

Answer 1 Question only

1. Figures 1 and 2 show partial isothermal sections and respective liquidus plans for two Ni-base alloy systems. As an alloy designer what alloy compositions in these two systems would you choose for investigation for possible high temperature-high strength applications? Give your reasons for each choice, which can be different for different types of application (specify which application for each composition selected), and make use of the following information:

<u>Element</u>	<u>Density g cm⁻³</u>
Ni	8.9
Al	2.7
Hf	13.1
Mo	10.2

2. a) How does the ductility of refractory metals vary as a function of temperature?
- b) What is the effect of interstitial content on the mechanical properties of Ti and its alloys?
- c) What are conceptual and evolutionary alloy design? Give an example of each.
- d) Explain the effect of grain size on the creep rate of Nickel from the deformation mechanism maps shown in the Figure 3.

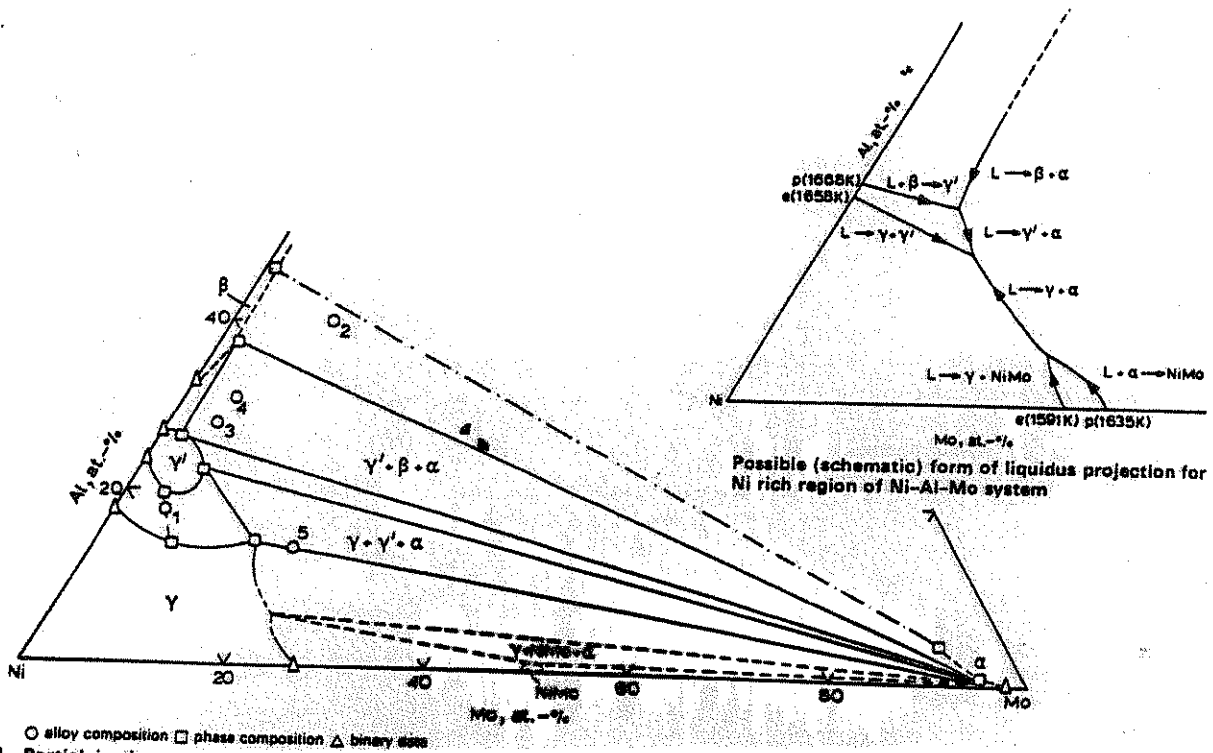


Figure 1. Isothermal section of the Al-Mo-Ni system at 1473K.

