UNIVERSITY OF GHANA

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BSc. MATERIALS SCIENCE AND ENGINEERING

FIRST SEMESTER EXAMINATION: 2016/2017

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MTEN 407: ENGINEERING CERAMICS (2 Credits)
INSTRUCTIONS: ANSWER ANY THREE QUESTIONS

TIME ALLOWED: TWO HOURS (2 hrs)

1. (a) Mention two ceramic materials that can be used in the following applications;
   (i) Solid Oxide fuel cells (ii) Oxygen Sensors [3 marks]

   (b)
   (i) Draw Current –Voltage (I-V) characteristic of an Ideal varistor [2 marks]

   (ii) Explain its function in terms of protecting circuits from high voltage transients [5 marks]

   (iii) Explain why metal oxides are preferable as Varistors. [3 marks]

   (c) The figure below shows the introduction of a varistor (VDR) with $\alpha = 5$ and a characteristic such that the current through it with switch is 0.024 A so that $K_I = 0.024/(24)^5$. When the switch is opened the instantaneous current through VDR is approximately 0.24 A since the impedance of the capacitor is very large (about 22k Ω).

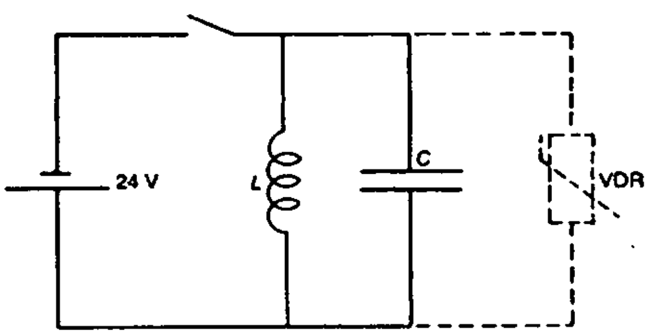

Figure 1: Use of a varistor (VDR) in a highly inductive circuit.

Calculate:

(i) Maximum instantaneous voltage if the maximum energy stored in capacitor (with capacitance 100pF) equal to that stored in inductor (Inductance 0.05 H). Is the voltage sufficient to cause a spark and consequent damage?

(ii) The resulting voltage across the voltage dependent resistor (VDR)
(iii) The new total voltage across the switch. What is the significance of the VDR in relation with this total (new) voltage? [7 marks]

2. (a) Give the elements and some principal applications of;
(i) Cordierite
(ii) Sialon [4 marks]

(b) 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;
(i) In spite of this fact, explain a method on how to produce stable and comparatively strong ZrO_2 pieces. [5 marks]
(ii) Describe two transformation induced toughening mechanisms in ZrO_2. [4 marks]

(c) (i) What is the main driving force that is responsible for the strength of non-oxide ceramics? [2 marks]
(ii) What is the main purpose of adding graphite to sintered silicon carbide (SSiC)? [3 marks]
(iii) On what account is the mechanical strength of hot-pressed and isostatically-pressed silicon carbides much better than pressureless sintered silicon carbides? [2 marks]

3. (a) (i) Explain liquid phase sintering as associated with Silicon Nitride. [2 marks]
(ii) Describe the stages involved in the transformation of $\alpha - Si_3N_4$ to $\beta - Si_3N_4$. [6 marks]

(b) (i) Give the differences between $\alpha - Si_3N_4$ and $\beta - Si_3N_4$. [2 marks]
(ii) Explain how the toughened Silicon Nitride can be achieved. [2 marks]
(iii) Why is liquid phase sintered silicon carbide (LPSiC) much stronger mechanically than solid state sintered silicon carbide (SSiC)? [2 marks]

(c) 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? [6 marks]

4. (a) If all significant flaws or defects could be eliminated from the structural ceramics, what properties might be present and what features might still limit their possible applications? [3 marks]

(b) The strength (MPa) for various engineering ceramics is shown in table 1. Find the;

(i) Average strength of the Y-TZP material,

(ii) Standard deviation of the Al_2O_3 material,

(iii) Standard deviation of the Al_2O_3-SiC material.

(iv) Estimate the probability that Si_3N_4 material will fracture at 716 MPa.

Table 1. Strength data for some selected engineering ceramics

Si_3N_4	Y-TZP	Al_2O_3	Al_2O_3-SiC
710	925	272	584
835	840	410	572
740	1048	402	615
680	1012	320	567
815	970	371	586
764	937	315	602
615	865	418	593
632	1071	351	595
716	992	335	582
682	914	380	562
790	980	248	578
702	894	307	604
734	917	480	585
602	968	218	574
728	957	385	598

[8 marks]

(c) (i) 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? Explain your answer. [3 marks]

(ii) Mention and briefly explain factors that affect ionic conductivity in ceramics. [6 marks]