Plans for Incorporating Sustainability Concepts into 2012-2013 Courses

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- **What courses do you expect to teach during the Fall 2012 semester? What is the anticipated student enrollment?**

  Fall 2012 – Introduction to Engineering Materials (ENMA 300/ENME 382)

  Enrollment = >250 (85 in my sections)

- **Plans for integrating broad issues of sustainability into courses.**

I serve as the mechanical engineering department's course leader for the Introduction to Engineering Materials course which is cross-listed between the materials science (ENMA 300) and the mechanical engineering (ENME 382) departments, and is offered to students in all engineering and physical science disciplines. This course is required of all mechanical engineering students, and, as such, provides an optimal vehicle to introduce the entire mechanical engineering student body, as well as students from the other disciplines, to the concept of materials selection to support design for sustainability. Plans for integrating sustainability into the course will be discussed with the other instructors and with the undergraduate director in each department.

In this course, I will guide students to choose materials for their product designs that not only meet performance and cost targets, but also promote cradle-to-cradle sustainability throughout the entire product lifecycle. For example, students will be encouraged to consider criteria such as availability, environmental impact, recyclability, and resource limitations in their materials selection. Furthermore, they will be introduced to the concept of assessing the energy and water expenditures and greenhouse gas emissions involved in the mining and refining processes for different metals. They also will be shown how to choose and/or design manufacturing processes (e.g. casting, forging, welding, heat treating, nanomanufacturing, stereolithography) that minimize energy use and will be introduced to the concept of biomimetic processing. For polymers and ceramics, similar assessments will be made of different synthesis and manufacturing processes.

One way in which these sustainability concepts will be introduced is through the use of Ashby-type diagrams. These diagrams provide a graphical method for selecting materials that meet specific multi-objective criteria. For example students can choose materials that have strength-to-weight ratios that exceed a required value or that have the best combination of fracture toughness, tensile strength, and cost. Concepts of sustainability have yet to be included in these diagrams, but ways in which they could be considered include 1) incorporating environmental impact (e.g. waste/clean-up) costs into material costs, 2) evaluating materials for the best combination of a specific performance attribute (e.g. strength, toughness, conductivity) and the energy required for processing, 3) evaluating materials with the best combination of a specific performance attribute (e.g. strength, toughness, conductivity) combined with availability or biodegradability. In this way, students will possess a methodology for implementing sustainability into the materials selection aspects of their product designs as well as having a more global perception of sustainability instead of focusing on minimizing impact in just one phase of the product lifecycle. Furthermore, they will see how their design decisions affect the choices that will remain available for future generations.

I also teach graduate level and senior undergraduate elective courses in the reliability, packaging, and thermal management of electronic products and systems, with a specific course (ENME 780) focusing on extreme temperature and high power applications. In these courses, students learn about materials, designs, and manufacturing processes for the latest generation electronics. Electronic products have become ubiquitous in modern society. High temperature electronic systems are used to maximize efficiency in fossil fuel production, and high power electronics are used widely in renewable energy generation (e.g. wind and solar), and in energy conservation (e.g. hybrid and plug-in electric vehicles). Because of this, they serve as an excellent testbed for educating students on the concepts of incorporating sustainability throughout the entire product lifecycle as mentioned above, from materials selection, to manufacturing process selection and development, to design for end of life. One example of manufacturing process design that promotes sustainability is the direct writing of electrical circuitry onto biodegradable paper, using copper oxide or carbon nanotubes – a sustainable additive process. This is replacing the older non-sustainable process of coating a sheet of non-biodegradable plastic (e.g. fiberglass epoxy composite) with a sheet of copper and then patterning the circuit by etching away the undesired portion of the copper – a subtractive process that results in a toxic waste stream. Furthermore, students in these courses will be instructed to consider designing products that conserve energy during product use, and that permit reuse, repurposing, and recycling, thereby minimizing waste streams at end of life. Students also will be exposed to methods for improving the reliability and robustness of products, thereby delaying the time to failure and the need for replacement. One example of this would be studying degradation mechanisms in automotive batteries to maximize their lifetime and recyclability followed by considerations of secondary markets for those batteries when they no longer meet automotive standards, such as home energy storage and energy use leveling.