國立清華大學 105 學年度碩士班考試入學試題

系所班組別：核子工程與科學研究所 (0526)

考試科目（代碼）：物理冶金 (2605)

　　*請在【答案卷】作答

1. Consider you are working as a principle engineer for transistor module development at tsmc and are now in a weekly meeting for project assignment. A topic is assigned to you for the development of source / drain to metal wire connection. Metal silicide is a suitable candidate for leakage control in this connection. You are in charge of growing the metal silicide (MSi_X) ultra-thin film in the thickness of 10 nm atop surface of source / drain SiGe epitaxy. Self-aligned technique with subsequent annealing is a proper method for building the MSi_X thin film. (1) Please index the crystal phases of M_5Si_3, MSi, M_5Si_4, MSi_2, and amorphous-interlayer at the noted regions in the following film scheme (**Figure 1b**) and explain the mechanisms for growing these phases (20%); (2) The heterojunction battier high is an important thin films property for leakage control of transistor. Please state the possible crystal defects with locations that affecting the heterojunction barrier high of this MSi_X film scheme (6%); (3) **Figure 2** compares three types of the annealing process for growing the MSi_X (**Figure 1a** → annealing → **Figure 1b** that offered by your sponsor. Please select the proper one and explain the microstructure transformation of the regions in the selected case (4%). <30/100>

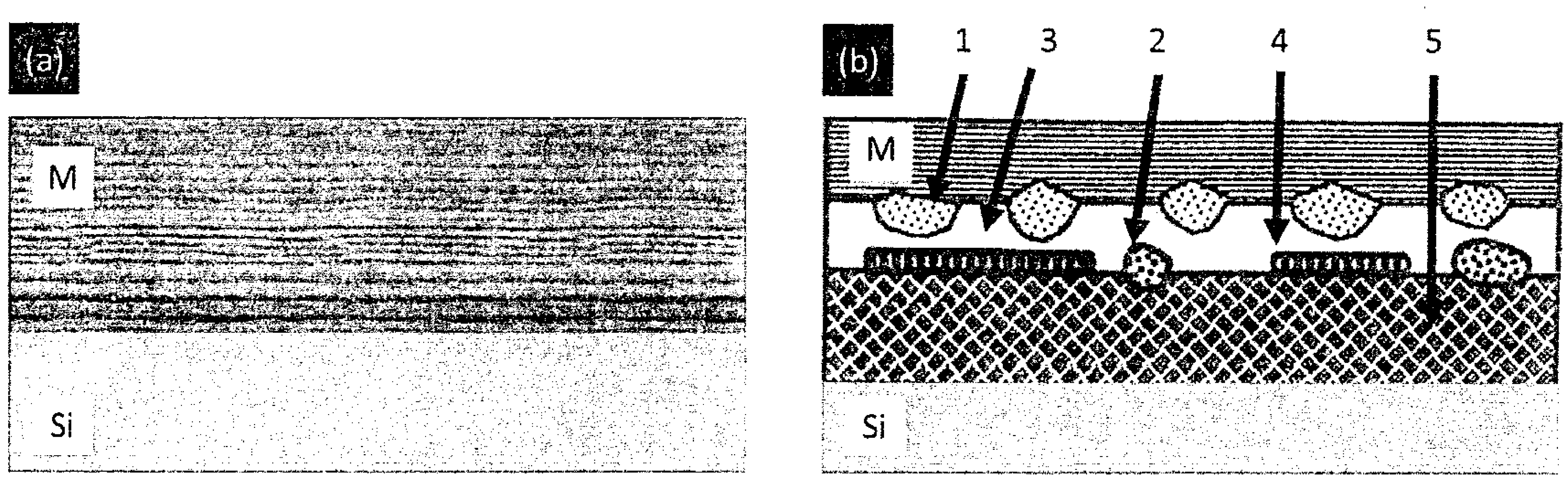

Figure 1. The film scheme of MSi_X w/ and w/o proper annealing.

