C. Materials Science: The Study of the Stuff from which Useful Things are Made
Multi-professor course
Thursdays, 9:30 - 11:00 a.m. Norris University Center

Do you ever wonder what makes objects around you strong, flexible, long-lasting, or weather-proof? From concrete used in Ancient Rome to the airplane skins of today, learn from Northwestern's Materials Science and Engineering Department's world-famous faculty how material science is crucial to the design and production of items that affect our daily lives.

Jan. 9 What Stuff? The Different Kinds of Materials
Steve Carr, *Professor Emeritus, Materials Science and Engineering, and Chemical and Biological Engineering*
Vinayak Dravid, *Abraham Harris Professor of Materials Science and Engineering; Founding Director, Northwestern University Atomic and Nanoscale Characterization (NUANCE) Center*

Everything we use and touch in our everyday lives is made from a material that is the result of profound human progress. In prehistoric times this involved using art to convert natural substances into useful objects, but as civilization progressed these arts led to more valuable materials, such as pottery and eventually metals. It wasn't until the 20th century that engineering and science were brought to bear on creating materials, such as plastics and semiconductors, that enable all the technologies on which we depend daily.

Jan. 16 Metals: From the Iron Age to the Present
Ian McCue, *Assistant Professor, Materials Science and Engineering*

Metals emerged in civilization nearly four millennia ago, starting with alloys of copper and later iron. These materials led to progress in agriculture, coinage, warfare, transportation, and tools. In the last half-millennium additional metals have been obtained through processes that convert other minerals into objects on which we depend. Science and engineering have been instrumental in achieving such a dazzling array of useful things – just think of orthopedic implants and jet engines.

Jan. 23 Ceramics: Not Just Clay Pots
Scott Barnett, *Professor, Materials Science & Engineering*

Articles made from ceramics emerged over 25 millennia ago because the processes for converting minerals, which are typically oxides, into a finished item are relatively simple. Things like dishes, pottery, bottles, and even stained-glass windows and eyeglasses emerged from continuous progress in the ceramic arts. However, the 20th century saw a proliferation of new ceramic materials that are key to many electronics applications we all enjoy so well.

Jan. 30 **Polymers: What They Are and What They Do**
Ken Shull, *Professor, Materials Science & Engineering*

Wood, which is arguably the earliest material used by humankind for the activities of life, is a polymer; as are synthetic materials like polyethylenes and nylons polymers. What they all have in common is a molecular structure that can be described as a long chain macromolecule. The very molecules of life: proteins, carbohydrates, and DNA/RNA, are polymers!

Feb. 6 **Composites: The Evolution from Wood to Concrete to FRPs**
Gianluca Cusatis, *Professor, Civil and Environmental Engineering*

Physical combinations of materials are what we call composites. Probably the earliest examples are concretes. Many of us have visited the Pantheon in Rome, built a little over 2000 years ago, and were astonished to learn that it was made of concrete. Over the ensuing millennia the chemistry of the cement binder has improved remarkably, and the mix of materials combined has led to Portland cement concretes, which are the most abundantly-used man-made substances on earth. Wood is the only kind of materials that rivals concrete, and now wood is being modified to make things ranging from fabrics to skyscraper girders. An entirely new class of materials is fiber-reinforced composites. Applications that were enabled by fiber-reinforced plastics range from the hulls of modern recreational boats to most of the structural parts of modern aircraft.

Feb. 13 **Materials for Electronics: We've Come a Long Way since your Transistor Radio**
Jeff Snyder, *Professor, Materials Science and Engineering*

In the 20th century, solids made from novel combinations of metals and non-metals began to be investigated in earnest. Interesting properties, especially involving electronic and optical behavior, were discovered, and soon those classified as semiconductors were put to use as transistors in electronic circuits. Then the ability to microminiaturize such circuits was developed, and this led to the mass production of "chips" – and we know that "chips" are everywhere, right? In contrast, the ability to produce the widely used semiconductor silicon in large plates has allowed us to have large photovoltaic panels that convert sunlight into electricity for the electrical power supply of entire countries. LED lights and lasers all are based on semiconductors, too.

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Feb. 20 **Sustainability: How Do We Achieve It?**
Steve Carr, *Professor Emeritus, Materials Science and Engineering, and Chemical and Biological Engineering*

The concept of a sustainable material is that its supply cannot be exhausted – that we cannot ever run out of it. Therefore, except for wood, almost none of the materials we have covered is sustainable. However, we can approach that limit by choosing materials that can be recycled indefinitely or whose supply comes from a source that is enormous in comparison with our demand for it. Accordingly, we are exhorted to "reuse, reduce, recycle, or redesign." Examples of complying with this practice abound, but there is a need to align our judgement with the economics that goes along with each of them. Assessment of these alternative practices requires a thorough life cycle analysis (LCA), including such things as 1) water and energy consumption to make the article under consideration, 2) raw materials consumed in producing it, and 3) all the demands that using the article will impose on us when using it.

Feb. 27 **Materials Selection: How to Avoid Making Lemons**
Steve Carr, *Professor Emeritus, Materials Science and Engineering, and Chemical and Biological Engineering*

So many failed products can have their weakness traced back to an inadequate effort to choose the right material. Choosing the right material for a successful article involves a thorough but straightforward process. It starts with identifying what the item is to accomplish. This will assure that the product will meet users' expectations of what they value. From there, one can proceed to identify performance requirements and the properties that will lead to realizing that performance. However, the last part is essential - assure yourself that your selection will work. This involves testing of prototypes of your item under all plausible conditions, including conditions that lie well out of the normal range. This proof testing can seem extravagantly expensive, but it is the only path to follow, and furthermore one needs to have a way of monitoring – and correcting for – unexpected conditions that only show up when customers are using the product.

Mar. 6 **NO CLASS**

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Mar. 13 **Benefiting Society: The Ultimate Cost-Benefit Analysis**
Wei Chen, *Chair and Professor of Mechanical Engineering*
Steve Carr, *Professor Emeritus, Materials Science and Engineering, and Chemical and Biological Engineering*

This is where the "rubber meets the road," to use a metaphor that involves a material. What is the consequence of a new technology, given that it almost certainly depends on the material(s) of which it is made? Everything performs at limits set by these materials. Here's one example: the higher the temperature at which a jet engine operates, the higher will be its efficiency, but at some point, the metals used in the combustion chambers or in the turbine blades will fail from being too hot or spinning too fast. Thus, it is those metals that set the efficiency of that engine. It is no surprise that scientists are applying their methods to understand at a fundamental level how to create a metal that will operate at ever-higher temperatures. Yes, cost figures into this picture as well. Engineers need to understand the underlying science for each material because they are responsible for assuring performance, including avoiding failure and maximizing useful life. The combined efforts of scientists and engineers are essential for the appearance of new technologies based on new materials.