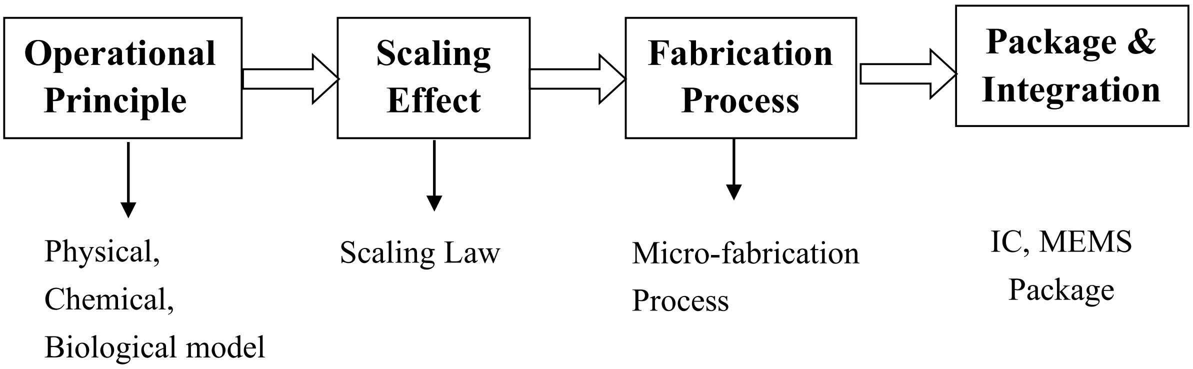
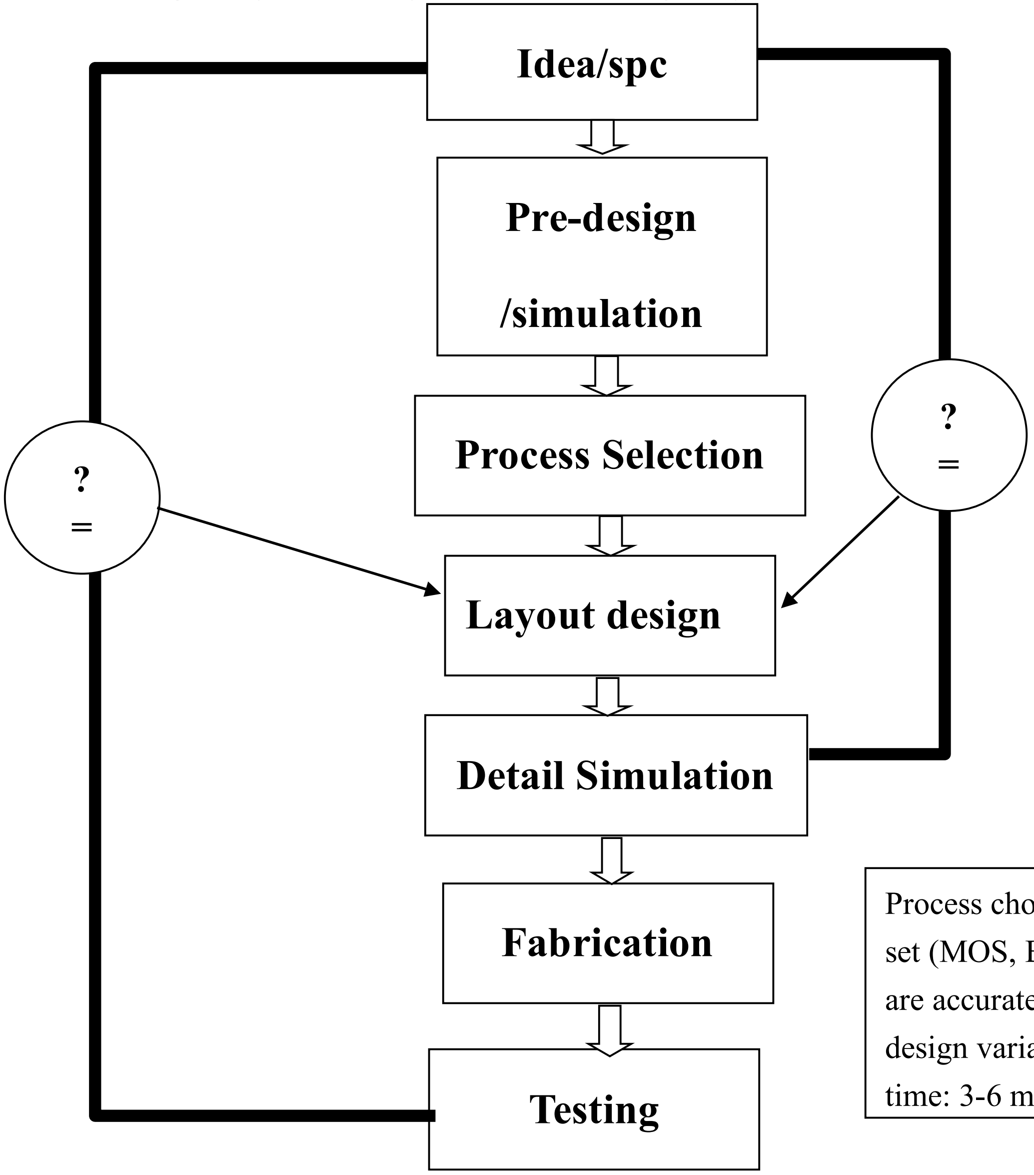
Lecture 5-1 Introduction to Micro System Design

