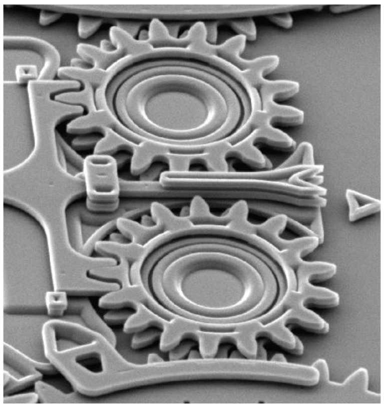
6.1.3 Uses of Silicon Outside of Microelectronics

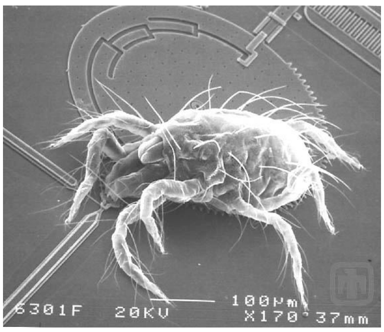
Solar Cells

- Besides integrated circuits, electronic grade **Si** is used in rather large quantities for the production of **solar cells**. While there are solar cells made from other semiconductors, too, the overwhelming majority of solar cells really producing power out there is made from (thick) **Si**. We may distinguish three basically different types.
  1. Solar cells made from "thick" (**< 300 µm**) slices of *single-crystalline* **Si**. The substrates are essentially made in the same way as wafers for microelectronics, except that quality standards are somewhat relaxed and they are therefore cheaper.
  2. Solar cells made from "thick" (**< 300 µm**) slices of *poly-crystalline* **Si** with preferably large grains. This material is therfore usually referred to as "**multicrystalline Si**".
  3. Solar cells made from thin (some **µm**) layers of fine-grained poly-crystalline **Si** deposited on a (cheap) glas substrate. This type of solar cell is at present (**2005**) in the research and development stage.
- We will not discuss solar cells here in any detail, but refer the matter to the Hyperscript "*Semiconductors*" where some background on Si solar cells is provided.

MEMS - Micro Electronic and Mechanical Systems

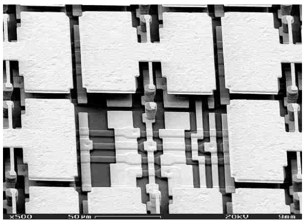
- Micromechanical devices made from **Si** are rapidly gaining in importance. Their production process utilizes most everything used in microelectronics, plus a few special processes.
- Again, we will not discuss **MEMS** in this Hyperscript, but show only a few pictures of what can be made.
  - Let's look at *mechanical* **MEMS** first. On top, a microscopic gear wheel systems from *Sandia Labs*. It could be used for mechanically "locking" your computer; which might be more secure than just software protection.
  - On the bottom, more or less the same thing with a dust mite on it. This is the little animal that lives in your rug, bed and upholstery and gives a fair share of us the infamous dust ("Hausstaub") allergy



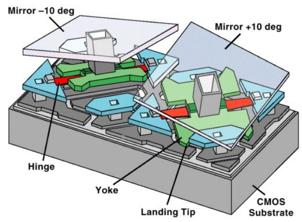


Pictures: Courtesy of Sandia National Laboratories, SUMMiTTM Technologies, www.mems.sandia.gov"

  - While gear wheels look very good, the real use of **MEMS** so far is in sensors, in particular for acceleration. The sensor exploding your air bag when you wrap your car around a tree is the paradigmatic **MEMS** product.
- If we look at *optical* **MEMS**, we are mostly also looking on a mechanical microstructure, in this case at arrays of little mirrors which can be addresses individually and thus "process" a light beam pixel by pixel.



Courtesy of "ISiT"
(Fraunhofer Institut Silizium Technologioe; Itzehoe, Germany)



Courtesy of Texas Instruments

- On the left we have an array of microscopic mirrors that can be moved up and down electrically (from the **ISiT** in Itzehoe). The central mirror is removed to show the underlying structure
- On the right a schematic drawing of the "mechanical" part of Texas Instruments ("***DLP***" = digital light processing) chip, the heart of many beamers.
- But many other things are possible with **MEMS**, suffice it to mention "bio-chips", micro-fluidics, sensors and actuators for many uses, microlenses and lens arrays, and tunable capacitors and resonators, and, not to forget, very down-to-earth products like the micro-nozzles for ink jet printers.

Miscellaneous

- There are many more applications, most in the development phase, that exploit the exceptional quality of large **Si** crystals, the unsurpassed technology base for processing, or simple emerging new features that might be useful. Here are few examples:
- While there are no conventional lenses for **X**-rays or neutron beams, some optics is still possible by either using reflection (i.e. imaging with mirrors) or diffraction.
  - An good **X**-ray mirror, like any mirror, must have a roughness far smaller than the wavelength. For useful applications (like "**EUV**" = Extreme Ultraviolet) lithography (it is really X-ray lithography, but this term has been "burned" in the **80**ties and is now a dirty word in microelectronics), this quickly transfers into the condition that the mirrors must be more or less atomically flat over large areas. This can be only done with large perfect single crystals, so your choice of materials is no choice at all: You use **Si**.
  - If you want to "process" a neutron beam, e.g. to make it monochromatic, you use Bragg diffraction at a "good" crystal. Again, mostly only large and perfect single crystals of **Si** meet the requirements
- Si is fully transparent for **IR** light and is thus a great material for making **IR** optics. In this field, however, there is plenty of competition from other materials. But **Si** is the material of choice for mirrors and prisms needed for **IR** spectroscopy.
- Since about **1990** "porous **Si**" is emerging as a totally new kind of material. It is electrochemically made form single-crystalline **Si** and comes in many variants with many, partially astonishing properties (optically activity, highly explosive, ...)
  - A review about this stuff can be found in the link . Here we simply note that a number of projects explores possible uses as for example electrodes for fuel cell, very special optical and **X**-ray filters, biochips, fuses for airbags, "normal" and biosensors, or special actuators.