

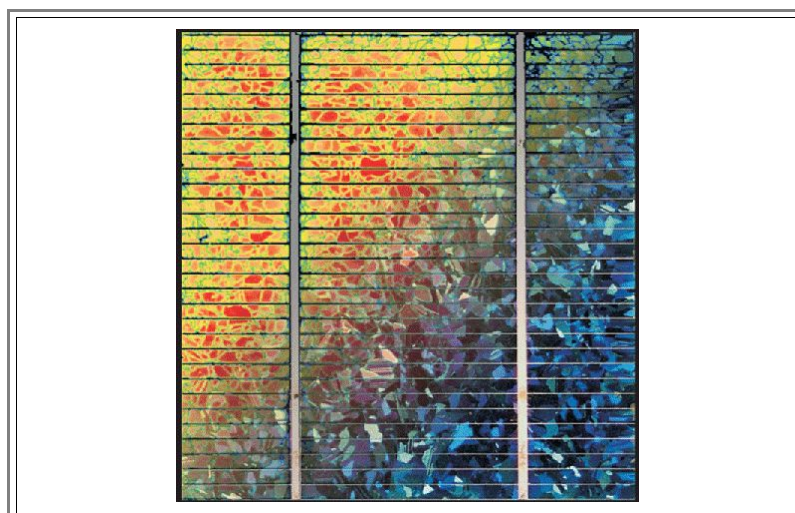
3.5.3 Local Properties

General

- Local properties, if seen as complementary to the *general* properties discussed before and where a single number was all you wanted, give pictures or maps of what is going on locally.
 - Of course, a number like "average grain size" may be seen as a local property, too - but what the hell, you know what is meant here.
 - In essence, here we are discussing methods that produce a kind of *picture* - directly like an optical microscope, or indirectly like a **STM**.
- Let's just enumerate the main techniques. Since they are covered in detail in other lecture courses, we will not go into any details here.

Optical Microscopy

- You can see a lot by just looking through an optical microscope *on* your thin film or *through* your thin film (if substrate and thin film are transparent) - provided that the things you see are $\geq 0.5 \mu\text{m}$ or so.
 - You have many different imaging modes at your disposal today. From classical microscopy, to all kinds of contrast enhancers (polarizers, phase or interference contrast, scanning, ...).
 - You also may prepare your specimen in such a way that things are better visible. Etching the surface with special etchants may delineate defects, for example (and may etch off your layer completely, so be careful).



- The example here shows the microscope image (very low magnification) of a solar cell in the lower right hand corner blended electronically with a short-circuit current image, i.e. a property image of the **pn** junction formed because there is a thin **n**-type layer "on top" of the **p**-type substrate. The colors denote quantitatively the local photo-current (yellow - red: large currents; green - blue: low currents).

Electron Microscopy

- There are two kinds of electron microscopes:
 - Scanning electron microscopes**, (**SEM**). Using a **SEM** you look at the surface of your sample; in its analytical mode you may "see" to a depth of a fraction of a micron
 - Transmission electron microscopes** (**TEM**). With a **TEM**, you look through a always thin sample. In one of the many imaging modes you can see and analyze what is inside your thin film at atomic resolution.

Scanning Probe Microscopy

- ▶ We can scan all kinds of probes across the surface of our thin film. if we desire very high lateral resolution we have
 - **Scanning tunneling microscopy, (*STM*)**. Using a **STM** you look at the electron density at the surface of your sample; this allows you to "see" single atoms
 - **Atomic force microscope (*AFM*)**. With an **AFM**, you measure the force that surface atoms (or coarser structures) exert on a close by oscillating probe tip.
- ▶ There are many more scanning probe instruments, e.g. for measuring surface charge (....) look it up!

Summary

- ▶ The whole sub-chapter just served to make you aware of a few basic and rather simple truths:

- 1. Thin films have just as many properties as bulk materials, but they might be far more difficult to measure.**
- 2. Thin films may have additional properties not defined for bulk materials with specific measurement techniques**
- 3. A lot of measurement and characterization techniques have been developed just for thin films**