

# MICRO-621 – MOOC on “Fundamentals of Microstructures”

## List of questions for preparing the exam

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### Part I: MEMS bimorph example and clean-room introduction

1. A simple example of a MEMS device is the **thermo-mechanical microactuator**. Describe its principle of operation and propose a suitable fabrication process.
2. Describe some commercially **successful microsystems** (MEMS) and discuss what technology stands behind to manufacture them in high volume and high yield.
3. Discuss different **contamination problems** in a clean room that can occur during a microfabrication process and different **clean room strategies** to avoid contamination of the air with particles.

### Part II: Chemical vapor deposition (CVD)

4. Discuss the mass transfer-controlled and reaction-controlled **regimes in a CVD process**. How do temperature and pressure have an influence?
5. Discuss the different **types of CVD** processes that are used in microfabrication.
6. Discuss the **thermal oxidation and local oxidation** (LOCOS) process of silicon.
7. Discuss the development of a **thermal and concentration boundary layer** near a heated substrate. How are these involved in or influence the Reynolds number of the system?
8. Comparing **reaction- and diffusion-limited growth rates** in a CVD process, how can one write and understand the dependence of CVD growth rate as a function of temperature?
9. Discuss the technique of **Atomic Layer Deposition (ALD)**. How can one deposit a layer of  $\text{Al}_2\text{O}_3$  with this process?
10. Discuss the **thermal oxidation** process of silicon and the **local oxidation of silicon (LOCOS)**.

### Part III: Physical vapor deposition (PVD)

11. List the various techniques that are called ‘**Physical Vapor Deposition (PVD)**’, briefly describe their principle of operation, and list their advantages and disadvantages.
12. Describe the physical vapor deposition (PVD) called “**sputtering**”, its working principle, basic configurations, typical materials used, as well as advantages and limits.

13. Describe the physical vapor deposition (PVD) called “**thermal evaporation**”, its working principle, basic configurations, typical materials used, as well as advantages and limits
14. Describe the **thickness uniformity of a thin film** on a flat substrate by thermal evaporation by analyzing the mass flow.
15. When **growing thin films** by PVD or CVD there is always possible occurrence of mechanical stress. Please discuss this issue by providing some examples of film growth mechanisms and solutions to remedy.
16. Describe the **lift-off process** to deposit for example a thin layer of Ti.
17. In which situation do you use **sputtering** instead of **evaporation** to form thin films on surfaces?

#### Part IV: Lithography

18. *Lithography often aims for highest resolution of the patterning. Discuss the **resolution limits for various lithography techniques using UV, DUV, electron beam, scanning probes, as well as soft and hard stamps for creating the patterns.***
19. Describe the principle of **photolithography using UV** exposure tools, exposure methods, masks, as well as photoresist contrast mechanism.
20. Describe the use of a **direct laser writing system** to make a photo-mask.
21. Describe the principle of **electron beam lithography** (EBL) by giving some examples and listing some advantages and disadvantages.
22. Describe the principle of **scanning probe lithography** by giving some examples and listing some advantages and disadvantages
23. Describe the principle of **microcontact printing** (or also called soft-lithography). What limits the resolution? What are typical applications foreseen?
24. Describe the principle of **nanoimprint lithography** (NIL). What limits the resolution? What are typical applications foreseen?
25. Describe the principle of **stencil lithography**. What limits the resolution? What are possible applications exploiting its unique strengths?

#### Part V: Dry etching

26. What are simple rules for designing **dry etching processes** for silicon, metals and polymeric materials? How can one favor anisotropy in a fluorocarbon plasma for the etching of Si?
27. Discuss the mechanism and features of the so-called **Bosch dry etching** process.
28. Explain what is an **ion sheath** in a dry etching plasma. What is the role of the working electrode size on etching?
29. Discuss what is the role of **adding hydrogen gas to CF<sub>4</sub>** for the dry etching of silicon.
30. Discuss two dry etching processes that do not use plasma generation, namely **XeF<sub>2</sub> etching** and **HF vapor phase** etching.
31. Discuss what is a **barrel reactor**, a **diode reactor** and an **inductively coupled plasma reactor** in dry etching.
30. Discuss the technique of **ion beam etching (IBE)**.

31. Why is **chlorine chemistry** rather than fluorine chemistry used for the etching of **Al and Al alloys**?

#### Part VI: Wet etching

32. Explain a **Piranha** wafer cleaning process.
33. Explain the **HF- and BHF-etching** mechanism for glass. How does the etching rate depend on the type of glass and the composition of the etching bath?
34. Explain the mechanism of the **HNA-bath** for silicon etching.
35. Explain how one can realize **micro-or nano-porous silicon**
36. Explain the mechanism of the **KOH-bath** for silicon etching. What is the influence of KOH concentration on the etching rate?
37. Explain two types of **etch stop techniques** for making thin membranes in silicon using a KOH wet etching bath.
38. Explain the principle of **supercritical drying** in surface micromachining.
39. Discuss how one can etch in a (100) silicon substrate simultaneously microstructures with **tilted side walls** and **vertical side walls** during the same KOH etching process.

#### Part VII: Inspection and Metrology

40. You need to measure the **electrical conductivity** of a PVD made thin film (e.g., Al, or Au). What techniques can you apply?
41. You need to measure the **surface profile** of a step in a micro-structured thin film with high vertical resolution. What methods can you apply?
42. You need to know the **thickness of a silicon nitride** film with a known refractive index  $n$ . What methods can you apply?
43. You need to know the **surface roughness** of a CVD or PVD made thin film with highest possible resolution. What methods can you apply?