4.2.2 No Need For Single Crystals

- There is an important product line of modern semiconductor technology could not exist at all if you would always need single crystal substrates:
  - Large area displays in the form of "**liquid crystal displays**" (**LCD**) and - quite new - "**OLED**" displays based on organic semiconductors.
  - **Solar cells** based on large-area thin film technology and employing as the main functional semiconductor:
    - **H**-rich, doped, amorphous **Si** (**a-Si:H**).
    - **H**-rich, doped, micro-crystalline **Si** (**µc-Si:H**).
    - "**CIS**" and "**CIGS**" based solar cells.
    - **CdTe** based solar cells.
- Then we have one major product line where single crystals compete with other structural forms of the semiconductor:
  - Solar cells made from single crystal wafers and solar cells made from multi-crystalline wafers
- In the laboratory is much more along these lines. There is a unifying element however, in all of this:

Large areas are needed; preferably or necessarily in one piece

- This is self-evident for solar cells, let's have a quick look at displays:
  - Any display processes light in pixels. There are two basic ways of doing this:
    1. There is always plenty of light in the "back" of the display; processing consists of allowing only the proper amount of light (and the proper color) to pass through the pixel at the proper time.
    2. The pixel actively generates the right amount of light at the right time.
  - **LCD's** and all beamers belong in the first category; **OLED** displays in the second. Of course, the second category has the option of being more energy efficient (since you don't waste most of the light you generate) but the first category is presently (**2008**) more advanced
- In both case, however, an individual pixel needs to be "told" what to do.
  - At the crossing of a matrix of (**n × m**) conductors each pixel can be individually addressed by its coordinate (**n,m**). For good display, you need to have at least one transistor at the cross-point to allow efficient addressing.
  - You thus need a large substrate that allows to make at least simple transistors with **100 %** yield (one "dead" transistor = one dead pixel!). Single crystals are mostly not large enough, would be prohibitively expensive and very troublesome because they are not transparent to light.
  - Thin layers of **a-Si:H** or sometimes microcrystalline **Si** on glass, while not good enough for, e.g., the kind of transistor needed for microprocessors or memory chips, are good enough for **LCD** displays - since about **1990**. Before that time, there simply were no (affordable) flat panel displays!
- Remember the credo: Products only sell if they are cheaper and / or better.
  - If you can make a transistor matrix on a large size substrate, you can make a flat panel display, and that is certainly *better* than the good old picture tube (***CRT***).
  - The transistor matrix is then one of the **enabling technologies** you need for the **LCD** display (the other one are the liquid crystals)