Appendix: Test

Test Questions

This test consists of two parts covering a total of 6 pages. Part I consists of 16 multiple-choice questions. Part II consists of 17 questions in the conventional style.

Part I (32%)

Choose the best answer for each question.

1. (2%) In relation to structural vibration control, what is meant by active control?
   a) Use of a viscoelastic material.
   b) Use of a sensor.
   c) Use of an actuator.
   d) Combined use of a sensor and an actuator.
   e) Energy dissipation.
2. (2%) Flexible graphite is a flexible sheet that is all graphite. The fabrication of flexible graphite involves the following procedure:
   a) Intercalation.
   b) Exfoliation.
   c) Intercalation and exfoliation.
   d) Compression.
   e) Intercalation, exfoliation, and compression.
3. (2%) The fabrication of high-strength carbon fiber from pitch fiber involves the following procedure:
   a) Carbonization.
   b) Carbonization and graphitization.
   c) Stabilization and carbonization.
   d) Stabilization, carbonization, and graphitization.

4. (2%) What is the main advantage of pultrusion compared to compression molding for fabricating a continuous fiber polymer-matrix composite?
   a) Higher fiber volume fraction.
   b) Lower fiber volume fraction.
   c) Long length of the resulting composite.
   d) Composite has a constant cross-section.
   e) Unidirectional configuration.
5. (2%) The rule of mixtures expression for the modulus of a unidirectional continuous fiber composite is:
   a) $n = 0$ for the isostrain situation and $n = -1$ for the isostress situation.
   b) $n = -1$ for the isostrain situation and $n = 1$ for the isostress situation.
   c) $n = 1$ for the isostrain situation and $n = 0$ for the isostress situation.
   d) $n = 0$ for the isostrain situation and $n = 1$ for the isostress situation.
   e) $n = 1$ for the isostrain situation and $n = -1$ for the isostress situation.
6. (2%) Give an example of a glassy sealant that is used to improve the oxidation resistance of carbon–carbon composites.
   a) HfC
   b) B_2O_3
   c) Ni
   d) Si_3N_4
   e) SiC
7. (2%) Describe the process of liquid metal infiltration involved in the creation of a SiC particle aluminum-matrix composite.
   a) Mixing SiC particles with molten aluminum and subsequent casting.
   b) Mixing SiC particles with molten aluminum and subsequent spraying.
   c) A SiC particle preform is created and molten aluminum is forced into the preform.
   d) Mixing SiC particles and aluminum particles and subsequent hot pressing above the melting temperature of aluminum.
   e) Mixing SiC particles and aluminum particles and subsequent hot pressing below the melting temperature of aluminum.
8. (2%) Describe the coated filler method of power metallurgy that is used to create a SiC particle copper-matrix composite.
   a) Mixing SiC particles with molten copper and subsequent casting.
   b) Mixing SiC particles with molten copper and subsequent spraying.
   c) Mixing SiC particles and copper particles and subsequent hot pressing below the melting temperature of copper.

d) Hot pressing copper-coated SiC particles below the melting temperature of copper.

e) A SiC particle preform is created and molten copper is forced into the preform.

9. (2%) The rusting of iron in air involves the following anodic and cathodic reactions:

a) $Fe \rightarrow Fe^{2+} + 2e^{-}$; $O_2 + 2\,H_2O + 4e^{-} \rightarrow 4OH^{-}$

b) $Fe \rightarrow Fe^{2+} + 2e^{-}$; $O_2 + 4H^{+} + 4e^{-} \rightarrow 2\,H_2O$

c) $Fe \rightarrow Fe^{2+} + 2e^{-}$; $2H_2O + 2e^{-} \rightarrow H_2 \uparrow + 2OH^{-}$

d) $Fe^{2+} \rightarrow Fe^{3+} + e^{-}$; $O_2 + 2\,H_2O + 4e^{-} \rightarrow 4OH^{-}$

e) $Fe^{2+} \rightarrow Fe^{3+} + e^{-}$; $O_2 + 4H^{+} + 4e^{-} \rightarrow 2H_2O$

10. (2%) Figure A.1 shows specimen configurations for measuring the shear bond strength between a ceramic and a metal (e.g., steel). In Fig. A.1a, the ceramic is bonded to only one side of the metal. In Fig. A.1b, the ceramic is bonded to both sides of the metal. The configuration in Fig. A.1b is advantageous compared to that in Fig. A.1a. Give the main reason.

a) Larger joint interface area.

b) Larger amount of ceramic.

c) More brazing material.

d) The steel is better protected.

e) No bending moment during shear.

