재료의 기계적 거동
(Mechanical Behavior of Materials)

Lecture 14 – Composite Materials

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Introduction

• We've addressed the improvement of the mechanical properties of materials by modifying the internal structure of the material system either by alloying or processing.

• We can also develop materials with even different properties by introducing additional phases/materials into a host material. This mixture of phases is termed a composite.

• In general, composites are relatively macroscopic mixtures of phases/materials. These mixtures are sometimes natural, but are generally artificial.

• By mixing two different phases or materials, we can develop materials that have properties which are an average of those of the two components.

Introduction

• In a composites, strength/properties = average of strength/properties of the individual materials. We design composites so as to obtain the best attributes of the individual constituents.

• Microstructure of a composite = matrix + reinforcement

–Matrix:

- phase that holds reinforcement together
- protects the reinforcement
- transmits load to the reinforcement.

–Reinforcement:

• filaments, fibers, whiskers, etc., which have intrinsically high strength and modulus ; reinforcements are often too brittle to use in monolithic forms. Sometimes "soft" reinforcements are used too.

Introduction

- **Interface between reinforcement and matrix is often the most critical element in determining materials properties and performance.**

- **Interface influences transfer of stress from matrix to fiber.**

- **Interface influences crack propagation.**

- **Chemical reactions in interface change the properties of the fiber and matrix locally as well as the chemistry.**

- **Stress concentration occurs.**

Classification of Composites

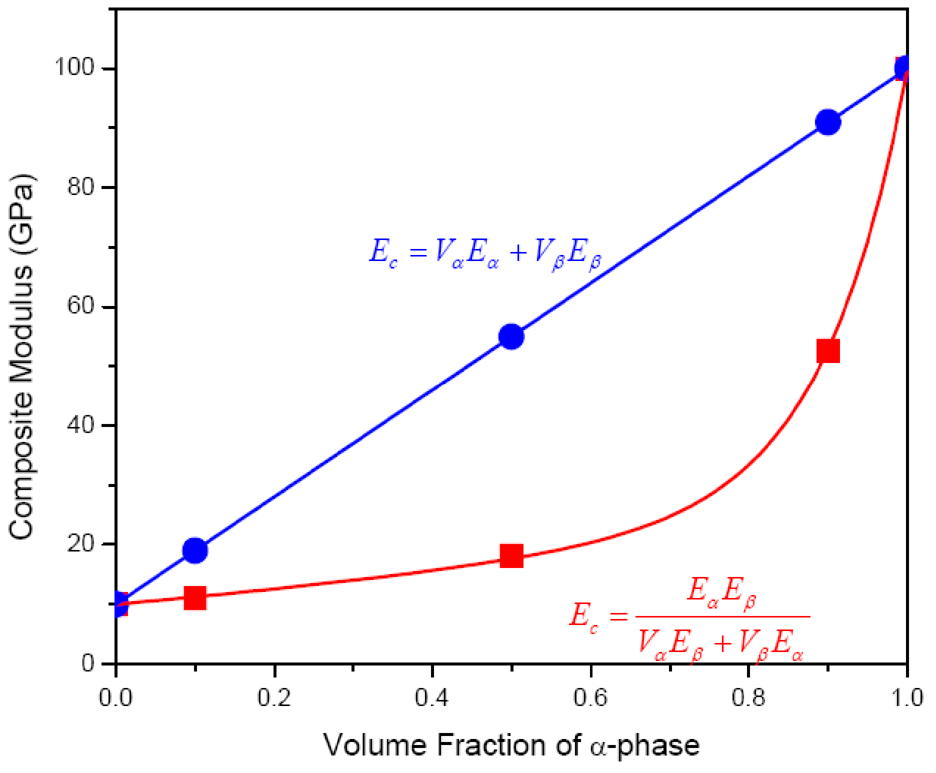
- **On basis of matrix:**

– Polymer matrix composites (PMCs)
– Metal matrix composites (MMCs)
– Ceramic matrix composites (CMCs)

- **On basis of reinforcement**

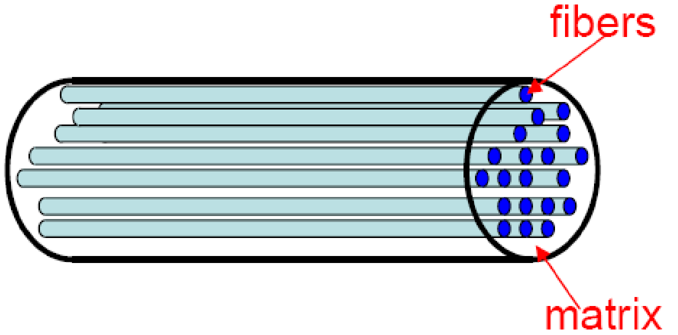
– Particle reinforced composites (e.g. Precipitates)
– Short fiber or whisker reinforced composites (e.g. Continuous fiber or sheet reinforced MMCs)

What do properties depend upon?

