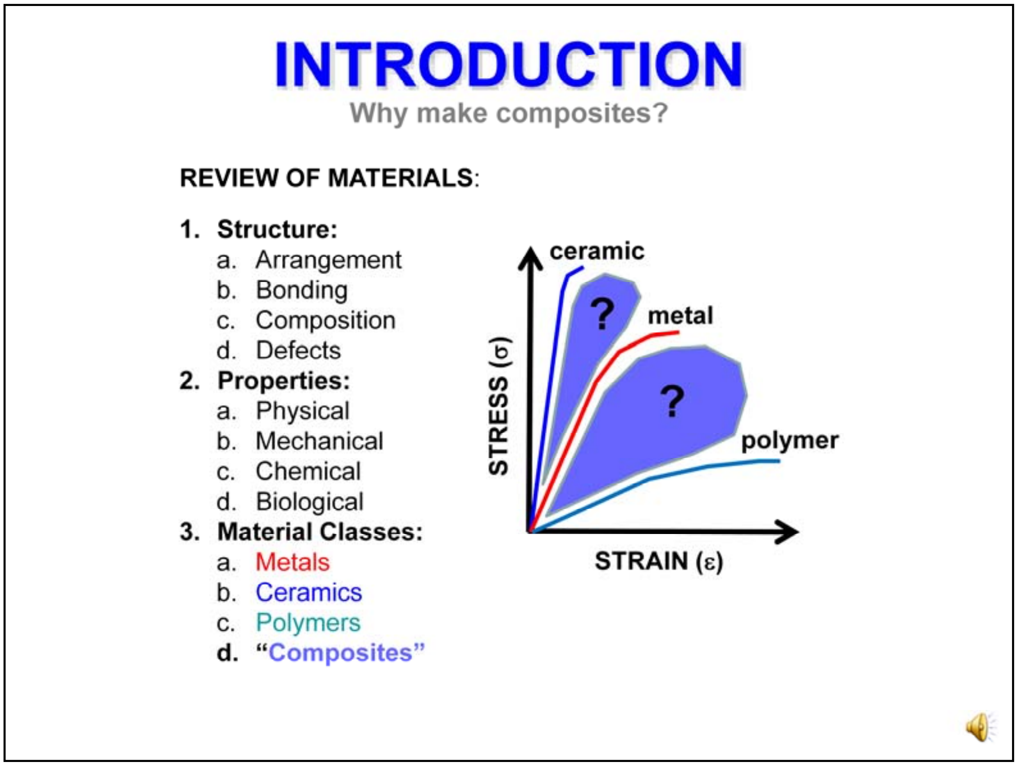
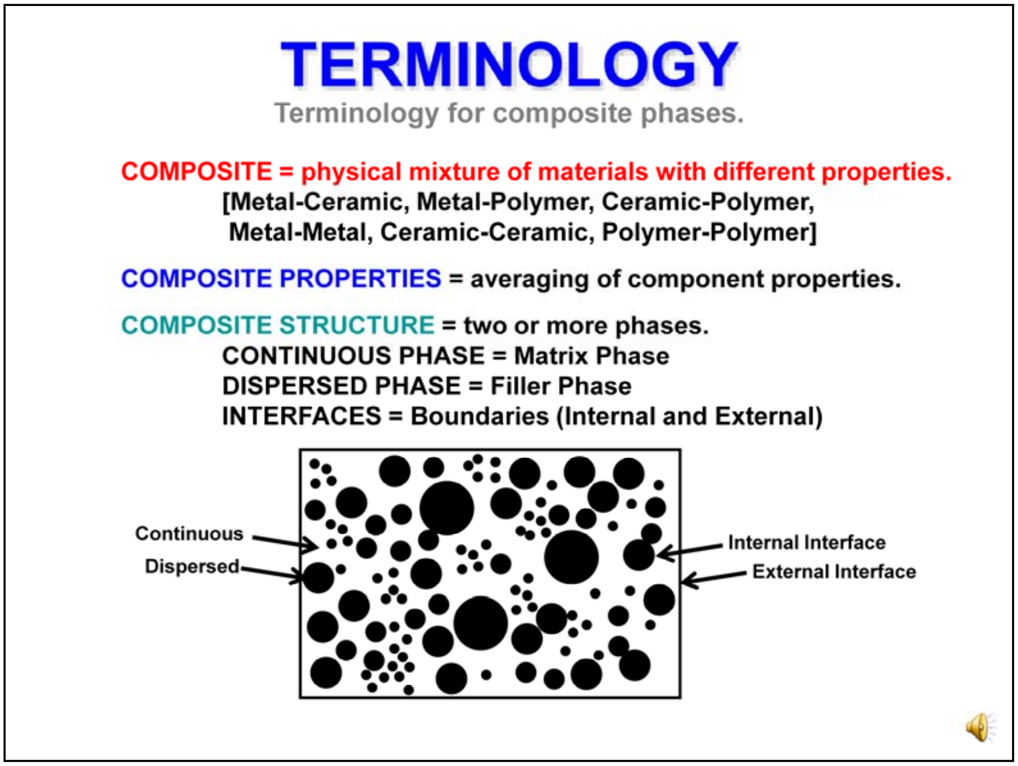
Now it is time to start the discussion of the final major class of materials called “composites.”



