EE 45X – Biomedical Nanotechnology
Course Proposal
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1 Introduction
The purpose of this document is to propose a new course in the area of Biomedical Nanotechnology in the Department of Electrical and Computer Engineering (ECE) at the University of Alberta (UofA). The course number will be referenced as “EE 45X,” since a number has not yet been assigned. This document has three major sections. Section 2 provides a description for this course; a week-by-week syllabus is also appended to this document. Section 3 addresses issues related to the implementation of the course, including its relation to other “nano” and “bio” courses offered to third- and fourth-year students at the ECE Department, UofA. Section 4 provides a final recommendation based on the material discussed in the preceding sections.

2 Course Descriptions
What is “Biomedical Nanotechnology” and why should such a course be offered at the University of Alberta?

2.1 What is Biomedical Nanotechnology?
- *Biomedical Nanotechnology* is an emerging area which deals with nanoscale design for disease diagnosis and therapy.

- It extends and applies knowledge from the traditional ECE disciplines of electronic devices and materials, in order to understand new nanoscale materials such as carbon nanotubes, nanowires, molecular devices, and nanoparticles, and their use in biomedical applications.

2.2 Why Biomedical Nanotechnology?
- “Lifescience” and “Nanotechnology” has been defined by the Canadian and Alberta government as strategic important areas.
• **The reason to propose this course:**

According to the National Institute of Health (NIH) Roadmap (http://nihroadmap.nih.gov/nanomedicine/),

“Biomedical Nanotechnology, an offshoot of nanotechnology, refers to highly specific medical intervention at the molecular scale for curing disease or repairing damaged tissues, such as: bone, muscle, or nerve. A nanometer is one-billionth of a meter, too small to be seen with a conventional lab microscope. It is at this size scale – about 100 nanometers or less – that biological molecules and structures inside living cells operate.

Nanotechnology involves the creation and use of materials and devices at the level of molecules and atoms. Research in nanotechnology began with discoveries of novel physical and chemical properties of various metallic or carbon-based materials that only appear for structures at nanometer-sized dimensions. Understanding these nanoscale properties permits engineers to build new structures and use these materials in new ways. The same holds true for the biological structures inside living cells of the body. Researchers have developed powerful tools to extensively categorize the parts of cells in vivid detail, and we know a great deal about how these intracellular structures operate. Yet, scientists have still not been able to answer questions such as, "How many?" "How big?" and "How fast?" These answers must be provided to fully understand cellular structures in order to repair them or build new "nano" structures that can safely operate inside the body. This will lead to better diagnostic tools and engineered nanoscale structures for more specific treatments of diseased or damaged tissues.”

2.3 The Challenge for Future Electrical Engineers

• Future technologies will require ECE engineers to understand the nature of biological structures inside living cells of the body so that powerful devices can be built for disease diagnosis and therapy.

• As an example, consider the diagrams in Appendices A and B of this document. In the Appendix A, we show various nanoparticles (NPs). NPs can be made the same size as proteins or smaller and can help deliver genes or drugs to targeted locations where conventional delivery methods cannot reach. NPs can be semiconducting, magnetic, or metallic. Semiconductor NPs, or quantum dots, have been used for cell labeling. Magnetic NPs, or magnetic beads, can be used for cell separation, MRI imaging enhancement, and cancer magnetic fluid hyperthermia therapy. In Appendix B, the picture shows NPs uptake by cancer
cells. The diagram shows most of NPs enter the cytoplasm of cancer cells. By applying X-ray, the diagram shows that NP combined with X-ray treatment is more effective in treating cancers with minimal in vivo side-effects than conventional radiotherapy alone or X-ray alone treatment. These results indicate that nanotechnology can help reduce cancer patients’ side effect by focusing the treatment only on cancer cells but not on normal tissue. The clinical study shows that this targeted treatment can successfully replace conventional radiation therapy.

By using this example, the main point that the author try to make is that for future technologies to succeed, electrical engineers will need to know how to bridge the gap between nanoscale designs and biomedical applications.

- As a leader in nanotechnology education, the ECE department at the U of A should have an explicit course that provides its graduating students with the opportunity to learn how to apply nanotechnology into biomedical application.

2.4 This Course

- **The aim of this course will be to introduce electrical engineers to the basics of applying nanotechnology in biomedical applications.** The key concepts will be developed from scratch, such that an electrical-engineering audience with no background in biology and nanotechnology can follow and appreciate the points; for those interested in further study, the main ideas introduced in this course can then be used as a starting point for a more detailed understanding.