- **Design: combination of ideas, intuition, background knowledge, hand-on experience, and arts.**
- **Knowledge required for Micro System Design:**

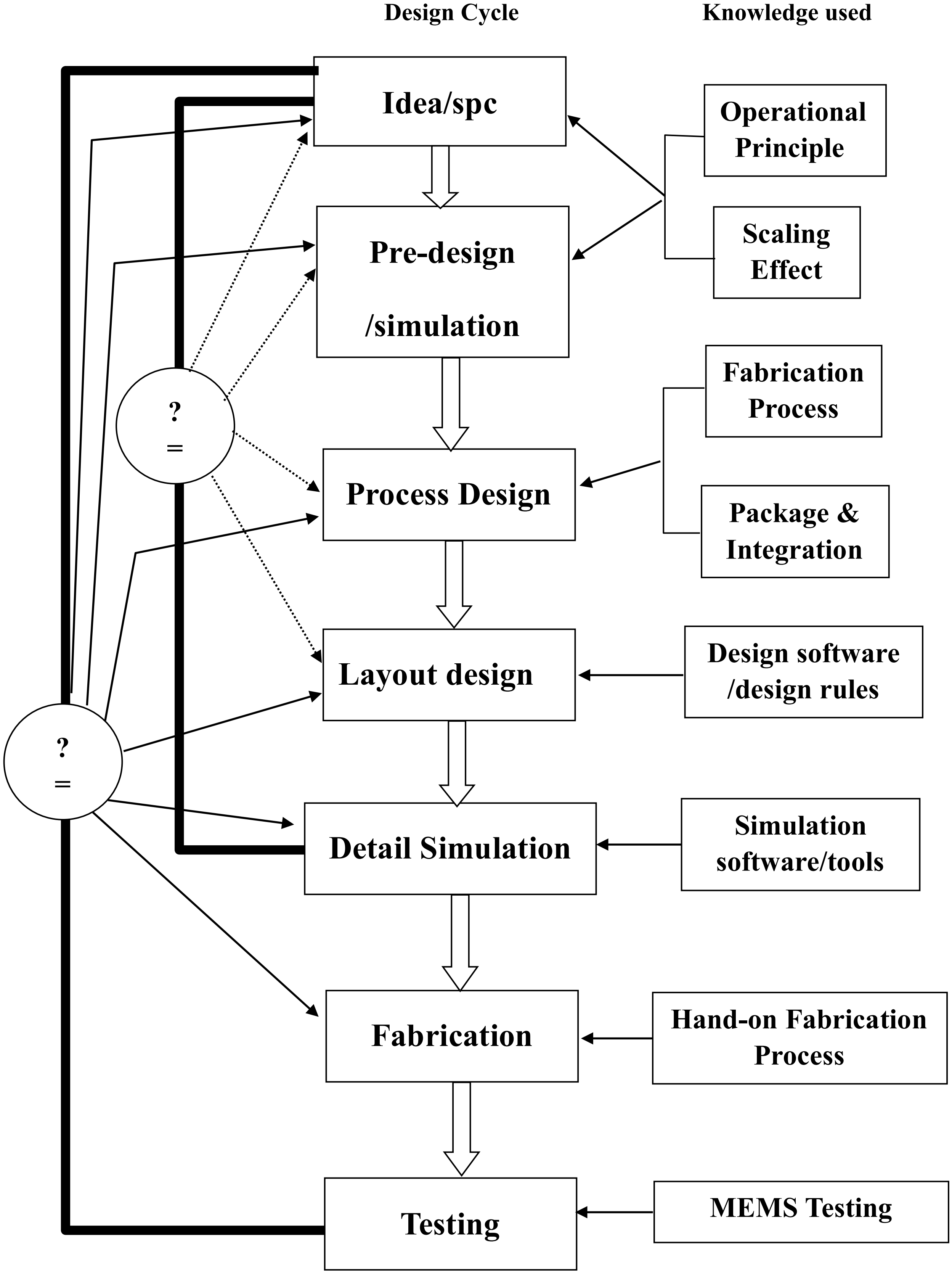


- **Design Cycle: Typical IC design cycle**



Process chosen from a limited set (MOS, Bipolar), simulators are accurate, layout is the only design variable. Typical cycle time: 3-6 months.

