Development of Bio-Active Fabrics

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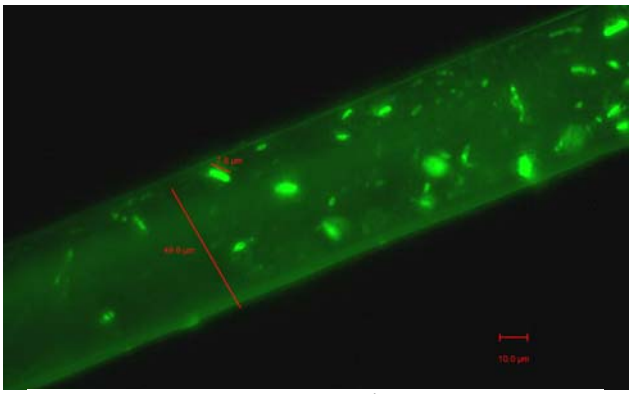
The tools of genetic engineering enable people to design and create cell based machines to perform useful tasks for mankind. The number and effectiveness of these living devices is rapidly expanding. Recent examples include bacteria that are engineered to remediate chemical and oil spills, bacterial bioreactors for the generation of drugs and chemicals, and engineered plants that resist pests and disease. Only the most basic and obvious cell based devices have yet to be realized; but it is becoming increasingly clear that these genetically engineered machines represent a new paradigm in micro-fabrication.

Clothing is an obvious habitat for biological micro-machines. Clothing materials are generally bio-friendly (non-toxic to cells); and sources of heat, moisture and even nutrients for cellular micro-devices are all readily available from the human body. Fairly obvious applications of bioactive fabrics include the control of odors in clothes and shoes by secretion of deodorizers or by the bacterial digestion of odor producing proteins and water repellent coatings on jackets or shirts that could be continually replenished by imbedded bacteria. Limiting our thinking, however, to these obvious applications is to assume that little or no progress will be made in the design of cell based machines. Our goal is to prepare ourselves not only for the inclusion of the simple cell based devices of today; but for the unknown yet potentially awesome cell based devices of the future.

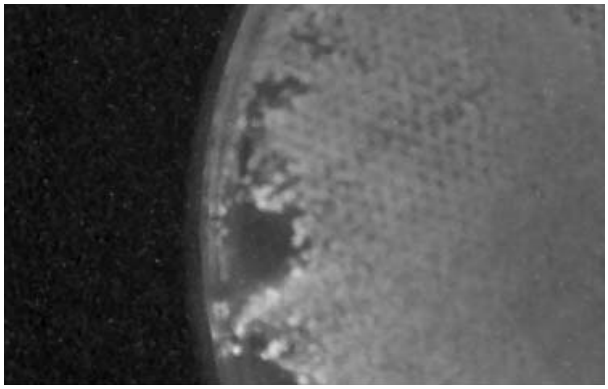
Our vision is to create fabric based bio-reactors in which colonies of mammalian cells or bacteria can live and function for extended periods of time. We began by loading bacteria into hollow fibers and assessing their growth and function. Using *e. coli* bacteria that have been genetically engineered to produce green fluorescent protein we can study bacterial function in the fiber as a function of time and environmental stress. We currently can maintain bacterial life and function for up to one month in bio-active milkweed fibers (See Photo below); and we are exploring means to extend that function for much longer.



Bio-active Fiber
Genetically engineered bacteria fluoresce three days after loading into a milkweed fiber.

We are developing fabrics that contain genetically engineered cells that will enable them to generate and replenish chemical coatings and chemically active components.

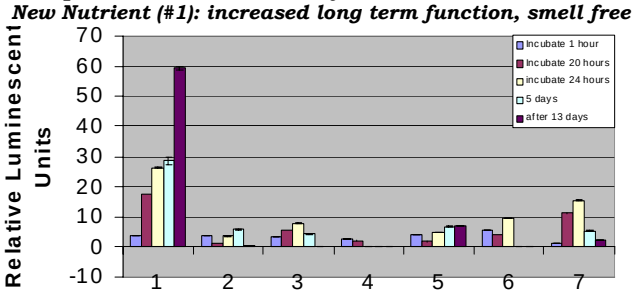
We have begun developing the first bio-functional fabric. Based on a poly-laminate fabric design, we have engineered fabrics that glow in the dark due to the presence of light emitting bacteria (See Photo below).



Bio-active Fabric
The above photo was taken in complete darkness. Illumination is providedsolely by the glow from the first bio-functional fabric which uses bacteria that are genetically engineered to glow in the dark.

We have now identified a new nutrient source that allows the engineered bacteria to live and function significantly longer (See Bar Graph). Even more important may be that our newly developed media has virtually no smell while standard bacterial culture media has a repulsive odor. This nutrient source also serves to immobilize the bacteria on the fabric surface.

Improved Nutrient Source for Luminescnt Bacteria
New Nutrient (#1): increased long term function, smell free



1=New Nutrient; 2-6 = Other Candidates; 7=Standard Broth

Finally we are involved in a large and multi-institutional effort to preserve cellular life in the dry state. Dried cellular systems have many medical applications; but they also could provide the basis for stable fabric systems that could become active by the simple addition of water or sweat. We already have the ability to preserve mammalian cells in the dry state by using a genetically engineered pore forming protein to load sugar inside the cells prior to drying. We are currently focusing on the design of microfabricated environments to protect and contain the cells in a polylami-

nate fabric. The design we are currently testing is a PDMS (polydimethylsiloxane) microlayer covered with 25-micron long, cylindrical posts (of 25μ diameter) protruding from the surface, which appear to provide protection for the cells during drying, storage and handling.

At the completion of our work we will have identified a number of different fabric designs that are able to sustain bacterial life and function for known periods of time; and we will have created the first examples of bio-active fabrics.

Other Contributors: **Graduate Students**: *Wenjian Wang, Zhonglin Zhao*; **Post-doctoral researcher**: *Jason Acker, Tani Chen*; **Technician**: *Jennifer Cusick*

Industry and Government Interactions: 10 [Engineered Yarns; Adidas; Natick Labs; Footjoy; Natural Fibers Corp., KBIG, Henkel KGAa, Han Jong Enterprises, Mimco Inc. Unilever Corp.]

Project Web Address:

http://www.mne.umassd.edu/faculty/alexbio.html

For Further Information:

1. Chen, Acker, Eroglu, Cheley, Bayley, Fowler and Toner, *Beneficial Effect of Intracellular Trehalose on the Membrane Integrity of Dried Mammalian Cells*, Cryobiology, p 168 (2001)
2. Acker, Fowler, Lauman, Cheley and Toner, *Survival of Desiccated Mammalian Cells: Beneficial Effects of Isotonic Media*, Cell Preservation Technology **1**:129 (2002)

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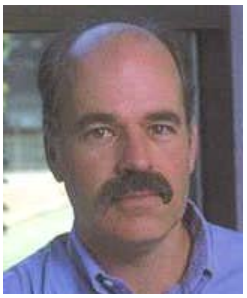

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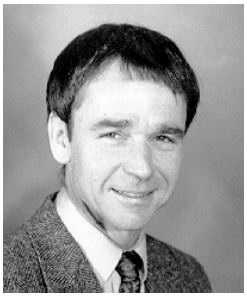

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