11. (2%) Why are both fine and coarse aggregates used in concrete?

a) To attain a low total aggregate volume fraction.

b) To attain a high total aggregate volume fraction.

c) To decrease the fluidity of the mix.

d) To increase the fluidity of the mix.

e) To increase the rate of curing.

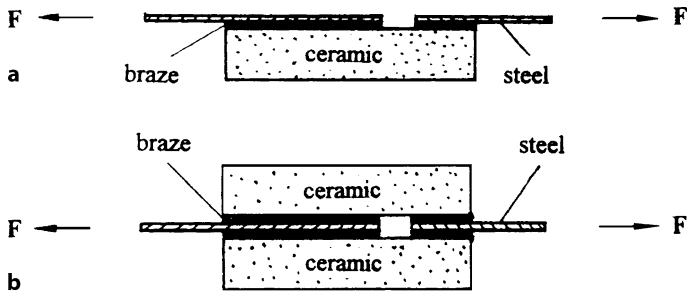


Figure A.1. Specimen configurations for measuring the shear bond strength between a ceramic and a metal (e.g., steel). **a** Ceramic is bonded to one side of the metal only. **b** Ceramic is bonded to both sides of the metal

12. (2%) What is the main advantage of using activated carbon fiber rather than activated carbon particles for water purification?
    a) Faster water flow.
    b) Greater surface area.
    c) Larger pores.
    d) Higher strength.
    e) More flexibility.
13. (2%) Why are polymers typically advantageous compared to ceramics when used as electrically insulating layers in microelectronics?
    a) Higher thermal conductivity.
    b) Higher coefficient of thermal expansion.
    c) Lower coefficient of thermal expansion.
    d) Lower value of the relative dielectric constant.
    e) Higher value of the relative dielectric constant.
14. (2%) A Bingham plastic refers to the following:
    a) A material that exhibits Newtonian behavior.
    b) A material that exhibits elastic behavior.
    c) A material that exhibits shear yielding.
    d) A material that exhibits shear thinning.
    e) A material that exhibits shear thickening.
15. (2%) In relation to viscoelastic behavior, the quantity $\tan\delta$ refers to the following:
    a) The ratio of the storage modulus to the loss modulus.
    b) The ratio of the loss modulus to the storage modulus.
    c) The magnitude of the shear modulus.
    d) The product of the magnitude of the shear modulus and $\sin\delta$.
    e) The product of the magnitude of the shear modulus and $\cos\delta$.
16. (2%) A remendable polymer is:
    a) A thermoplastic polymer.
    b) A thermosetting polymer.
    c) A polymer that melts upon heating.
    d) A polymer that decomposes upon heating.
    e) A polymer for which the degree of crosslinking decreases reversibly upon heating.

Part II (68%)

1. (4%) Name two main advantages of high-modulus carbon fiber compared to high-strength carbon fiber.
2. (4%) A piezoresistive material exhibits a gage factor of 22. The gage factor is defined as the fractional change in resistance per unit strain. A piece of this material has a resistance of 46 Ω. What is its resistance when the strain is 4.5%?
3. (4%) A unidirectional continuous fiber composite contains fibers of modulus 3.4 GPa. The fiber volume fraction is 57%. The modulus of the matrix is 0.12 GPa. Assuming that the bonding between the fiber and the matrix is perfect, calculate the modulus of the composite in the longitudinal direction (i.e., in the fiber direction).
4. (4%) In relation to carbon materials, the inhibition factor of a treated carbon is defined as the ratio of the oxidation rate of untreated carbon to the oxidation rate of the treated carbon. The oxidation rates are 9.9%/min for the untreated carbon and 2.8%/min for the treated carbon. Calculate the inhibition factor.
5. (4%) The rate r of a thermally activated process relates to the activation energy Q of the process by the equation

