注意：考試開始鈴響前，不得翻閱試題，
並不得書寫、畫記、作答。

國立清華大學 111 學年度碩士班考試入學試題

系所班組別：工程與系統科學系
甲組

科目代碼：3001

考試科目：物理冶金

—作答注意事項—

1. 請核對答案卷（卡）上之准考證號、科目名稱是否正確。
2. 考試開始後，請於作答前先翻閱整份試題，是否有污損或試題印刷不清，得舉手請監試人員處理，但不得要求解釋題意。
3. 考生限在答案卷上標記「▛ 由此開始作答」區內作答，且不可書寫姓名、准考證號或與作答無關之其他文字或符號。
4. 答案卷用盡不得要求加頁。
5. 答案卷可用任何書寫工具作答，惟為方便閱卷辨識，請儘量使用藍色或黑色書寫；答案卡限用 2B 鉛筆畫記；如畫記不清（含未依範例畫記）致光學閱讀機無法辨識答案者，其後果一律由考生自行負責。
6. 其他應考規則、違規處理及扣分方式，請自行詳閱准考證明上「**國立清華大學試場規則及違規處理辦法**」，無法因本試題封面作答注意事項中未列明而稱未知悉。

國立清華大學 111 學年度碩士班考試入學試題

系所班組別：工程與系統科學系碩士班 甲組(0530)

考試科目（代碼）：物理冶金 (3001)

1. Fig. 1 illustrates the core structure of a curved dislocation line AGHC on the slip plane BDEF when there is a shear stress applied on the Top surface upward also another one at the bottom surface downward, where the circles represent the atomic plane just above the slip plane, and the small dots represent the atoms just below. (a) What are the type of dislocation AG, GH, and HC? (3%) Also, indicate the Burgers vectors and the motion of the three sections AG, GH, and HC. (3%) (b) Assuming that all atoms shown were all originally above (or below) each other, indicate the region of slipped material. (3%) (c) Can this dislocation line AGHC cross-slip to another slip plane? Yes or No? Justify your answer. (3%) (d) If there is a perfect dislocation which can slip on (0001) plane and $(\bar{1}100)$ plane of one HCP single crystal, please calculate the Burgers vector of this dislocation. (3%). (Total 15%)