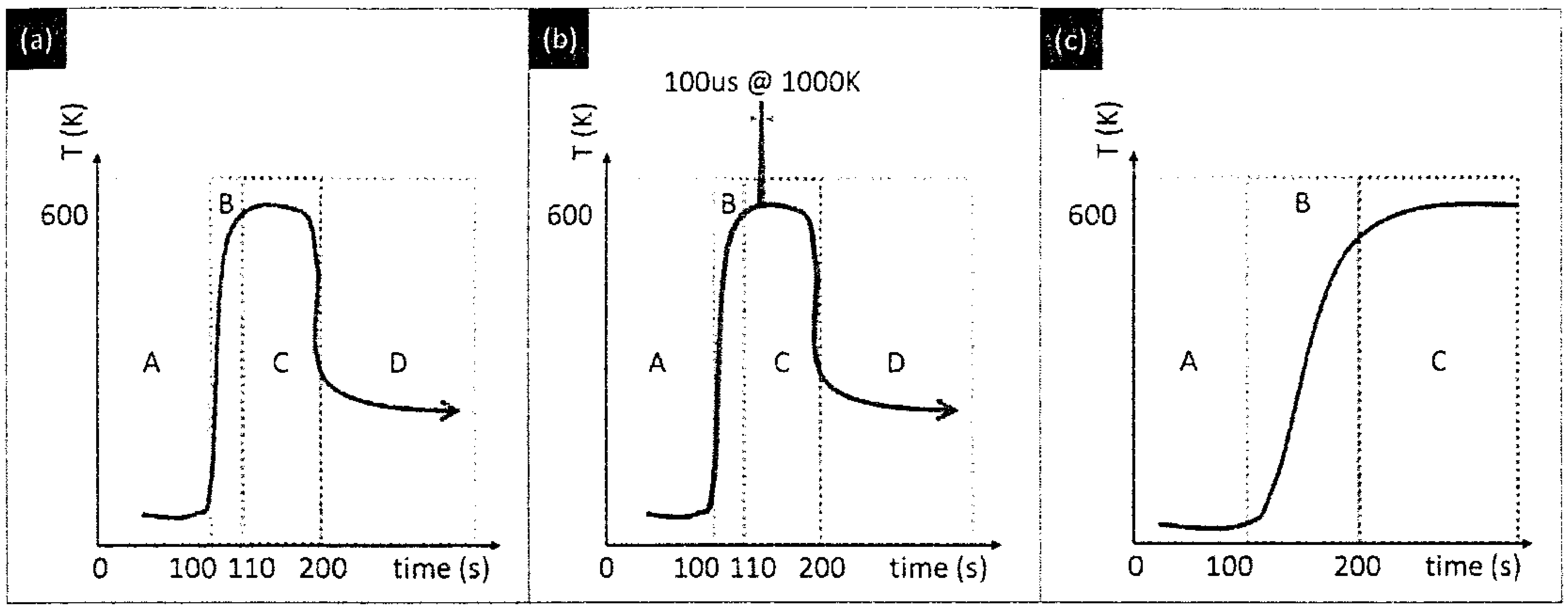

Figure 2. The proposed thermal budgets for growing the MSiX.

2. David Su is a product manager who is dealing with the wind turbine power generator project issued by China Steel Co ltd. (CSC) In this project, he get the order of 10,000 sets of giant wind blades made by Co / Ni doped super alloy. The size of the blade is designed as 20 meter long with the cross section of 0.5 by 0.2 meter square. A prototype demo sample for the blade was made one week ago and shipped to China Steel today. You are in charge of import qualification control in CSC and found that this blade was dropped with a large distortion due to the improper shipping from David's company by truck. For recovering the shape, you are assigned to utilize certain mechanical assessments at room temperature. (a) Please describe the microstructure changes of the metallic blade by your mechanical treatments with increasing mechanical work loading at room temperature (**8%**). (b) Explain the reason why your treatments come with the hardening of the metallic blade. (**8%**) (c) The hardening will suppress the toughness therefore the operation lifetime of the blade as the components of turbine in the wind power generator. Please provide proper thermal assessments (assuming that the melting temperature of the super alloy is T_m) for restoring the toughness of the blade. In this case, please describe the mechanisms and characters for the microstructure evolutions of the blade upon the thermal treatments (**8%**). <54/100>

3. Assuming that you are building the metal deck on a battleship with your colleagues at National Chung-Shan Institute of Science and Technology. (a) Basing on the phase diagram (**Figure 3**), please describe the receipt of Al-Cu alloy (Cu denote the dopant) for precipitation hardening and the subsequent thermal process on strengthening the metal deck materials without mechanical deformation (**10%**). (b) phase diagram for the precipitates θ1, θ2, θ3, θ4, and GP zone was shown in **Figure 3**, please draw the cooling curves (TTT curve) of these phases as a function of cooling time (**5%**). (c) please describe the phase transformation pathways and the hardening curves for these as a function of aging time at the selected temperatures (**5%**); (d) please explain the mechanisms of the precipitation hardening (**5%**); (e) In this blade, the precipitates are core (α phase) – shell (β phase) nanodisk; where the diameter and thickness of core is Dc and Tc, respectively) with the shell thickness of T_S. Considering cases for the homogeneous and heterogeneous nucleation of these precipitates, please derive the free energy changes of the system when interface energies of the precipitates are denoted as γ (i) (for example free energy at core-shell interface is $\gamma(\alpha,\beta)$) (**5%**). (f) please explain the presence of critical precipitate grain size by sketching the free energy diagram in your case (**5%**). <89/100>

