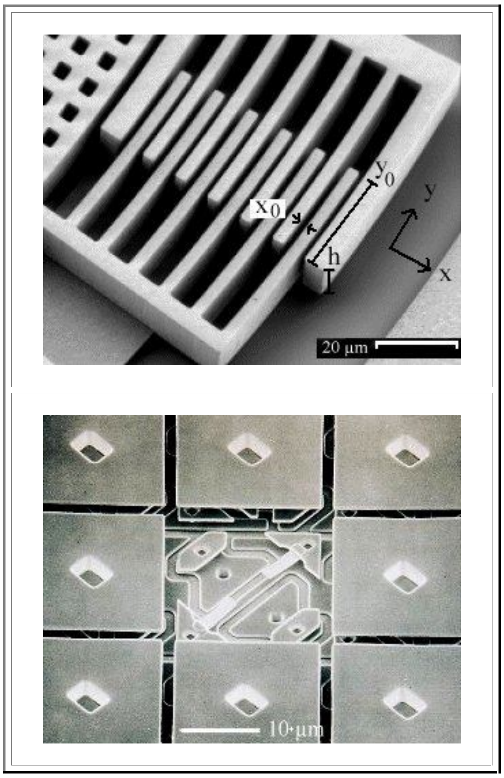
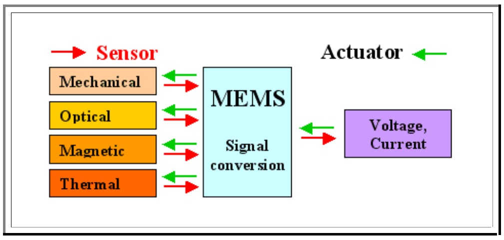
7.3 Summary

7.3.1 Summary to 7: MEMS

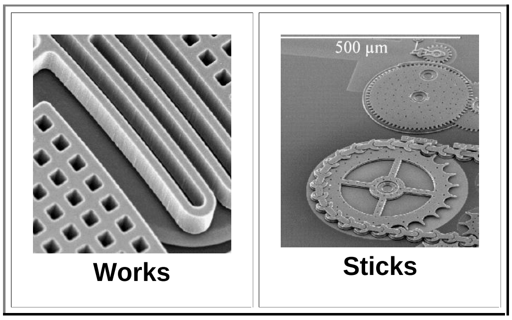
- **MEMS** are "Micro Electro Mechanical Systems" including also micro optics, micro fluidics and generally meaning micro systems.
  - **MEMS** uses **Si** substrates and technologies because "it is there and cheap" for the non-electronic part *and* because electronic components can be integrated on the same chip.
  - Examples of high-volume **MEMS** products are
    - (Pressure) sensors.
    - Accelerometers.
    - Gyros
    - "Beamer" chips (**DLP**)
  - More products are to come; **MEMS** is an *emerging* and often an *enabling* technology
- **Gyros** are particular complex **MEMS** sensor products with a huge range of applications.
  - There must be a physical principle behind the sensor design; different approaches can be used.
  - One approach uses the **Coriolis force** causing detectable additional vibrations in an oscillator with two degrees of freedom if some rotation is experienced.



- Many **MEMS** devices are either sensors or actuators.
  - Looking only at mechanical **MEMS**, there is a need to couple mechanical movements to electrical signals and vice verse.
  - Ways to do this include.
    - Capacitive coupling
    - Piezoelectric and piezoresisitive coupling.
    - Thermal coupling (expansion, resistivity changes).
    - Magnetic coupling.
    - Optical coupling.
  - There is no "ideal" coupling; all methods suffer from certain problems.



- MEMS uses all of "known" **Si** technology and has some specifics of its own.
  - Making cantilevers and membranes necessitates making "large" cavities.
  - Staying absolutely planar and stress-free is essential
  - Packaging can be far more demanding than for chips (e.g. transparent tops for **OMEMS**, keeping defined pressures for **> 10 a** in gyros).
- The ***bane*** of **MEMS** is **stiction**.
  - If you can't lubricate, it will stick sooner or later. Never bring moving parts in contact!
  - **MEMS** design therefore cannot just miniaturize exiting mechanical designs; it must look for new approaches.



Works **Sticks**

- **MEMS** employs some special processes and materials; they are the drivers of progress

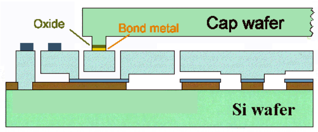
- Anisotropic chemical etching
- High-rate plasma etching ("Bosch process")
- Chemical-mechanical polishing
- Sacrificial layers and removal (including chemical etching with "vapors")
- Wafer bonding; in particular for packaging.

Making "large" cavities and extremely deep "holes"

Planarization

Free-standing structures

Process integration looks simple if compared to an advanced **CMOS** process, but is actually rather involved due to the special processes needed and quality requirements



Exercise 7.3-1

All Questions to 7.