Let's review quickly where we are. We have talked about STRUCTURE (arrangement, bonding, composition, and defects), PROPERTIES (physical, mechanical, chemical, and biological), and MATERIALS (metals, ceramics, and polymers).

What are composites? Composites are mixtures of materials from two or more classes.

Why do we need these mixtures? **[CLICK]** Let's examine the mechanical properties (from strongest-to-weakest) of ceramics, metals, and polymers. **[CLICK]** We might need properties that are intermediate and which are hard to achieve using regular materials. Or, we might need manipulation options for fabrication that are in between those for traditional materials. So, we make mixtures.

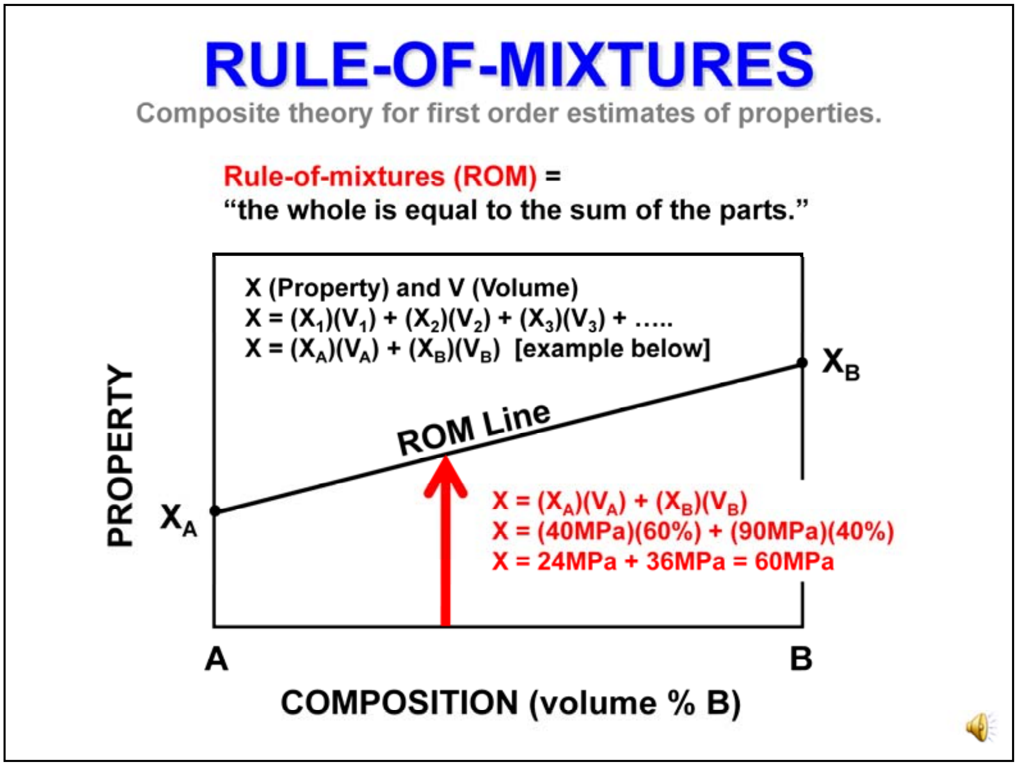


Consider the simple schematic representation of a composite. This is actually quite an accurate model for most composites.

