that can be permanently implanted within tissues to measure biomechanical stresses in situ at a micron scale. This sensor integrates an array of piezoresistive strain gages that produce the raw data needed to extract a stress tensor and a transmission/reception coil and electronics for wireless power and data transmission. Osteointegration of the device, when placed within remodeling bone tissue, is enhanced through a combination of optimized surface topology and a thin coating of osteoconductive coating. Such sensors could be deployed within the biopolymer scaffold of the UBI. Of special interest is the development of base technology for other ultra-miniature RF powered implantable devices. An integral RF-based telemetry system, which would provide for wireless transmission of energy and data to either a base station fixed to the UBI or an external reader, would eliminate practical problems associated with hard wiring to micro-embedded sensors.