- The course will benefit students of different options, such as biomedical, engineering physics or traditional electrical engineering. They will get an opportunity to refine and apply their knowledge of quantum and solid-state physics as applied to biomedical engineering.

2.5 Overview of Course Topics

The course will achieve three major goals:

1. Examine the basic ideas and concepts required to understand biological structures inside living cells of the body, such as DNA, gene, antibody, and tumor growth.

2. Provide students with the ability to calculate information regarding various nanomaterials, such as the energy levels and the mass of nanostructures, since such information is crucial to understanding the properties of nanomaterials for biomedical applications.
3. Apply the concepts covered in points 1 and 2 to apply nanotechnology in biomedical applications.

2.6 Individual Course Topics

A week-by-week syllabus is attached to this document.

2.7 Suggested Textbook


2. “Introduction to Genetic Analysis” Publisher: W. H. Freeman; 8 edition ISBN: 0716749394. This course will cover Chapters 1 and Chapter 17 for students to understand biological structures inside living cells of the body and tumor mechanisms.

3. “Immunology” Publisher: W. H. Freeman; 6 edition, ISBN 1429202114. This course will cover Chapter 1 through 3 for students to understand immunology basics. The knowledge will help them to bind nanomaterials with materials such as antibodies for specific targeting.

3 Course Implementation

3.1 Relationship of the Proposed Course to EE 459 (Introduction to Nanotechnology), EE 456 (Introduction to Nanoelectronics) and EE 457(Microfabrication and Devices)

The proposed course will focus on biomedical nanotechnology. This topic forms only a small portion of the material covered in EE 459, EE456 and EE457. For instance, the aim of EE459 is to provide more of a general survey of the nanotechnology. EE456 focus on current flow in nanoscale device. EE457 focus on micro/nano-fabrication. Unlike the previous listed course, the proposed course focuses applying nanotechnology for biomedical applications (such as tissue regeneration, gene therapy, DNA sequencing, and cancer diagnosis and treatment).

3.2 Relationship of Proposed Course to EE 455 (Engineering of Nanobiotechnological Systems)
The course description of EE455 is the following: “Microfluidic and nanobiotechnological devices and design. Fabrication techniques for devices: self assembly, lithographic technologies. Applications of nanobiotechnology in computing, electronics, human health, environment, and manufacture.” At present, there is a low degree of overlap between the proposed course and EE455.

The proposed course first covers the basics in biomedical area, such as gene structure, protein structure, biomarkers and cancer mechanism. The course then covers nanoscale material properties and ways to engineering these materials for imaging and treatment. To achieve intelligent nanoscale design, we conclude the course with more advanced nanoscale designs, such as binding nanodesign with biomarkers to achieve specific targeting and drug delivery, and nanostructure for gene therapy.

The author of this proposal offered the course as a technical elective course (EE498) in Fall 2008. He also invited senior scientist from local biotech companies to give lectures in the course. Feedback from students was very positive (refer to the appendix) that such material would be of greater interest to them because they feel this purpose-driven course can benefit their career development.

3.3 Design Component of the Course

A key benefit of the proposed course is that many of the assignments require hand-on experiments. Such experience will help students understand the theoretical concept of biomedical nanotechnology. The presence of experimental component could be used to justify a significant design component to the course, which may be useful for accreditation purposes. It is also worth mentioning that as the field of biomedical nanotechnology evolves and the course matures, it may be possible to have common lectures but different sets of assignments specifically tailored for electrical-engineering, engineering-physics, and graduate students.

4 Recommendation

It is recommended that the course EE 45X, “Biomedical Nanotechnology,” be offered starting in the Fall 2009 term. In the future, if a second course, “Advanced Nanobiology,” is deemed worthwhile, it can be appropriately implemented. The author of this proposal would also like to state that his current students in EE 498 (Biomedical Nanotechnology) have provided him with feedback showing strong support for what is proposed here. When students learned this course, the enrolment was doubled (total enrolment is now 26). The author of this proposal hence expects a high enrolment for the proposed course in upcoming years. The author of this proposal would also like to mention that he has also received feedback from several faculty members that indicates support for what is proposed here.
Overall, the proposed course will augment existing courses in nanotechnology and biomedical engineering, which will strengthen the leading position of the University of Alberta in the area of nanotechnology education. The proposed course also has strong student interest and faculty support.

Appendices

A. Various nanoparticles

B. Nanoparticles enter cell cytoplasm.

Most of the nanoparticles are distributed within the cell cytoplasm. Nanoparticles enhanced cancer killing.