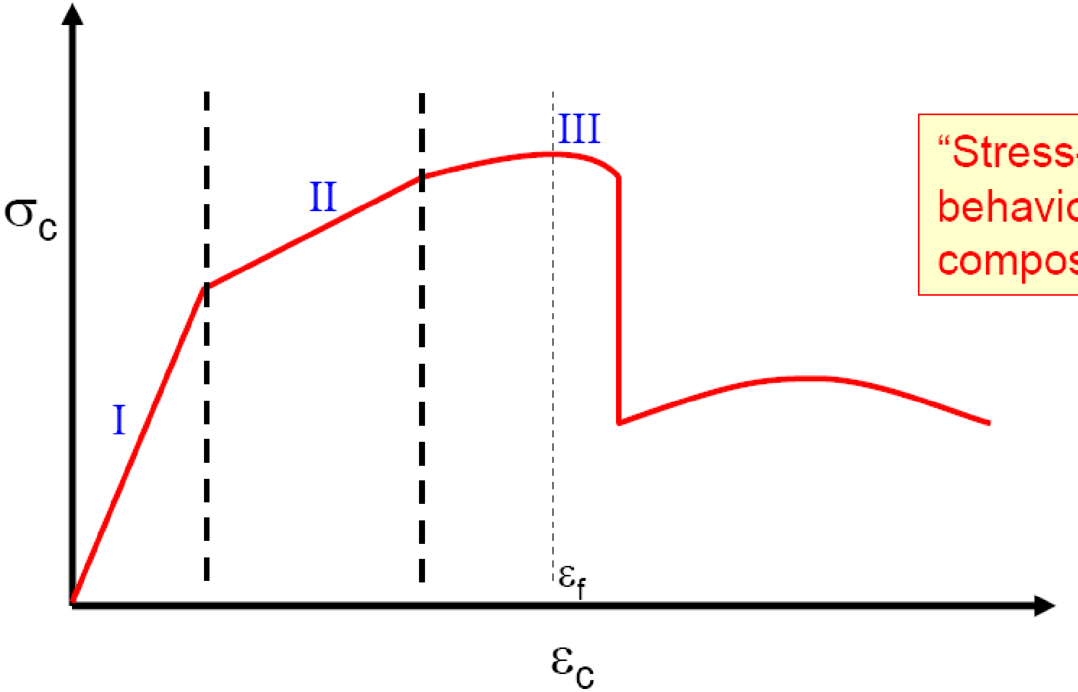


The blue curve shows the upper bound for modulus and the red curve shows the lower bound as calculated using the rule of mixtures. The moduli of particle-reinforced materials generally lies between the values predicted for laminate composites, but near the lower bound.