$$r = A\mathrm{e}^{-Q/RT}$$

   where T is the temperature in K (not in °C), R is the gas constant (a universal constant equal to 8.314 J/(mol K)) and A is just a proportionality constant. The rate at temperature T_1 is r_1 and the rate at temperature T_2 is r_2. Derive an expression for Q in terms of T_1, T_2, r_1 and r_2.
6. (4%) Using a graph, define the plastic viscosity and the apparent viscosity.
7. (4%)

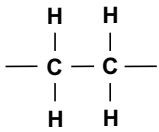
$$\tau = \eta\,,$$
$$\tau = \tau_\mathrm{o}\mathrm{e}^{\mathrm{i}\omega t}\,,$$
$$\gamma = \gamma_\mathrm{o}\mathrm{e}^{\mathrm{i}(\omega t-\delta)}$$

   In the above equations that pertain to viscoelastic behavior, τ is the shear stress, γ is the shear strain, and η is the viscosity. Derive the equation

$$|\eta| = |G|/\omega\,,$$

   where G is the shear modulus.
8. (4%) Using a graph of stress versus strain, explain the phenomenon of pseudoplasticity.
9. (4%) A brittle material is much stronger under compression than under tension. Explain the scientific origin of this phenomenon.

10. (4%) Polyvinyl chloride is stiffer than polyethylene. Explain the scientific origin of this observation. Note that the mer of polyethylene is



while the mer of polyvinyl chloride is the same as this except that one for the four hydrogen atoms has been replaced with a chlorine atom.

11. (4%) What are the main problems with the method of self-healing involving microcapsules of a monomer?
12. (4%) Describe an effective method of improving the vibration damping ability of a continuous carbon fiber polymer-matrix composite.
13. (4%) Why does the time spent below the melting temperature prior to bonding affect the quality of the bond for polyphenylene sulfide (PPS)?
14. (4%) Why is aluminum foil sufficiently temperature resistant that it can be used in cooking?
15. (4%) Why does corrosion tend to occur in a fastened metal joint?
16. (4%) Why does sand blasting help to improve the corrosion resistance of steel rebars?

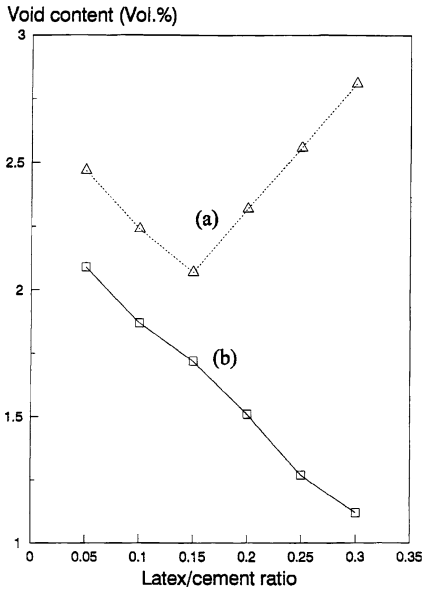


Figure A.2. Effect of the latex/cement ratio on the air void content of cement paste: **a** with 0.53 vol% carbon fibers; **b** with no fibers

17. (4%) Figure A.2 shows the effect of the latex/cement ratio on the air void content of cement paste. Curve (a) is for the case with 0.53 vol% carbon fibers. Curve (b) is for the case without fiber. Explain the features of curve (a) in terms of their scientific origin.

