Things to know/remember:

(you should also know the equations listed below)

Introduction

- The main applications of macroelectronics
- The semiconductor materials used for these applications
- The basic functioning of these applications

Deposition

You should

- Be able to describe a plasma
- Describe the voltage drop at sheath
- Know the working principle of PECVD and sputtering
- Know what governs the transition a-Si / µc-Si
- Understand V_p and the role of ion bombardement
- Know the advantage and disadvantage of VHF-PECVD
- Know the difference between pure CVD, PECVD, sputtering

Material and structure

- What is an amorphous material and how they are obtained.
- Glass transition in amorphous materials
- The scale of order in crystalline, polycrystalline and amorphous materials
- The differences in material characteristics between amorphous and crystalline material (case of Si). Description of the disorder in a-Si:H.

Density of states and defects

Band tails

Several experiments suggest that the density of states at the band edges tails off exponentially.

$$N_t(E) = N_C e^{E/kT_0} = N_C e^{E/E_0}$$

You should:

- Be able to name one of those experiments
- Remember typical values for E_0 (a-Si:H case)
- Know how the weak bond model explain band tails

Thermal equilibrium defect density

A (simple) formula predicts the density of neutral defects N_D at high temperatures.

$$N_D(T) = N_0 \frac{1}{1 + e^{(E_{BB}/kT)}} \approx N_0 e^{(E_{BB}/kT)}$$

You should know

- The concept behind the formula, what E_{BB} is (and how it changes when the defects are not neutral but charged).
- The effect of temperature (cooling down) and the typical values for the defect density (for a-Si:H) at room temperature.
- At least one experiment to measure N_D

Defect kinetics

The kinetics of defect-creation and -curing (in addition to the equilibrium density) is described empirically by the stretched exponential formula.

$$N_D = N_{sat} - (N_{sat} - N_0)e^{-(t/\tau)^\beta}$$

You should know

- The quantities in the formula
- Its effect/signature of defect kinetics in the context of solar cells

Electronic transport

Temperature dependence of the DC conductivity:

For the devices and basic characterization of films, the most important part of the temperature dependence is an exponential relationship between RT and 200°C.

$$\sigma(T) = \sigma_0 e^{-E_a/kT}$$

- You should know what the quantity E_a is (and possibly know typical values for intrinsic, n-, and p-doped a-Si:H material).
- Bonus: Where does the statistical shift (Meyer-Neldel rule) come in?

Temperature dependence of the drift mobility:

The drift mobility is also thermally activated.

$$\mu_D(T) \approx \mu_0 \frac{N_C kT}{n_t} e^{-E_t/kT} = \mu_{00} e^{-E_t/kT}$$

- What is the idea behind the (simple) formula? What is the quantity E_t?

Recombination

Shockley, Read and Hall gave a formula for the recombination rate:

$$R_{SRH} = \frac{n_f p_f - n_1 p_1}{(n_f + n_1)\tau_p + (p_f + p_1)\tau_n}$$

You should know

- The common approximations to the formula, particularly for doped material.
- The located in the band gap of the "efficient" recombination centres
- If SRH formula is applicable to a-Si:H and why.
- The notion of amphoteric defects

Photoconductivity

$$\sigma_{\text{photo}} = e \cdot (\mu_n n_f + \mu_p p_f)$$

- The relationship between photoconductivity and recombination (and lifetimes)
- The effect of generation rate and temperature on photoconductivity

Photovoltaics and solar cells

- Spectral conversion efficiency and effect of band gap and illumination spectra
- Diode equation, ideality factor

$$I_{dark} = I_0 \left[\exp\left(\frac{qV}{nk_BT}\right) - 1\right]$$

- Effect (qualitative) of bandgap, temperature and illumination on I_{sc}, V_{oc}, *FF* and efficiency
- Equivalent circuit
- Multi-junction devices: motivation for, a few examples and the *I(V)* characteristics compared to single-junction
- List of main PV technologies, distinction between bulk and thin-film

Thin film silicon and solar cells

- Differences between a-Si:H and c-Si solar cells
- What is limiting a-Si:H solar cells performance (compared to c-Si)
- Effect of defect creation/annealing on the a-Si:H solar cells performance
- Limiting factors for photogenerated carrier collection
- The importance of light-trapping
- The benefit of multi-junction devices

Photodetectors and photoconductors

- The difference between primary and secondary photocurrent
- Operating conditions of a photodiode (in contrast to solar cells)
- Material properties for “best” photoconductor (highest dark to photo-conductivity ratio)
- Functioning of a copy machine and the requirements for the choice of photoconductor

Thin film transistors and flat panel displays

- Active vs passive matrix display
- Basic functioning of main types of displays
- Structure of an AMLCD
- Typical TFT configuration
- TFT operation, comparison with standard c-Si FET, regimes (off, linear, saturation regimes)
- FET mobility, determination of the FET mobility and typical mobility values for various forms of Si materials, transconductance, source drain current dependence,

  $$I_{DS} \approx \mu_n^{FET} \frac{W}{L} C'_{nitride}(V_G - V_{T,mean})V_{DS}$$
- Reasons for the absence of a-Si:H TFT p-type transistors
- a-Si:H TFT instabilities (origin and effects)
- One or two examples of alternative materials (for TFT in displays)

Large area sensors

- Interaction of particle with matter (charged or photons), main mechanisms, energy loss (qualitative), material choice
- Direct vs indirect particle detection, typical number of electron-hole pairs, resp. photons generated
- Functioning of AMFPI
- Depletion condition for diode sensors (scaling with diode thickness)
- Structure and functioning of a position detector

Emerging material and applications

- Examples of applications of amorphous semiconductors