1. (8%) Give a good physical reason for the following statements: (a) Elements that are soluble in all proportions in the solid state have the same crystal structure. (b) Unlike substitutional solid solutions, interstitial solid solutions do not range over all compositions.

2. (10%) If Ti atoms assume an FCC array and all octahedral interstices are occupied by C atoms, we have the structure of TiC. Sketch the unit cell of TiC and compare this with the NaCl structure unit cell. TiC is largely metallic with some covalent bonding character, where NaCl is ionic. In terms of bonding and atomic or ionic sizes, explain why identical structures result for TiC and NaCl.

3. (10%) An inorganic glass can be strengthened by the following treatment. After the glass is heated above the softening point, its surface is cooled rapidly by blasts of air or an oil bath, while the interior remains at a higher temperature. When the temperature becomes uniform throughout, the resulting tempered glass exhibits a greater strength than would be realized with more uniform, slower cooling. Why?

4. (10%) CaO can dissolve into ZrO₂ because Ca²⁺ and Zr⁴⁺ have nearly the same size. There is a 15/85 ratio of Ca²⁺/Zr⁴⁺. The charge is balanced by O²⁻ ion vacancies. Write an equation showing the defect reaction and explain it in terms of the mass balance, electro-neutrality and preservation of regular site ratio. What is the ratio of O²⁻ ion vacancies to O²⁻?

5. (10%) The inherent brittleness of regular ceramics and glass can lead to mechanical failure by thermal shock, but glass-ceramic materials, such as Corning’s Corning Ware, can withstand thermal shock. Explain the reason based on the microstructure and properties.
6. (10%) In a phosphorus-doped \((n\text{-type})\) silicon, the Fermi level \((E_F)\) is shifted upward 0.1 eV. What is the probability of an electron’s being thermally promoted to the conduction band in silicon \((E_g = 1.107 \text{ eV})\) at room temperature \((25 \text{ degC})\)?

7. (12%) (a) Make a schematic illustration of the lithography and etching process steps for producing fine metal pattern on a silicon wafer covered with dielectric film; (b) Explain Moore’s law; (c) What techniques can be used in the lithography process in the upcoming and future production of advanced devices? (d) Explain with examples (1) homoepitaxy and (2) heteroepitaxy.

8. (10%) The thermal behaviors of polymers include crystallization, glass transition, melting, decomposition, and cross-linking. The differential scanning calorimeter \((\text{DSC})\) is used to observe those transition behaviors. Based on the following DSC thermogram, indicate the representative behavior for transitions \((A) \sim (E)\).
9. (10%) Two monomers A and B are copolymerized via different polymerization methods. The obtained polymers can be classified into five different types of copolymers, i.e. random, alternating, block, graft, and cross-linked copolymers. Please draw them.

10. (10%) Infrared and Raman spectroscopies are both useful for structural characterization of organic materials. Please compare these two spectroscopic techniques by (a) physical behavior of incident light; (b) light source; (c) sample preparation; (d) influence of water; and (e) sample damage from light source.