[CLICK] Composites are physical mixtures of materials. The materials do not dissolve or chemically react to form new components. **[CLICK]** More times than not the mixture contains metal-ceramic, metal-polymer, or ceramic-polymer. The last one of these is very typical of dental materials. Most dental materials are composites. **[CLICK]** It is also possible to make metal-metal, ceramic-ceramic, or polymer-polymer composites if the properties of the materials make them practical.

[CLICK] Composite properties are the average of the component properties. Shortly, we will explain how to calculate the resulting properties. For now, it is important to know that the properties depend on the VOLUME of the components or phases being rather than the WEIGHT.

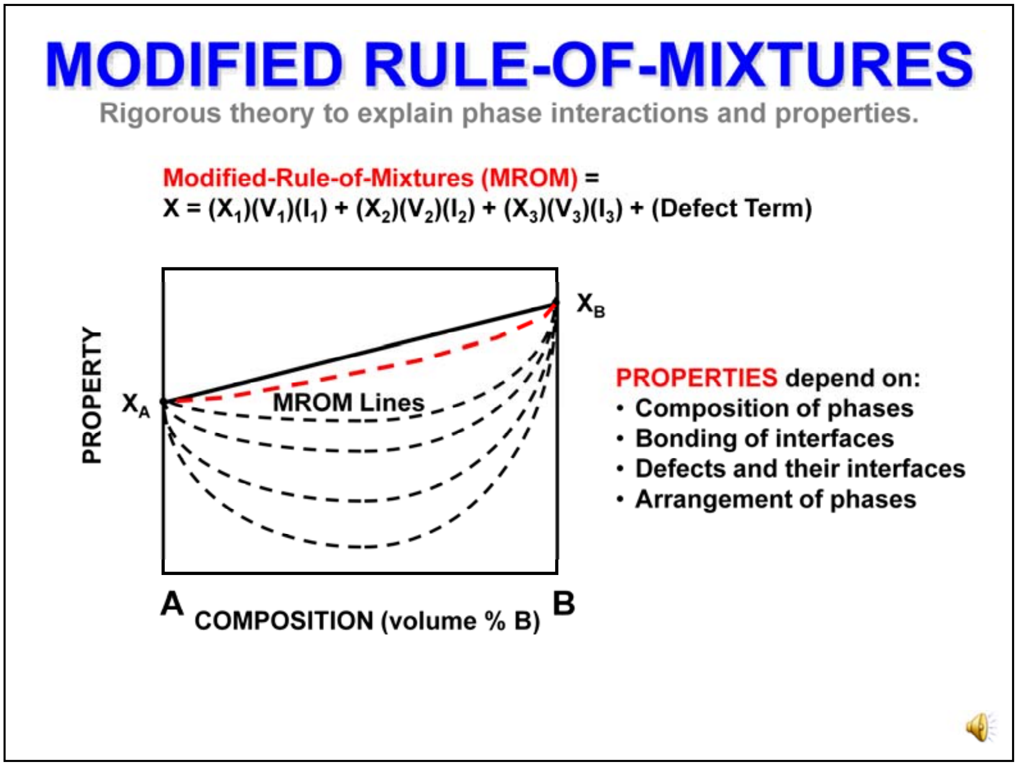
[CLICK] Structure of composites is well described in terms of the components or phases and the interfaces. **[CLICK]** The continuous or matrix phase connects all the pieces. **[CLICK]** The dispersed or filler phase is just that. **[CLICK]** There are internal interfaces between the continuous and dispersed phases. **[CLICK]** There is an external interface associated with the outside of the matrix. It is important to start learning this terminology because we will use it frequently.



The simplest approach to estimating the properties of a composite is by applying the **[CLICK]** rule-of-mixtures or ROM. **[CLICK]** It states that the "whole is equal to the sum of the parts" based on the volume contributions of the components. If the composite contains 50 volume % of A and 50 volume % of B, then its overall property should be derived half from A and half from B. **[CLICK]** If you multiply the phase property by the volume percentage for each phase or component and add them together, you arrive at the average property. This can be graphically represented by a line connecting the properties for A and B over the range of volume percentages possible for mixtures.

In some cases, this estimate of the composite properties is very close to the real properties, but often if is in error because it (1) assumes that the phases are all well-bonded together which they are not, and (2) assumes that the material is defect free. We will discuss these in just a second.

