Materials Synthesis. Examination questions

Part I. Basics, main principles of synthesis, bulk crystal growth (Units 1-7).

1. Intrinsic and extrinsic properties of solids.
2. Main types of binary phase diagrams. Ternary phase diagrams.
3. Thermodynamic and kinetic aspects in the synthesis strategy.
4. Particle size effects.
5. Metastable state.
6. Synthesis of intermetallic compound (HF melting, cold crucible, arc melting, mechanochemical alloying).
7. Ceramic method
8. Sol-gel technique
9. Solvothermal synthesis
10. Post-reaction thermal treatment, hot pressing, spark plasma sintering.
11. Defects in crystalline solids. Equilibrium defect concentration.
12. High pressure synthesis: Thermodynamic and kinetic aspects, techniques.
13. Driving forces of crystallization.
14. Nucleation: thermodynamics and kinetics.
15. Ostwald-Myers region.
16. Seed control.
17. Crystal growth mechanisms.
18. Transport processes in crystal growth.
19. Crystal growth from gaseous phase.
20. Crystal growth from the melt. Basics and techniques.
21. Crystal growth from solution (flux, hydrothermal). Primary crystallization field.
22. Constitutional supercooling.
23. Industrial synthesis and crystal growth of silicon. Main defects.
24. Industrial crystal growth of GaAs. Main defects.
25. Industrial crystal growth of SiO_2.
26. Artificial diamonds.
27. Crystal growth experiments in space.

Part II. Amorphous and naonocrystalline materials (Units 8-9).

1) What types of phase diagrams and time-temperature behavior represent possible preparation of amorphous materials?
2) What about “crystal structure” and symmetries in amorphous materials?
3) How can the “structure” be determined? What is Pair distribution?
4) Volume –density – differences amorphous- crystalline?
5) Glass forming ability? Glass – stability?
6) Possible production?
7) What about gas layer and atmosphere during production?
8) Influence of parameters for production?
9) How to determine cooling rate? What is the effect of different cooling rates?
10) Effect of cooling/annealing on magnetic properties?
11) High temperature behavior of amorphous materials?
12) Magnetic properties in contrast to crystalline materials?
13) General comparison of different properties for amorphous and crystalline materials?

14) Difference of properties amorphous- crystalline…what for applications?
15) Sensors—actuators?
16) Applications of amorphous materials in magnetic devices
17) Losses of magnetic materials – differences in amorphous and crystalline materials?
18) Properties and applications of nanocrystalline materials?
19) What can be seen in X-ray in nanocrystalline materials?
20) What is Finemet?
21) Consequences of different domain structure of different types of magnetic materials?
22) Properties of different soft magnetic materials?
23) FeSi and rapid quenching?
24) Rapid quenching – not amorphous? Is it useful?
25) Magnetostriction of different magnetic materials?
26) Is it possible to get bulk amorphous materials?
27) Electrical resistivity of amorphous materials?

Part III. Thin Film Technology (Units 10-11).

1. Define the terminus "Thin Film"?
2. Describe at least three basic methods of thin film synthesis.
3. Define the Terms "Substrate" and "Monolayer".
4. Which deposition rates can be achieved by PVD methods?
5. Outline the similarities and differences between evaporation and sputtering.
6. Write down the Hertz-Knudsen-equation and discuss its solutions for different geometries.
7. Give examples for different evaporation sources.
8. Discuss the dependence of the evaporation rate on the source temperature and the consequences thereof.
9. Give the principle mechanisms involved in the sputtering process.
10. Define the sputtering yield and discuss the influence of the target material and the ion species on the yield.
11. What is the mean energy of evaporated and of sputtered particles. Discuss the reasons for the different energies.
12. Discuss the difference between conventional CVD and Plasma Assisted CVD.
13. Discuss the main mechanisms involved in the electrochemical deposition of metals.
14. Compare the cooling rates of casting processes to those of PVD processes. What are the consequences?
15. What is a "Structure Zone Diagram"? Discuss the mechanisms responsible for the formation of the different zones.
16. Define the termini "Potential Energy Surface" and "Ehrlich Schwöbel Barrier".
17. Discuss the different energies which are important for particle adsorption and migration and for the formation of multi particle aggregates.
18. Which quantities can be assessed from rate equations?
19. Define the critical nucleus.
20. What is a "Kinetic Monte Carlo Simulation"?
21. Define the terminus "Epitaxy" and give examples on how epitactic films can be grown.
22. Define the different modes of thin film growth.
23. Discuss the possibilities for the gravimetric measurement of the film thickness. Which factor introduces the largest error into this method?

24. Explain the Acronyms LEED and RHEED and describe what can be monitored by these methods during thin film growth.

Part IV. Nanotechnology (Units 12-13).

1. What does the term “nano” in the word “nanotechnology” refer to?
2. Who gave the famous speech “There is plenty of room at the bottom”?
3. What nanotools do you know?
4. Explain the terms “bottom-up” and “top-down” approach.
5. What is the operating principle of an STM?
6. What are the advantages and disadvantages of constant-current imaging and constant-height imaging?
7. What is the operating principle of an AFM?
8. What is the main advantage of an STM over other SPM's?
9. How does the dimensionality of a system affect its density of states?
10. What are buckyballs?
11. Are carbon nanotubes metallic or semiconducting?
12. What is so special about graphene?
13. Explain the phenomenon “Coulomb blockade”.
14. What is a 2-DEG?
15. What do you know about titanium dioxide nanoparticles?
16. Name a few lithography methods.
17. If you had to make an anisotropic etch, would you use dry or wet etching?
18. What is a FIB? What can it be used for? What are useful optional additions?
19. What are the advantages/disadvantages of using WF_6 or $W(CO)_6$ for EBID?
20. How are Langmuir-Blodgett films produced?
21. What is a SAM?
22. What do you know about “solvothermal synthesis”?
23. What is the VLS mechanism?
24. What does the term “pyrolysis” mean?
25. Name and explain three bottom-up approaches to synthesize nanoparticles.
26. What is the Sol-Gel method? What is an aerogel?
27. How are nanotubes produced? Name a few methods.
28. List a few properties of graphene. To whom and when was the Nobel prize awarded?
29. What does the term “mesoscopic physics” mean? Name two examples.
30. How is the conductance quantum defined? How does it come about?
31. What is a quantum point contact? How big is its resistance?
32. What is the current like through a small conductor in the ballistic regime?