7 BIG CONCEPTS TO LEARN ABOUT *MATERIALS ENGINEERING*

Materials engineers specialize in knowing which materials to use in different applications, why certain materials should be used, how to make materials, how to test and characterize materials, and how to design and test new materials. Successful application of such knowledge leads to safe, predictable, and reliable use of materials, which are major goals of the engineering profession. The big concepts listed herein are essential for effective use of engineering materials (solid matter), and they epitomize our materials paradigm (an accepted way to think about materials—a set of relationships).

1. **Materials have sensitive structures, and their behaviour is path dependent**
   - Solid materials are never in thermodynamic equilibrium–they may come close, but they never get there. There is a thermodynamic driving force, no matter how small, for the material to change in some way to lower its internal energy.
   - The history of a material is of critical importance for how materials behave because materials can, and will, store within themselves various forms of energy. Many forms of energy (of seemingly insignificant magnitudes) are irreversible and can interact with the material to change the structure, and therefore behaviour.
2. **Material properties are dictated by *very* small length scale structures**
   - The field of Materials is a structure-centric discipline–the material structure along with intrinsic and extrinsic defect structures are of paramount importance because structure dictates the properties (i.e., structure-property relationship).
   - Small-scale structure (microstructure at the level of crystals and even atomic or subatomic bond lengths) gives rise to macroscopic behaviour (properties); it often seems completely unbelievable that such small scales matter, but it is true!
   - Understanding and elucidation of processing-structure-property-performance relationships is the heart and soul of materials science and engineering because it allows for descriptive modeling of what we observe and predictive modelling of behaviour we want.
3. **Materials processing affects structure**
   - The way we make materials changes their microstructure–a good outcome for flexibility in changing properties for design aspects, and a relationship crucial to understanding how to get desired material properties (i.e., processing-structure relationship).
   - Materials processes for shaping, joining, and surface treating are numerous, and have varying degrees of influence on the microstructure; such processing-structure relationships need to be known in order to make materials in a reproducible fashion for target properties to meet performance targets (i.e., processing-structure-property-performance relationships).

4. **<u>Materials & process selection is as important as component design and implementation</u>**
   - Technical issues are only part of the intelligent use of materials; materials performance is often more than just a combination of material properties–how to design *with* different materials requires involvement in front-end design, not just a selection of a particular material at the end.
   - Avoid focus on purely technical aspects: Human factors, how the material will actually be used, and business case development underpin effective materials use.
5. **<u>There are sooooooo many materials, and they are NOT created equal</u>**
   - There are 5 classes of engineering materials, but thousands of materials–each with different properties and therefore different performance capabilities.
   - Certain materials are *better* for certain applications; there is no "optimum" material for any application: there will **<u>always</u>** be trade-offs and compromises.
   - Intelligent material choices require knowledge of the differences between materials, and the origins of such differences (which are rooted in atomic bonding theory and processing history).
6. **<u>No material is perfect</u>**
   - An inherent flaw population is present in all materials–**<u>always</u>**.
   - There are many types of flaws, and they exist at numerous length scales.
   - Different flaws affect different materials in different ways.
   - If flaws are large, or numerous enough, they can become defects–defects lead to failure.
7. **<u>Materials respond to their environment</u>**
   - Environmental exposure (use, operation) conditions can change the microstructure, and thus alter properties, leading to a different performance than might have been desired.
   - Environmental exposure can lead to creation of new, or more, flaws, or conversion of existing flaws into defects that can cause loss of performance or failure.
   - All materials can, and will, degrade (accumulate damage) and can, and will, fail if not chosen, processed, implemented, or maintained appropriately; acceptable use conditions must be known and maintained, and effects of such conditions on the material should be assessed and monitored.