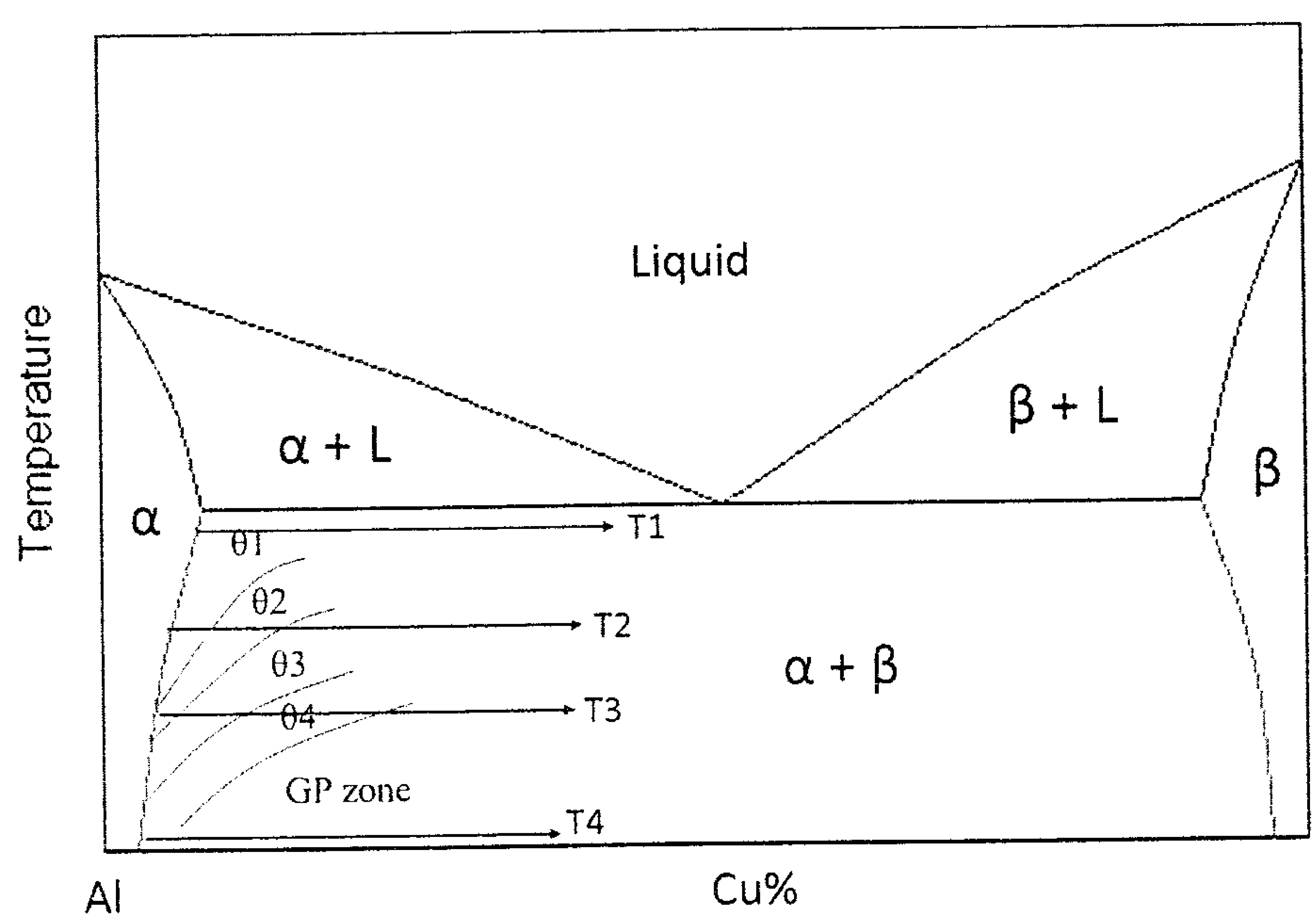

Figure 3. The phase diagram for Al-Cu system.

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4. Ion implantation (IMP) is one of the promising techniques for developing the ultra-shallow junction in next generation transistors. In your project, you are assigned to increase the dopant level of 20 nm Si oxide thin film by using this technique. (a) Please specify the factors that affecting solid solubility of dopant in this silicon thin film. (**3%**) (b) increasing the dopant level facilitates the carrier mobility of the thin film. Please explain the reason why there is an upper limitation of dopant level with optimized mobility by using IMP. (**3%**) (c) Nelson (your boss) assigned you to dope 10 at% of Phosphorus ions in the 20 nm Si thin film. You are consulting your mentor and figure out that this condition can be done by using baseline receipt (10 keV with 200 PA P precursor in ion chamber at room temperature) with proper annealing conditions. Please discuss the microstructure differences between the Si thin films with Baseline receipt and at the cases of 1MeV and at 400oC, respectively. (**5%**) <100/100>