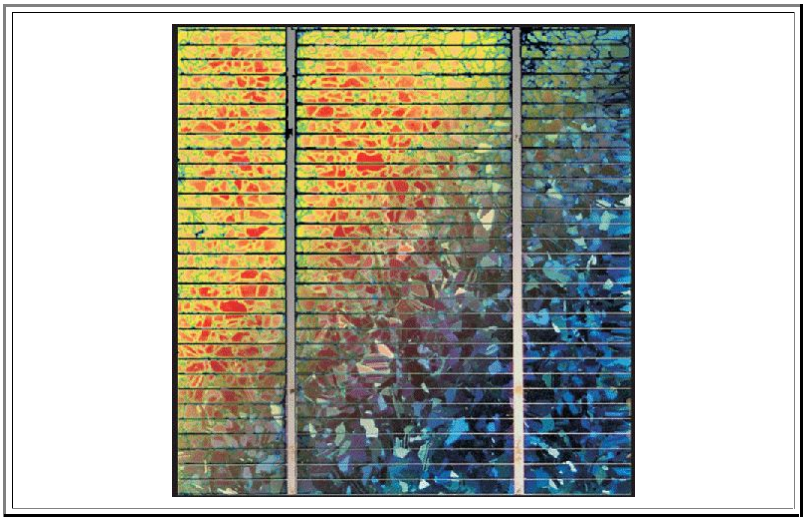
3.5.3 Local Properties

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 ≥ **0.5 µm** 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 ways 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