Reinforcement with continuous fibers

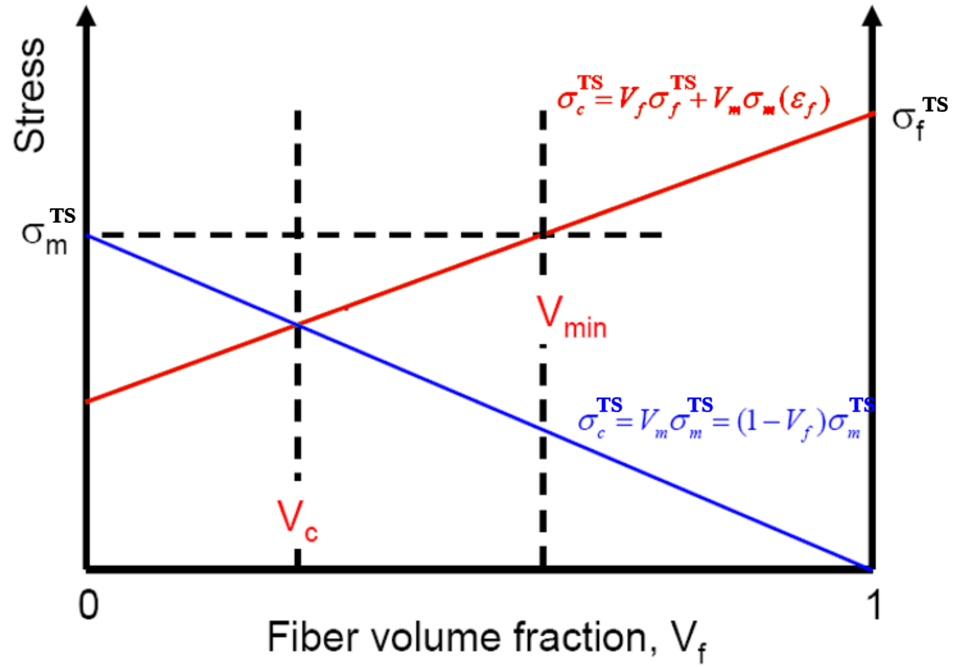


$$\sigma_c = V_f \sigma_f + V_m \sigma_m$$



"Stress-strain behavior is a composite too"

Reinforcement with continuous fibers (Tensile strength)



- V_c = critical volume fraction of fibers

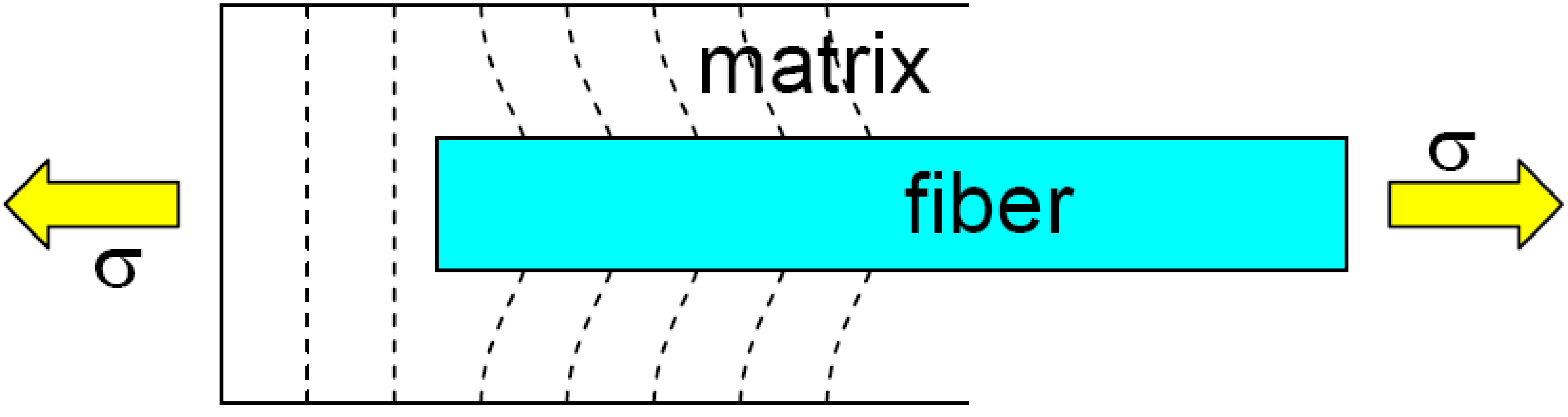
$$V_c = \frac{\sigma_m^{TS} - \sigma_m(\varepsilon_f)}{\sigma_f^{TS} + \sigma_m^{TS} - \sigma_m(\varepsilon_f)}$$

- V_{min} = minimum fiber volume fraction required to increase strength of matrix

$$V_{\min} = \frac{\sigma_m^{TS} - \sigma_m(\varepsilon_f)}{\sigma_f^{TS} - \sigma_m(\varepsilon_f)}$$

Typical values for V_c and V_{min} range from 0.02 to 0.10

Reinforcement with discontinuous fibers



- No load is transferred to the fiber at its ends.

- Load is transferred along the length of the fiber.

Reinforcement with discontinuous fibers

- In discontinuous fibers, there is a critical fiber length L_c for effective strengthening.

$$L_c = d_f \sigma_f / 2 \tau_{my}$$

where σ_f= tensile strength of fiber, τ_{my}= shear strength of fiber-matrix interface, and d_f= fiber diameter.

- Fibers that are shorter than the critical length have less strengthening per unit volume than continuous fibers.