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Fall 2019, Ceramics (5000/4000 level course)

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•The course is divided into the following topics. The topics concentrate mostly (but not exclusively) on zirconia as the ceramic material of interest.

I. Elastic deformation and fracture
II. Sintering and Superplastic Forming
III. Electrochemical applications: fuel cells, batteries, gas sensors, gas separation and catalysis

•For each topic you will have practice homework questions which you may work on by yourself or with friends. These will not be graded, but I can discuss the answers in class (no written solutions).

•At the end of each topic you will have an in-depth take home HW (essentially like an exam). You will have ten days to submit your answers (e.g. Monday to Friday of the following week).

•Each such take home HW will carry 25% of the grade.

•The remaining 25% will be based upon a 15-20 min presentation on a topic of your choice (towards the end of the semester). I will provide feedback on your presentations starting in early November so please submit your preliminary ppt file by then.

HW-TakeHomeExam-1 Elasticity and Transformation Toughening

Please submit your solutions on Monday, October 07 during class. Please do not consult others when doing this exam. It is a take home exam. This take home carried 25% of the grade. All questions carry equal weight.

1. In one page draw and/or write *five* iconic sketches and/or equations which you feel embody the subject matter we discussed in class during this first phase of the course. Explain each “object” in two lines of text.

2. Consider a simple uniaxial tensile test where the response is related to the Youngs Modulus and the Poisson’s Ratio. Show that B, the bulk modulus is related to E and ν by

$$B = \frac{E}{3(1-2\nu)}$$

3. Why is a threshold strain a better "universal" parameter to describe fracture and plastic yielding, instead of fracture-stress or yield-stress for each material?

4. Show that the incremental expansion of small crack in an elastically deforming body always leads to the consumption of energy, whether the experiment is carried out under constant load or constant displacement.

5. Consider a penny shaped crack, of diameter $2c$, in an elastically deforming body which is loaded with a uniaxial tensile stress, σ. Derive that

$$2\gamma_F = \frac{2K_{IC}^2}{2E} \qquad (1)$$

Where $K_{IC} = \sigma_{crit}\sqrt{2c}$.

6. The force displacement relation for a cantilever of length L, width w and thickness h, with a load P applied to the free end is given by

$$y = P^* \frac{4L^3}{3Ewh^3} \qquad (2)$$

Note that P^* here has units of Newtons. The force per unit width of the beam is then

$$P = \frac{P^*}{w} \qquad (3)$$

Now consider a double cantilever beam specimen used to measure the work of fracture of the material. In this instance the crack length, c, is equal to L. Further the force per unit length of the crack front is given by the Eq. (2) just above.

If fracture occurs at $P = P_{crit}$ then show that the work of fracture is given by

$$2\gamma_F = \frac{P^2}{2}\frac{dS}{dc}$$

where S is the compliance.

Remember that in a double cantilever beam the total displacement is twice the displacement given by Eq. (2).

7. Combine Eqns (1), (2) and (3) to obtain a relationship between the geometry of the double cantilever beam design of the fracture experiment, the critical load to fracture, and K_{IC}. Use this equation to design the geometry of a double cantilever beam made from glass when its fracture toughness is 1 MPa $m^{1/2}$, and the Elastic modulus of the glass is approximately 100 GPa.

8. Give the reason why the fracture toughness measured in plane strain experiments is always lower than the fracture toughness measured in plane stress experiments.

9. Write a brief essay, about one page long, with equations and one or two sketches that describe sub-critical crack growth in glass when submerged in a solvent such as water or methanol or aniline. Start with a list of clearly defined parameters in this phenomenon that you discuss later in your brief.