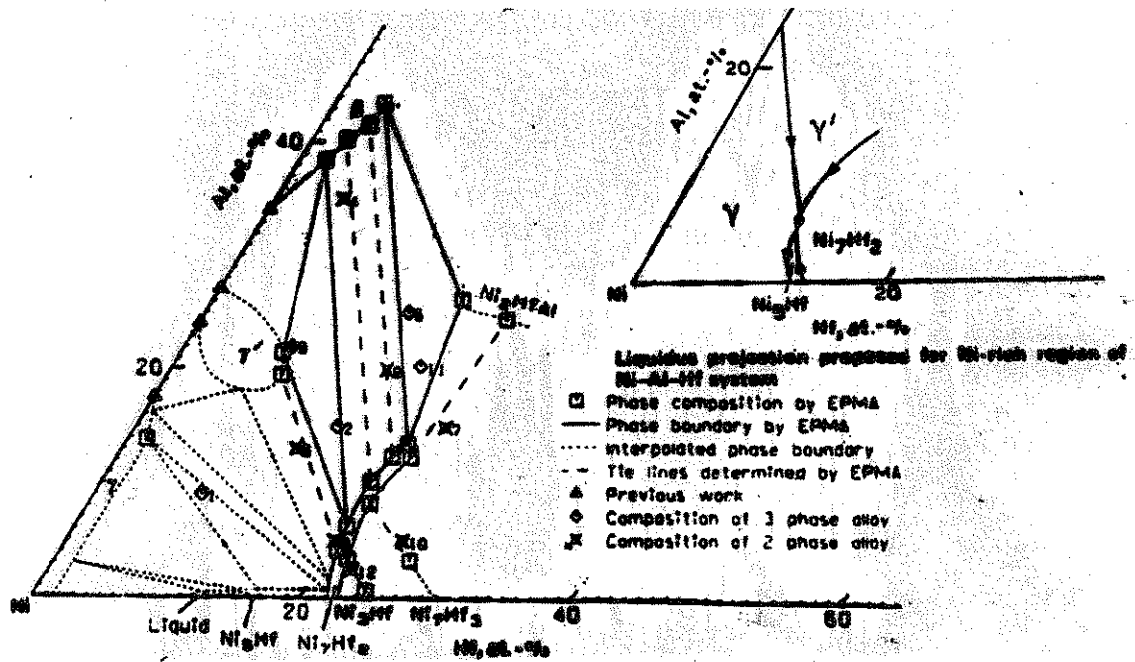


Figure 2 Isothermal section of Al-Hf-Ni system at 1473K

Deformation Mechanism Maps

EFFECT OF GRAIN SIZE

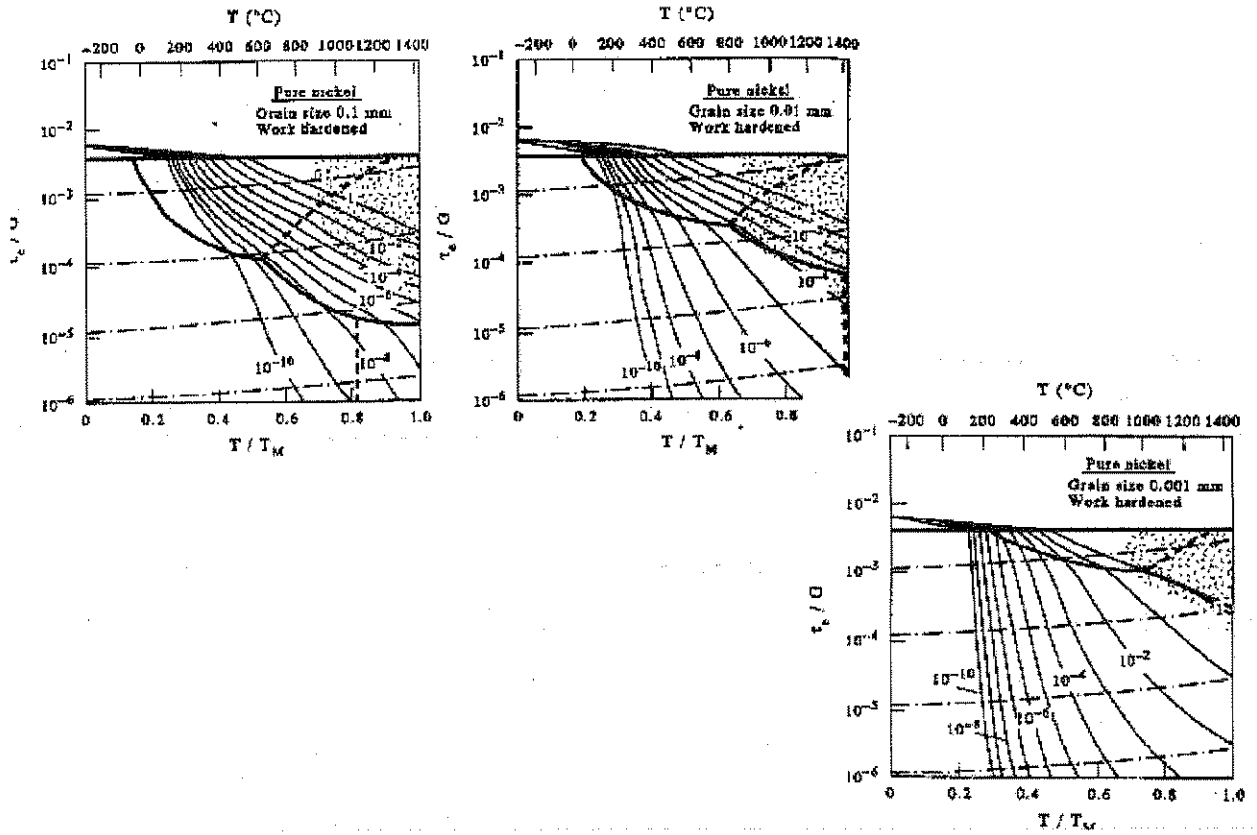


Figure 3 Deformation Mechanism Maps for pure nickel at 3 different grain sizes.

Answer 1 Question only

1. a) Draw a schematic TTT diagram. What do the curves on the diagram represent?

b) The JMA equation is: $f = 1 - \exp(-kt^n)$

How would you plot a series of data of volume fraction transformed, f , versus time, t , to obtain the rate constant k and the time exponent n ?

c) Draw a free energy curve for a binary alloy at a temperature where phase separation has occurred and indicate the spinodal points.

d) The chemical free energy change for precipitation of a solid spherical nucleus in a solid matrix is given by:

$$\Delta G = -\frac{4}{3}\pi r^3 (\Delta G_v - \Delta G_s) + 4\gamma\pi r^2$$

From this equation derive equations for the critical free energy for nucleation, ΔG^* and the critical radius, r^* .

e) Draw a figure showing the variation of ΔG as a function of r .

2. a) Convert the following weight % compositions to atomic %:

	Ni	Ti	Al
1	45.25	36.92	17.83
2	59.66	26.01	14.33

The atomic weights are: Ni=58.71, Ti=47.90, Al=26.9815

b) Locate the weight % compositions from part a) on the triangular coordinate graph paper.

c) Using the triangular coordinate paper plot the following three phase field:

