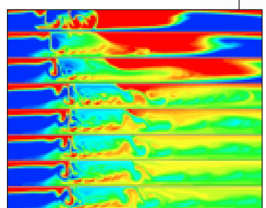
CEMS

CELLULAR ENGINEERING MICROSYSTEMS

An ICTAS Theme Area

Need for Research

In order to gain insight into life processes, we must break it down to the smallest system level – the cell. The National Science Foundation states that currently there is a lack of understanding of cell-to-cell interactions and the interaction of the cell with its environment. There is a need for a comprehensive, fundamental engineering approach to better understand cellular and biomolecular responses to stimuli at the molecular level, within and between cells, as well as with surrounding materials and the environment.



Microfluidic mixing is challenging and sometimes requires intricate and long passive mixers. Here, we show an improved active mixing technique. Images are at different times from terascale simulations of microscale mixing that is induced by using a magnetic fluid in a microchannel.

CEMS technology enables researchers to study the response of cells to physical, electromagnetic, and chemical stimulus in controlled microenvironments. The work will directly result in the development of vital and reliable technology for cellular and molecular biology and medical research. This will have a broad impact on society from detection and treatment of disease, understanding drug delivery, biodefense, genetic engineering, and the fundamental understanding of life evolution.

Furthermore, the implantable microsystems we are developing at Virginia Tech may have direct applications for in situ stem cell harvesting for tissue engineering, nerve cell regeneration or bone marrow replacement; as an "immune system on a chip" for immunodepressed patients (AIDS); as "artificial pancreatic beta cells" for in situ insulin production, storage and release; or even as implantable devices for cellular based surgery. Each of these applications will apply innovative techniques to solve some of the most fundamental challenges in biomedical engineering and advance our understanding of biological behavior at the cellular level.

Vision

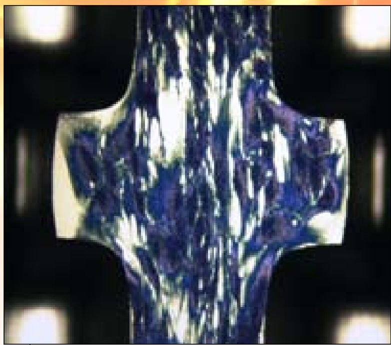
At Virginia Tech, we are laying the foundation for a paradigm shift in the treatment of disease from extrinsic drug-based therapies to implantable microsystems that mimic the functions of human cellular biochemical systems that act as supplements or prostheses for impaired systems.

Mission

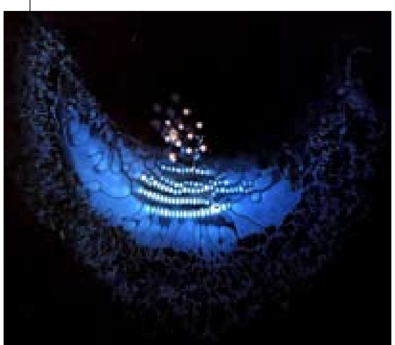
Cellular Engineering Micro Systems (CEMS) combines engineering technology known as MEMS (micro electrical mechanical systems) and cellular biology to monitor, transform, manipulate and genetically engineer cells in new ways with unprecedented precision and sensitivity. Our mission is to develop fundamentally innovative techniques for the diagnosis and treatment of diseases by exploiting phenomena that dominate at the micro- and nano-scales.

Current Focus "Implantable μ-Oncologists"

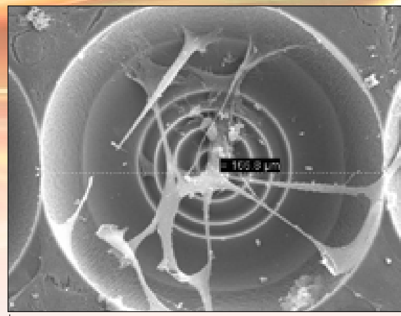
The current focus of our group is to develop implantable CEMS devices to detect the presence of circulating tumor cells in post-operative cancer patients. Oftentimes, treated cancer patients suffer from recurrence or even metastasis after their treatment. During early stages of tumor growth, there is a low concentration of cancer cells that exfoliate into bodily fluids. Circulating tumor cells (CTCs) have been identified by the National Cancer Institute as a potential conduit to detecting cancer at its earliest stages but are too low in concentration and surrounded by too many normal cells to be detected with existing technology. Our team hypothesizes that detecting the presence of CTCs in post-operative patients can be an indication of cancer recurrence and an active implantable device to monitor patients and destroy such cells would stifle the spreading of the disease and potentially cure patients.



Manipulations of cells in a microenvironment can provide insight into ways to distinguish between healthy cells and their malignant counterparts. We are studying cell-surface interactions using CEMS biosensors for cell separation and cancer diagnosis. We are also working on electrical and mechanical characterization of individual cells and investigating the effect of different anticancer drugs on cancer cells behavior.



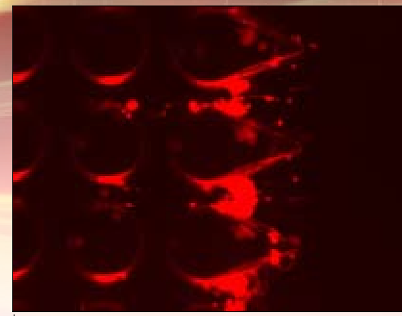
Combining (bio)chemical functionalization with "action-at-a-distance" through magnetic fields has considerable applications for superparamagnetic nanoparticles in CEMS including enhanced heat transfer, controlled mass transfer, and field-assisted self assemblies.



Technical or Scientific Approach

We are one of the newest focus groups, comprised of eight faculty members who can contribute to the most critical aspects of the research in order to demonstrate feasibility: microfluidics; microscale modeling; cell manipulation; microfabrication; power scavenging; imaging; advanced modeling; single cell analysis; measuring physical, chemical, and electrical properties of cells; biomaterials; ultra-low power-chip design; analytical chemistry; proteomics; and microfluidic structures.

Between our technical expertise, support from ICTAS, advanced micro-scale multi-physics analytical tools, and facilities with highly specialized equipment for this research, Virginia Tech is strategically positioned to become a leader in this field. Our state-of-the-art facilities at Virginia Tech include the MicrON Clean room, the Nanoscale Characterization and Fabrication Laboratory, and the new ICTAS I facility. Through support from ICTAS we are able to co-advise graduate students so that they are trained in the interdisciplinary nature of this research and become tomorrow's leaders in this high-impact and revolutionary field.



Accomplishments

The research team is multidisciplinary, consisting of experts in experimental bioengineering, electrical engineering, theoretical mechanics, and chemistry. The team is strongly connected through a shared philosophy that bringing together different disciplines will result in technological breakthroughs in this area.

Researchers on our team have developed methods to:

- Selectively isolate and enrich cells using microfluidics
- Transfect individual cells using micro-electroporation technology
- Induce micro-scale mixing using magnetic fields
- Distinguish between cancerous and non-cancerous cells using micro-patterned surfaces
- Use bioluminescence imaging to identify and monitor tumor progression in mice
- Create ultra low-power devices
- Profile cancer cells and tissues using proteomics
- Create biocompatible devices through novel methods
- Screen for cancer biomarkers using microfluidic-mass spectrometric platforms
- Fabricate three-dimensional independent complex microfluidic features in a single step
- Build advanced wireless technology
- Create micro-scale multi-physics numerical models

Key Personnel

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