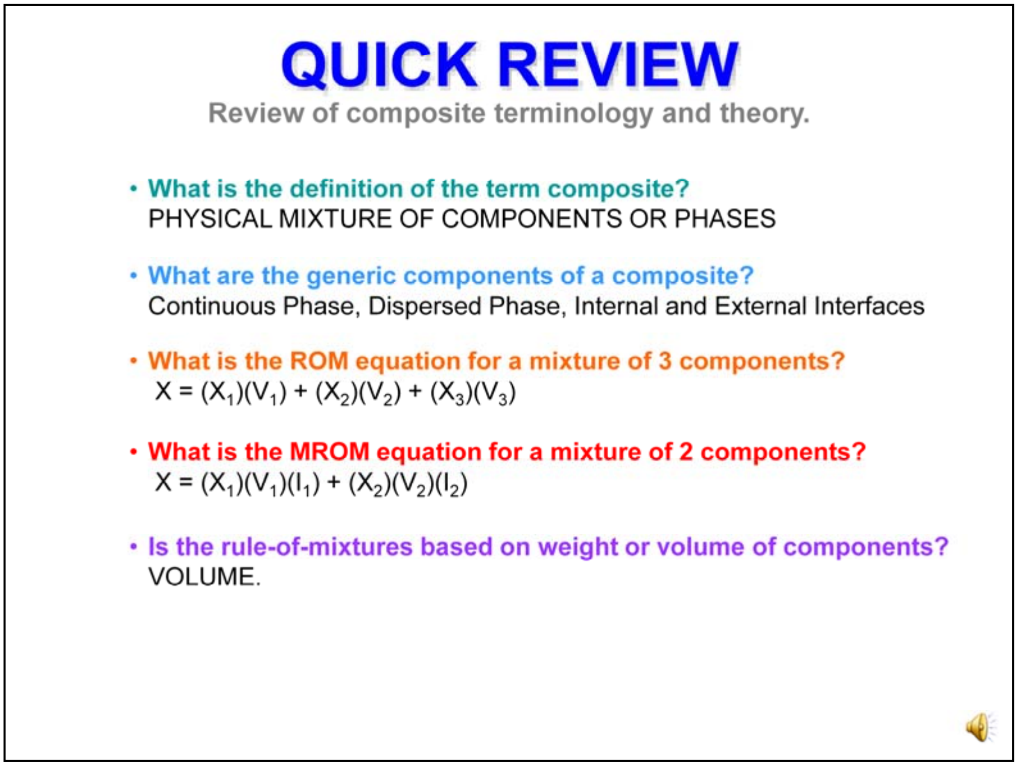
Consider a simple example where the tensile strength of A and B are 40 Mpa and 90 Mpa, respectively. Assume that you have a mixture of 60% A and 40% B. **[CLICK]** What is the predicted tensile strength for the composite? **[CLICK]** Use the formula to make the calculation. You would predict that the composite has a tensile strength of 60MPa but it may be less than that.



Now let's try to include consideration of the contributions of (1) interfacial effects and (2) defects. **[CLICK]** The rule-of-mixtures (ROM) is modified (MROM) to include an **[CLICK]** interfacial term (from 0 to 1) for each phase (e.g., $X_1V_1I_1$) and a defect term (for pores and cracks). The defects term is exponential that represents the rapid reduction in the estimated properties due to defects. You were exposed to this possibility earlier discussing pores and learned that 10-20% porosity can reduce the strength by a factor of 50%.

The resulting MROM curves represent negative departures from the ROM line and could be anyone of the types of curves shown in the diagram. As one can see, a badly formed mixture can become weaker than the weakest component and unacceptable. Draw an MROM curve that would represent all positive effects of the mixture on the resulting properties. **[CLICK]**

[CLICK] As we will see in the next module, it is crucial to provide BONDING to join the interfaces together and eliminate DEFECTS. There are still other factors that may affect the mixture's properties such as the distribution of sizes or ARRANGEMENT of dispersed particles. The final properties of any composite depends on the A-B-C-D information about the structure of the composite.



Here is a quick review of the concepts from this module.

[CLICK] (1) What is the definition of the term composite?
[CLICK]

[CLICK] (2) What are the generic components of a composite?
[CLICK]

[CLICK] (3) What is the ROM equation for a mixture of 3 components?
[CLICK]

[CLICK] (4) What is the MROM equation for a mixture of 2 components?
[CLICK]

[CLICK] (5) Is the rule-of-mixtures based on weight or volume of components?
[CLICK]

THANK YOU.