Typical MEMS Design Cycle

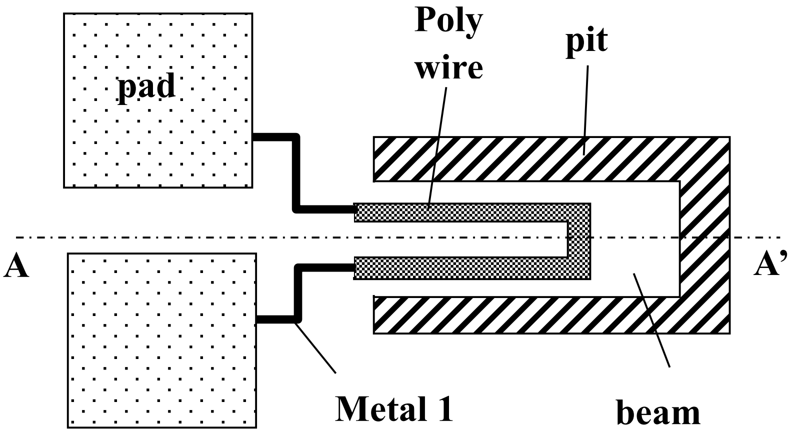


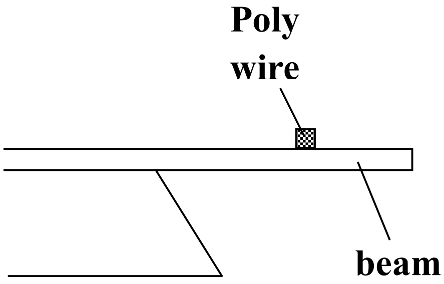
Design space is wide open, everything is available for optimization. Typical cycle time: 6-12 months

A design example for quick over-viewing the design process:

**A thermally driven cantilever beam for micro-mixing application:

Scratch of the idea





Design procedure:

1. **Literature survey—**

   ideas, performance, applications, problems/limitations, …etc.

   ⇨to decide a best direction on the chosen topic

2. **Decide Specs (from applications and material/device limitations):**

   a. **Frequency response: at least 1 kHz.**
   b. **Polysilicon resistor with resistance around 1 k ohms.**
   c. **Heating temp less than 400 degree C.**
   d. **Tip displacement larger than 4 μm**
   e. **Total area smaller than 200 μm square.**

   ⇨ those specs will be the guide lines/constrains of the

later-on design

3. **pre-design/simulation:**

needs information of

   a. **Operational principle—thermal expansion mismatch induced acuation**
   b. **Material properties—material densities, Yang's modulus, thermal expansion coefficient**
   c. **Pre-design device geometry (with a reasonable range)**

⇨ **this step provides an rough idea of device size and operation range, however, the real device size will be decided by fabrication process**

4. **Decide process flow- Use Mosis/Orbit 2 um process**

Consider physical issues:

   a. **actuation element—polysilicon wire**
   b. **supporting element—silicon dioxide**
   c. **how to fabricate the device—standard CMOS process +post bulk etching**
   d. **the problems may be encountered in the fabrication, packaging and testing methods, …etc.—the protection of the device on the top surface, the stiction problem, the residual stress of the beam, …etc.**

⇨ **then Draw the detail process flow**

5. **Change specs to final physical geometry based on the information from pre-design and process flow:**

   a. **Number of resistor "blocks" to get 1 k ohms—need information of sheet resistance of polysilicon in MOSIS/ORBIT**
   b. **geometry of the beam, including length, width, and thickness—need information of the process flow, materials used in process, thickness, physical properties of the beam,**

…etc.

- c. **Modify the geometry of beam to fit the requirements on steps 3 and 4 if necessary, until get the optimal value if possible.**
- d. **Decide the width of heater to meet temp requirement**
- e. **Arrange the positions of the device and accessories to meet the area limitation**
- f. **Design some testing structures for process verification**

⇨ **Then draw draft figure for further layout.**

6. **Layout drawing for mask fabrication**

● Design concerns for Micro Systems:

1. **Micro Sensors:**

   - a. **Operational principle (piezoresistive, piezoelectric, capacitive, tunneling, ultrasonic, electrostatic, magnetic, optical, mechanical, thermal, shape memory, …etc.)**
   - b. **Process feasibility (IC, bulk, surface micromachining, LIGA, molding, plating, non traditional machining, …etc.)**
   - c. **Responsivity (output signal/input physical quantity)**
   - d. **Sensitivity (signal to noise ratio)**
   - e. **Frequency response**
   - f. **Dynamic range**
   - g. **Limitations: shock resistance, Q factor, Failure mode**
   - h. **Temperature (or other factors) dependency**
   - i. **Stability of long term operation**
   - j. **Life**
   - k. **IC process compatibility**
   - l. **Package**

2. Micro Actuators:
   - **a. Operational principle**
   - **b. Process feasibility**
   - **c. Output force/energy/power**
   - **d. Frequency response**
   - **e. Dynamic range**
   - **f. Limitations: shock resistance, Q factor, Failure mode**
   - **g. Temperature (or other factors) dependency**
   - **h. Stability of long term operation**
   - **i. Life**
   - **j. IC process compatibility**
   - **k. Package, interconnections**

3. Micro Fluid/thermal Systems:
   - **a. Operational principle**
   - **b. Process feasibility**
   - **c. Flow rate/heat transfer rate**
   - **d. Controlable accuracy**
   - **e. efficiency**
   - **f. Leakage**
   - **g. Surface property (roughness, hydro properties, thermal properties, …etc.)**
   - **h. Frequency response**
   - **i. Package, interconnections**
   - **j. on shelf life**