MatE 115 G. Selvaduray
Fall 2006 November 9, 2006

SECOND MID-SEMESTER EXAMINATION

There are 5 questions. Please answer all questions. Answers to questions must be supported by evidence, either in the form of calculations or reasoning and logic. One word or single number answers ***will not*** receive any credit.

Each question is worth 20 points, for a total of 100 points.

You are permitted to use your textbook, class notes, homeworks and homework solutions, and class handouts only. ***No other material may be used.***

Question 1

The oxide of aluminum, Al_2O_3, is commonly used as a substrate for mounting Si chips because of its electrical insulating properties. Al_2O_3 can be purchased in several grades of purity, with the primary contaminant being FeO.

(a) Please identify the type(s) of defects, if any, which would be created in Al_2O_3 as a result of FeO contamination. (*10 points*)

(b) Y_2O_3 stabilized ZrO_2 is the membrane (or electrolyte) that is used in oxygen sensors in the catalytic convertors in automobiles. Because this material can be quite expensive, a prominent scientist has proposed that the Al_2O_3 substrates with FeO contaminants (or solutes) can be used instead. Please evaluate this scientist's proposition. (*10 points*)

Question 2

AlN is a material of great interest because of its high thermal conductivity, coupled with being a ceramic material with very low electrical conductivity. You are commissioned with the task of sintering an AlN disk that is 1 mm thick and 5 mm in diameter. The AlN powders that you are working with have a mean particle diameter of 5 μm. Upon sintering these powders you find that the shrinkage is approximately 25%. Your assignment is to reduce the shrinkage during sintering.

(a) Please suggest and develop avenues that you might pursue to reduce the shrinkage during sintering. (*10 points*)

(b) In what way will your "solution" affect the driving force for sintering? (*10 points*)

Question 3

"Fool's Gold" is a term that was very common during California's Gold Rush era. The miners who were looking for gold frequently mistook iron pyrite for gold because of the similarities in the color. Iron pyrite has the chemical formula of FeS_2, and is in the cubic crystal system.

(a) Suggest a crystal structure for FeS_2. (*10 points*)

(b) Draw a unit cell showing the location of the Fe and S ions. (*10 points*)

Question 4

The metal Sn (tin) has two crystallographic structures. Below 13.2°C its structure is diamond cubic, with a = 6.4892 Å, and it is called α-Sn or gray-Sn, with 8 atoms/unit cell. Above 13.2°C its structure is body-centered tetragonal, with a = 5.8315 Å and c = 3.1814 Å, and it is called β-Sn or white-Sn, which has 4 atoms/unit cell. α-Sn and β-Sn are polymorphs of Sn.

(a) Is the polymorphic transformation enantiotropic or monotropic? (*5 points*)

(b) Is this transformation a 1^{st} order or 2^{nd} order phase transformation? (*5 points*)

(c) If β-Sn is cooled down to below 13.2°C would you expect to see a volumetric expansion or contraction? (*5 points*)

(d) Would you expect the α-Sn to β-Sn transformation to be "dilatational" or "reconstructive"? (*5 points*)

Question 5

(a) Copper has a melting point of 1085°C and Ni has a melting point of 1455°C. Two wires, one of Cu and one of Ni, each having a diameter of 1 mm and length 20 cm is heated to 700°C. Which of the two wires would have a higher concentration of vacancies? (*10 points*)

(b) A good friend of yours suggests that you use Monel – a 30% Ni-70%Cu alloy as an electrical conductor, rather than OFHC copper, because the Monel has higher strength. What is your response to this suggestion? (*10 points*)