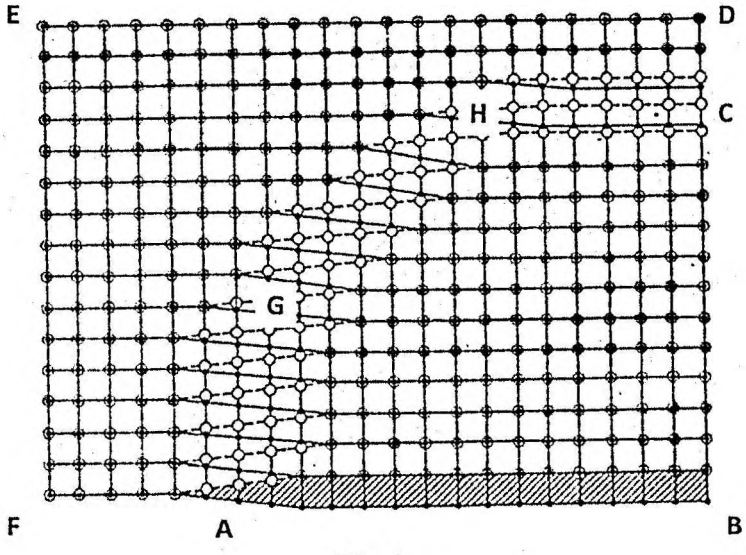


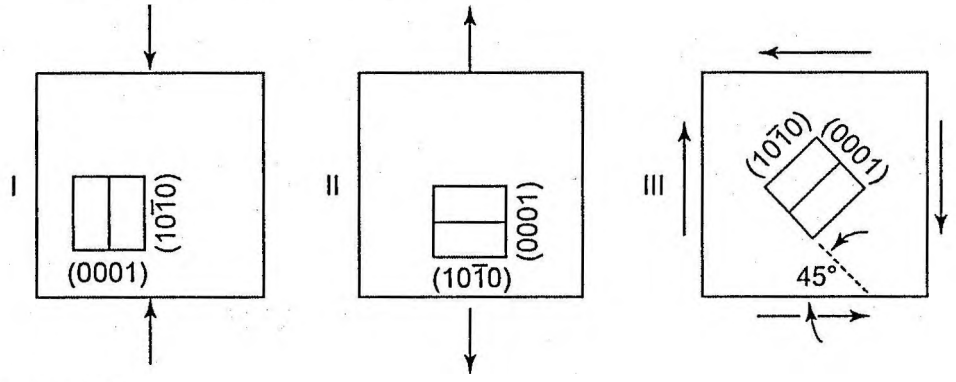
Fig. 1

2. (a) Three senior students Marco, Clark and Fiolina are each given a cube-shaped single crystal of an HCP metal. It is not known whether the cubes are of identical material. The students are to cut out tensile and compression specimens and measure the loads necessary for yielding. In addition, they are to observe the nature of deformation in each case. A summary of their results is given in the accompanying table.

Test \ Student	Marco	Clark	Fiolina
Tension	Low Loads for yielding. Only slip observed.	Low loads for yielding. Little slip and much twinning.	High loads for yielding.. Little slip and no twinning.
Compression	Low loads for yielding. Only slip mechanism.	High loads for yielding. Little slip and no twinning.	Low loads for yielding. Little slip and no twinning.

From these results, Marco and Clark concluded that three different materials were involved in the test program. Fiolina claimed that the materials were the same. Here comes the problems: (i) Who was correct? Could both conclusions be correct? (4%) Explain the reasons to your answer in (i). (6%) (ii) To confirm that if the three materials were identical, what additional information would have to be known? (3%) and how could it be used to support the claim of similar materials by just using mechanical testing? (3%) (iii) What kind of similar results could be expected by the XRD characterization about the three HCP metals if the materials were indeed identical? (4%)

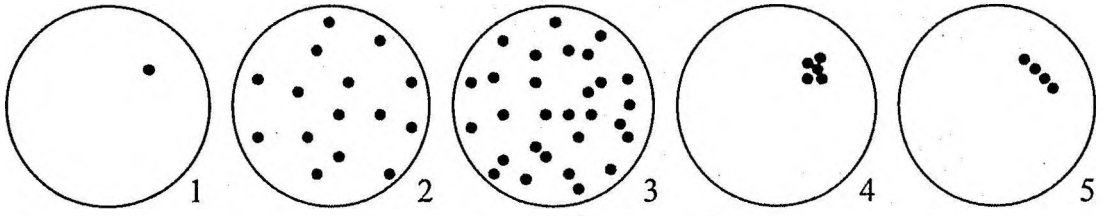
(b) Given this HCP metal has a c/a ratio of 1.600 and most probable slip system for this material is $\{10\bar{1}0\}<1\bar{1}20>$. For each of the following diagrams, determine whether slip will occur and whether twinning will occur (consider only $\{10\bar{1}2\}$ twinning). Also, justify your answers. (6%)



(Total 26%)

