Solution to

All Quick Questions / Class Exercises to

2.1 General Chemistry and Structure

Ponder the history of "***LCD***" flat panel displays.

- Well - no. You do that yourself. Here just a few hints:
  - The first commercial color flat panel displays larger than the black-and-white stuff in cheap watches and based on **LCD** technology hit the market around **1990** - and they were small and incredibly expensive.
  - You need two things for a large **LCD**: liquid crystal technology and a lot of transistors in a matrix to control every pixel of the display.
  - Flat panel displays are much larger than the biggest wafers available. So how do you make a transistor matrix?

Why does the world need saving? How shall it be done?

- Two words are sufficient: **Climate catastrophe** and dwindling **resources of oil**. However, if nothing is done about that rather soon, it's not the world that will need saving, only the humans presently over populating in ever increasing numbers the surface of the planet.
- If the humans are to be saved, the magic word is: *solar energy*. In all its forms - direct heat, water power, wind and solar cells.
- Semiconductor technology is instrumental. Not only for making plenty, efficient and cheap solar cells, but also for controlling the other solar energy sources and for distributing power generated by untold millions of small power plants over large distances.

Why do we use crystals, preferably single crystals; preferably "perfect" single crystals in case of doubt?

- Because then we know that the electronic properties are the best we can get. If we need to adjust them to values other than those of the perfect crystal, we can try to do so. Dirty words like "Fermi level pinning" will not make our efforts useless.

Supply examples for critical parameter - component couplings.

- Fast transistors need high *mobilities* = small defect densities.
  Solar cells need large *life times* or diffusion lengths = small defect densities.
  Power devices need to sustain *high field strengths* and need very uniform conductivity and thus uniform doping.
  .....

What makes a semiconductor interesting for technology?

- Bandgap size and type.
  Properties of defect states.
  Can it be easily p- and n-doped?
  Production potential. Perfect or at least decent single crystals available for littel money? Thin films on suitable substrates achievable?
  Are materials needed for technology plentiful and cheap? Extremely dangerous or simple to handle and and to dispose off?

How would you like your Bandgap, Sir?

- Well, thanks for asking. But that depends on my present taste:
  - Rather small for **IR** detectors or thermoelectric devices like Peltier elements for active cooling.
  - Around or just above **1 eV** for common and cheap electronics.
  - Around **1.5 eV** if I want to make high-efficiency solar cells.
  - Direct and exactly **1,325 eV** if I want to make light with that energy.
  - Rather large if I have high temperature applications in mind.

What does it mean to dope a semiconductor in reality?

- To shift the Fermi energy close to the band edges. This can be done by introducing defect levels close to the band edge, but this will only work if you do not have a lot of other defect states in the band gap already.

Come up with **2 - 3** examples where product requirements transfer to shape / structure requirements.

- • The overwhelming product requirement for a solar power station is to have a huge area (and decent efficiency) of the solar cells. This transfers to making the solar cells thin to save material and not to make them single crystals to save costs.
  • Flat panel displays need a matrix of transitors to address single pixels. Sizes are kow in the $\mathbf{m^2}$ region

Can you still afford it if your present product is hugely successful? - What could that mean?

- You are presently producing **1 GB** memories - **DRAM's**, **SRAM's**. Flash, whatever, and making a lot of money. Your engineers have been working on the next generation, the **4 GB** memory, and have made a few functioning prototypes. Should you start to dig a hole, throw some concrete in it and built a **4 GB** factory to the tune of roughly $\mathbf{5 \cdot 10^9}$ **€**? Or wait a bit longer, enjoying the money coming in instead of spending it on a new factory that may not be needed so soon?
  That is what that question could mean for just one product example.
- You should be as sure as you can be that two conditions are met before you built the new factory:

  1. Your **4 GB** memory chip sells for less than **4** times the price of your **1 GB** memory. Otherwise you customers buy four **1 GB** chips instead of your new chip.
  2. The market for memory *bits* per year should grow at least **4**-fold during your **4 GB** production time. If it would be always constant, for example, the number of **4 GB** chips you could sell would only be **¼** of the number of **1 GB** chips. That means your income is far too small to recover the cost of your **4 GB** factory (that was far more expensive than your **1 GB** factory!)...
- In total: Being able to *make* the new product does not mean that your are going to be able to *afford* making the new product. Semiconductor technology always has a money component, too!

Provide examples (and criteria) for the products listed

- You do that!