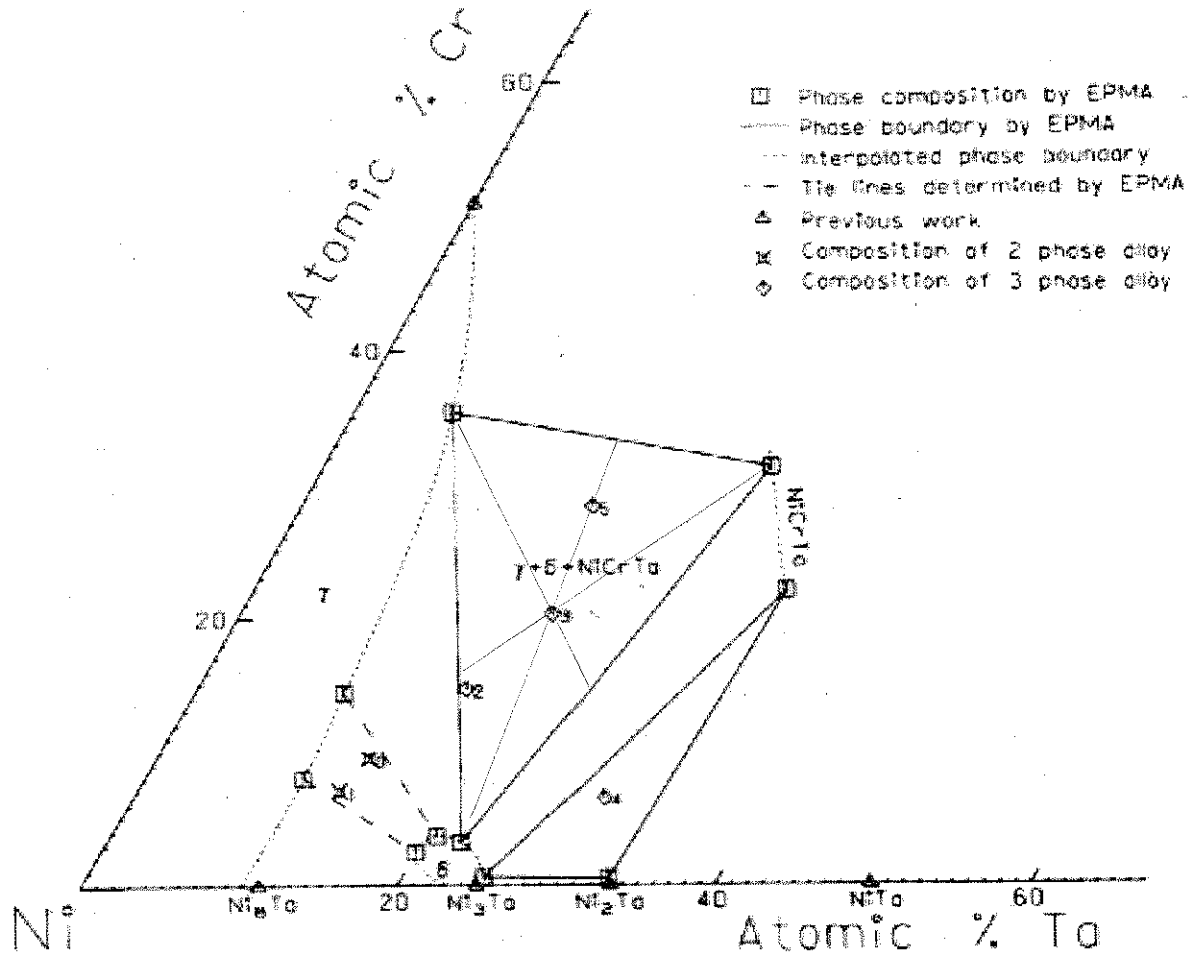
α composition 25%B, 10%C

β composition 55%B, 15%C

L composition 25%B, 35%C

d) Plot alloy X which has a composition of 35%B and 20%C. Determine the relative amounts of the α , β and L phases in alloy X.

- e) From the attached Ni-Cr-Ta isothermal section determine the following:
- the equilibrium phases in the alloy compositions 1, 3 and 4.
 - The phase fractions in alloy 3



Answer 1 Question only

1) Ni-base superalloys tend to possess an excellent combination of strength and corrosion resistance at elevated temperatures.

- a) Describe how the chemistry, microstructure and crystal structure of the constituent phases contribute to the high temperature strength and corrosion resistance,
- b) Describe in detail how the size, shape, morphology and volume fraction of the precipitates influence the mechanical properties of the alloy. How does this influence “strong” and “weak” coupling of dislocations?
- c) Creep deformation in superalloys occurs over a wide range of temperatures and stresses. Explain how the underlying mechanisms are affected by creep at low temperature-high stress, intermediate temperature-intermediate stress and high temperature-low stress conditions.
- d) At 900°C, the minimum creep strain rates for different stress levels are:

Stress (MPa)	Min strain rate (/s)
300	1.4e-5
225	5.0e-7
150	1.0e-8

If the activation energy is 250kJ/mol and $n=12$, estimate the minimum creep strain rate at $\sigma = 275\text{MPa}$ and $T=850^\circ\text{C}$.