Test Solutions

Part I (32%)

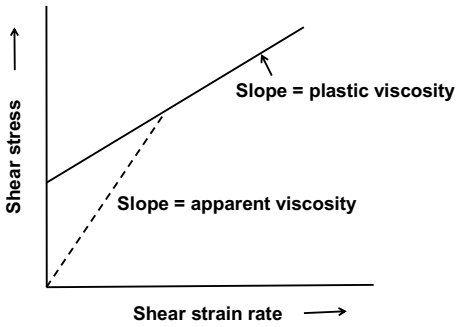
The correct answers are:

1. d
2. e
3. c
4. c
5. e
6. b
7. c
8. d
9. a
10. e
11. b
12. a
13. d
14. c
15. b
16. e

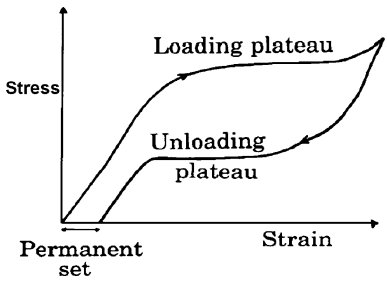
Part II (68%)

1. Any two of the following answers are acceptable: higher modulus; higher thermal conductivity; higher electrical conductivity; higher oxidation resistance.
2. $[(R - 46)/46]/4.5\% = 22$
   $(R - 46)/46 = 0.99$
   $R - 46 = 45.54$
   $R = 91.5\Omega$.
3. Modulus = (0.57) (3.4 GPa) + (0.43) (0.12 GPa) = 2.0 GPa.
4. Inhibition factor = 9.9%/2.8% = 3.5.

5. $r_1 = A\,\mathrm{e}^{-Q/RT1}$
   $r_2 = A\,\mathrm{e}^{-Q/RT2}$
   $r_1/r_2 = \mathrm{e}^{-Q/RT1}/\mathrm{e}^{-Q/RT2} = \mathrm{e}^{-Q/RT1+Q/RT2}$
   $\ln(r_1/r_2) = -Q/RT_1 + Q/RT_2 = -(Q/R)[(1/T_1) - (1/T_2)]$
   $Q = -R\ln(r_1/r_2)/[(1/T_1) - (1/T_2)]$.
6. The graph defining the plastic viscosity and the apparent viscosity should look like this:

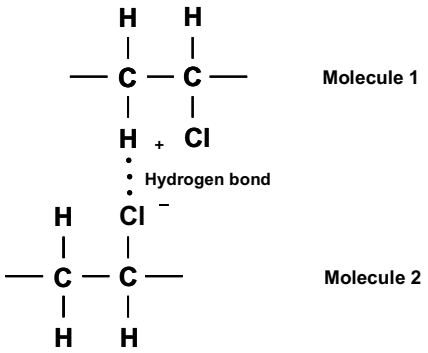


7. $\dot{\gamma} = \gamma_o \mathrm{i}\omega \mathrm{e}^{\mathrm{i}(\omega t-\delta)}$
   $\eta = \tau_o \mathrm{e}^{\mathrm{i}\omega t}/\left[\gamma_o \mathrm{i}\omega \mathrm{e}^{\mathrm{i}(\omega t-\delta)}\right] = -\mathrm{i}(|G|/\omega)\mathrm{e}^{\mathrm{i}\delta}$
   $|\eta| = |G|/\omega$.
8. A graph of stress versus strain that explains the phenomenon of pseudoplasticity should look like this:



9. The microcracks that tend to be present in a brittle material propagate much more under tension than under compression.

10. In PVC, there is hydrogen bonding (secondary bonding) between a hydrogen of one molecule and the chlorine of another molecule (the following diagram is not required):



11. Toxicity of the monomer; high cost of the catalyst.
12. Add either a viscoelastic material or a nanofiber material to the composite at the interlaminar interface (mentioning either material is sufficient).
13. PPS is a thermoplastic that has thermosetting character, so it cures to a limited degree as it spends time below the melting temperature prior to bonding.
14. It is covered with a nonporous protective layer of aluminum oxide.
15. The reduced availability of oxygen at the crevice in the fastened joint results in an oxygen concentration cell, meaning that the crevice region becomes the anode.
16. Sand blasting removes the impurities on the surface of the rebar, thus resulting in a more uniform surface composition.
17. The decrease in void content as the latex/cement ratio increases up to about 0.15 is due to the latex. The increase in void content as the latex/cement ratio increases beyond about 0.15 is due to the decreasing degree of fiber dispersion. (Fiber clumping increases the void content.)

Index