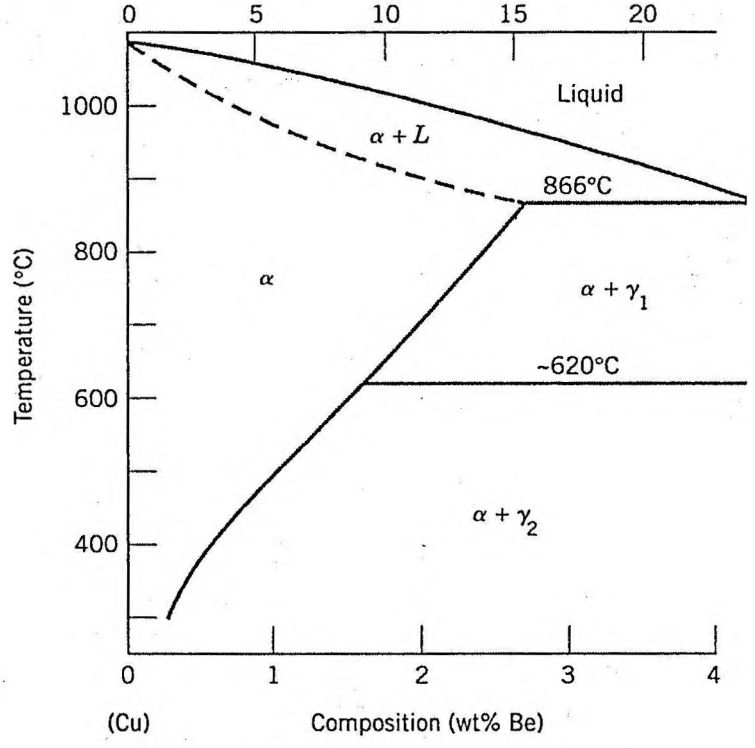
3. Think about the potential near future. You are a PI of Advanced Material Lab ten years after the graduation from the Master program at NTHU. One of your students, Tommy, is studying on a single crystal metal you gave him last month for his senior project. He prepared five specimens cut from that single crystal with HCP structure. Each sample went through different mechanical-thermal (MT) treatment These conditions are describe as the following: (a) Sample A was bent and then annealed lightly, (b) Sample B was deformed slightly in compression and annealed lightly, (c) Sample C was deformed slightly in compression and annealed thoroughly (d) Sample D was deformed heavily in compression and annealed, and (e) Sample E went through the condition as the same as '(d)' above and then was deformed heavily and annealed. After completion of the five MT treatments, he carried out

the orientation analysis of the crystals. Below are five stereographic projections presented in the external reference frame. The points represent the orientations of the c-axis (0001) of the crystals. Tommy spent about three weeks to finish of the processing and measurement. Which is about the end of senior project! Great!



A weeks later, Tommy cried to you and said "Damn it! Professor, I screw up! I forgot to record which treatment resulted in which stereographic projection because I didn't label on these specimen". You smiled at Tommy and told him, "OK, don't worry, the knowledge you leaned in Physical Metallurgy can save your life." Now, please teach Tommy that which of these projections corresponds to each of MT procedure. Also, please provide the explanation for each answer in the view point of microstructure and sketch the microstructure. (20%)

4. Copper-rich copper-beryllium alloys are precipitation hardenable. After consulting the portion of the phase diagram shown in Figure below, do the following:



(a) Indicate the range of compositions over which these alloys may be precipitation hardened. (2%) (b) Describe the heat-treatment procedures (in terms of temperatures) that would be used to precipitation harden an alloy having a composition of your choosing yet lying within the range given for part (a). (4%) (c) Using one figure of shear stress-shear strain relationship, please draw five stress-strain curves including the following five cases: (i) solid solution annealing followed by quenching of the alloy (2%); (ii) aged to peak hardness of the alloy (2%); (iii) the alloy aged to form GP zones (2%); (iv) Overaged alloy (2%). (v) another pure copper (2%). Also, explain the hardening mechanism to the corresponding condition of heat-treatment from (i) to (iv) mentioned above it might happen. (8%)
(Total 24%)

5. (a) Assume that there are N atoms occupied N lattice sites in a crystal. Next, n atoms inside the crystal were moved to the surface, which generate n vacancies. Please derive a formula to estimate the concentration of vacancies at equilibrium of this crystal at specific temperature T. Please define all the terms used in your formula. (6%)
(b) High entropy alloy (HEA) is new concept to prepare metallic materials since about two decades ago originated in NTHU. HEAs made of five or more elements with equal molar fraction can have high strength and hardness possess many comprehensive properties such as thermostability and corrosion resistance. Please calculate the mixing entropy of one HEA with six elements. (4%)
(c) Mary evaluated the concentration of vacancies at equilibrium of the HEA mentioned in (d) at room temperature and at 1 atm. The answer her calculated is 90%. Do you believe in Mary's answer? Please discuss the reasonableness about Mary's answer. (5%)
(Total 15%)