MMAE 571 Microstructure Characterizations of Materials

1. What are the characteristics of SE_I and SE_{II} ? What are the relative contributions of them to the total secondary emission? How those contributions affect the resolution of the secondary electron images?
2. What is (are) the requirement(s) for high depth-of-field image model? How the requirement(s) can be obtained?

MMAE 470
Questions for Ph.D. Qualifying Exam

Problem #1

- A) In a condensation polymerization, what two reaction conditions are required to yield a high molecular weight polymer?
- B) Poly(butadiene) has a glass transition temperature of $T_g = -90^\circ\text{C}$. Polystyrene, has a glass transition temperature of $T_g = 100^\circ\text{C}$. Two copolymers of butadiene and styrene are synthesized that have the same ratio of monomers. However, one copolymer is rubbery at room temperature and does not stiffen until the temperature is lowered to -30°C . The second copolymer is stiffer, very tough and opaque at room temperature. Explain the difference(s) between the two copolymers.
- C) Contrast the fringed micelle and lamellar models of the structure of crystalline polymers. Which was the first conceived and which was created later? What observations of polymer properties led to the development of the first of these structural models and what new developments lead to the replacement of the first with the newer model.
- D) Draw sketches of $\log(\text{Young's modulus})$ versus temperature for each of the following polymers, including as much quantitative information as possible:
- 1) an uncrosslinked polybutadiene (T_g as in (B) above)
 - 2) a crosslinked polybutadiene (T_g same as in (1))
 - 3) Nylon 6,6 ($T_g = 50^\circ\text{C}$, $T_m = 265^\circ\text{C}$).
 - 4) Nylon 6,6 after prolonged immersion in water.

Problem #2

- A) Name two types of secondary bonding (not covalent bonding, which is described as primary bonding) which can exist between molecules in a polymer solid or liquid. What impact does secondary bonding of these types have on the transition temperatures (glass transition and melting/crystallization temperatures) of polymers.
- B) Polyethylene and polypropylene produced with either a Ziegler-Natta catalyst or a Phillips-process catalyst are fairly rigid, transparent thermoplastics while an equimolar copolymer of the two, produced in exactly the same way, is a soft, transparent rubber. Explain these observations. How many glass transition temperatures would you expect the copolymer to have and approximately what temperatures would it (or they) be at?

- C) Sketch the stress vs. strain curves you would expect to obtain for the following polymers. Assume slow strain rates and testing at room temperature. Put all 3 curves on the same plot and label the curves.
- 1) Atactic polystyrene
 - 2) A butadiene / styrene copolymer (90% butadiene)
 - 3) High density polyethylene (semi-crystalline polymer with $T_g = -80^\circ\text{C}$ and $T_m = 135^\circ\text{C}$).
- D) A thin metal strip is anchored at its top and a weight attached to the bottom so that the strip is stretched. The mass of the weight is chosen so that the stress in the strip is well below the yield stress of the metal. If the temperature of this assembly is raised, the strip becomes longer, even if the mass of the weight is unchanged. If a strip of a rubbery polymer is loaded in a similar manner and the temperature is increased, the rubber strip gets shorter. Explain the atomic / molecular origin of this behavior in both materials.

Answer one question only

1. Plane stress fracture toughness of aircraft materials is done to determine the actual resistance to fracture under non-plane strain conditions. Describe how these tests are done and sketch the effect of thickness and test rate on the values of toughness determined on these materials. Give reasons why this technique is not in common use. The expression for plane stress fracture toughness is $K = \sigma\sqrt{\pi a}$, Where σ is the applied stress, a is the crack length and K is the resultant applied stress intensity factor for a wide plate in tension.
2. Creep in high temperature materials is determined in a standard "creep test" where strain vs. time data are collected for a range of applied stresses. These data can be represented in several different ways where temperature and time are combined into a single parameter for plotting against applied stress. These data although interesting as a first step in evaluating candidate material for high temperature applications is not used to determine long term behavior and expected "lifetime" Describe how these parametric plots are used and the current status of long term creep evaluation. Characterize the failure mode of these materials and at a given high temperature and compare the likely creep extension to failure with short term tests done at the same temperature.