ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2016 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

14-CH-B3 ADVANCED MATERIALS

Question 1 (20 pts.):

In the context of additive manufacturing of metals and alloys, a) compare Direct Metal Laser Sintering with Binder Jetting by identifying 3 advantages and disadvantages of each technology (10 pts); b) compare the microstructure you can expect from the latter two technologies in the as-manufactured condition (5 pts); c) Identify secondary operations that could be used to further improve the final microstructures of components produced using these two technologies (5 pts).

Question 2 (20 pts.):

« A US research project lead by UCLA is developing methods to produce room temperature ductile ceramics. The study suggests they could be developed based on transition-metal carbides and possibly transition-metal nitrides, which have similar structures. The team performed compression tests on single crystals of two transition-metal carbides, zirconium carbide and tantalum carbide, inside a transmission electron microscope. They observed that the crystals deformed — that is, they changed shape without cracking — at room temperature. The compressive stress in the material exceeded 20GPa at room temperature. » Identify at least 4 engineering applications that could benefit from the development of ductile ceramics (clearly justify your selection).

Question 3 (20 pts.):

A unidirectional fiber composite containing 60%-vol of HMS-4 carbon fibers (E=345 GPa) in an MA-24 epoxy matrix (E=3.45 GPa) has a young's modulus of 208 MPa. Knowing that Young's modulus of single-wall carbon nanotubes is 1 TPa, a) Determine the theoretical Young's modulus that could be expected from a composite material made of MA-24 epoxy and 60%-vol. of single-wall carbon nanotubes (5 pts); b) Would you anticipate problems related to the manufacturing and shaping of the composite discussed in a) (give a precise and detailed explanation) (15 pts)?

Question 4 (20 pts.):

Give a clear and concise explanation as to the effect of the following parameters on the Glass Transition Temperature of industrial polymers:

a) %-wt of plastifier;
b) isomerism;
c) lateral groups;
d) segment polarity;
e) crystallinity;

Question 5 (20 points):

The performance of any material in the human body is controlled by two sets of characteristics: biofunctionality and biocompatibility. Based on this statement, identify materials (Ex: ceramics, polymers, metals) or combinations of materials, that would be best suited to be used in the following biomedical applications (give a clear and concise explanation for each one):

a) Dental implants;
b) Heart valves;
c) Coronary stents;
d) Hip prostheses;
e) Breast implants;