UNIVERSITY OF GHANA

SCHOOL OF ENGINEERING SCIENCES

BSc. (ENG) FIRST SEMESTER EXAMINATIONS: 2014/2015

MTEN 407 ENGINEERING CERAMICS II (2 Credits)

TIME ALLOWED: 2 Hrs 30 Mins

ANSWER ALL QUESTIONS

Question 1

The inherent brittleness of ceramics makes special considerations necessary in designing with these materials. Several companies are conducting research programs aimed at increasing the ductiiity, or toughness, of ceramic materials. The directions that appear most promising involve transformation toughening and reinforcing the matrix with a dispersed phase such as fibers or whiskers.

a) Briefly discuss the brittle fracture of ceramics.

b) (i) What is micro-cracking mechanism?

(ii) How can this mechanism lead to increased fracture toughness?

c) How are silicon-nitride fibers in a silicon-carbide structure processed?

d) Why is reaction bonded silicon carbide not suitable for very high temperature exceeding 1350°C?

e) Mention one distinguishing feature between boron carbide and silicon carbide ceramics in terms of their mechanical properties. Give one important application of boron carbide.

25 Marks

Question 2

Pure ZrO_2 exhibits a phase transformation from the tetragonal structure to the monoclinic structure at 950°C. This transformation induces a volume increase of about 4-6% which can result in a catastrophic fracture and, hence, structural unreliability of the fabricated components;

a) Explain a method on how to produce thermally stable and comparatively strong ZrO_2 pieces.
b) Describe two transformation induced toughening mechanisms in ZrO_2.
c) Although Al_2O_3 has a high stiffness, it shows a brittle character with a low stress intensity factor (K_{Ic}). What would you suggest to increase the toughness of Al_2O_3?
d) Explain the use of Al_2O_3 as catalytic fuel in the Clauss process for converting hydrogen sulphide waste gases into elemental sulphur in refineries?

25 Marks

Question 3

a) Why would dense solid state sintered silicon carbide be a better choice of material for an application requiring the ability to withstand a load at 1600° C than pure sintered alumina?
b) Ceramic engines continue to constitute an area of considerable interest and are frequently discussed in popular literature. If perfected, they would allow higher operating temperatures with an increase in engine efficiency. In addition, they would lower sliding friction and permit the elimination of radiators, fan belts, cooling system pumps, coolant lines, and coolant. The net result would be reduced weight and a more compact design. Estimated fuel savings could amount to 30% or more.

(i) What are the primary limitations to the successful manufacture of such a product?
(ii) What types of ceramic materials would you consider to be appropriate?

c) A high strength glass-ceramics with negligible thermal expansion co-efficient (TEC} is now being used as cook top.

(i) Explain the process by which the negligible thermal co-efficient is achieved
(ii) At what percentage crystalline phase does the glass-ceramic attain a net TEC near zero?

25 Marks

Question 4

The strategies for achieving ceramics with improved mechanical properties, especially toughness, include the engineering of microstructures that either resist the propagation of cracks or absorb energy during the crack propagation process. Both goals can be achieved simultaneously in microstructures with fibrous or interlocked grains.

a) Explain a mechanism on how engineering of microstructures is used to achieve improved toughness in such ceramics.
b) Define fracture toughness; and compare the relative fracture toughness of conventional ceramics with ceramics that have fibrous or interlocked microstructures and particle-reinforced composites (ie. engineering ceramics).
c) Explain why transformation-toughened zirconia ((TTZ) ball bearings can be repeatedly bounced on concrete floors without noticeable surface damage.
d) How is increased fracture toughness achieved with micro-cracking mechanism?
e) What are some ceramic materials that are currently being used for cutting-tool applications, and what features or properties make them attractive?

25 Marks