The energy levels associated with point defects in silicon are fairly deep. They serve as centres for minority-carrier recombination and therefore reduce the carrier lifetime. The lifetime is inversely proportional to the concentration of point defects.

The diffusion of atoms in a crystal proceeds by thermally activated jumps from sites to sites. The diffusivity is expressed by the diffusion coefficient, D, with units cm^2/s:

$$D = D_0 \exp(-E_D/kT)$$

where D_0 is a constant and E_D is the activation energy for the jumping process.

At higher concentrations the impurities may agglomerate. The ability to be in solid solution increases with temperature (see Section 5.6.3). The impurities in a material at a certain purity level may thus be in solid solution at elevated temperatures and form *pairs* with other atoms or *precipitate* at dislocations, at grain boundaries or with other impurities at lower temperatures. The sequence of precipitation is characterised by *nucleation*, *growth* in which excess atoms diffuse to precipitates and Ostwald *ripening* in which a growth competition exists where large precipitates grow at the expense of small ones.

Minority carriers (being electrons on the p-side and holes on the n-side of the solar cells) flow more readily within a grain than across grain boundaries. Minority carriers may recombine with majority carriers at recombination centres like impurities, precipitates, dislocations and grain boundaries. The average distance that a minority carrier will travel within silicon depends upon the density of recombination centres and their recombination ability. The longer the distance between recombination centres, the better the efficiency of the cell. Precipitation of impurities reduces the number of atoms in solid solution and may therefore change the minority-carrier diffusion length. The density of precipitates is governed by the cooling rate, the ramping sequences and the diffusivity of the impurity elements.

At the surface there are many recombination sites. In the final cell production sequence, gettering and passivation will change the conditions near/at the surface.

Measurements of the local electronic properties in individual grains and near grain boundaries show that the properties may vary from grain to grain. It is hoped that the results of such measurements may stimulate further theoretical and experimental work to clarify the relations between grain structure and the electronic properties in multicrystalline silicon.

The density of dislocations influences the lifetime of the minority carriers. Experiments show good correlation between areas having a high dislocation density and a short effective lifetime. To control the dislocation density has therefore become an important task. The dislocation movements and multiplication and their interaction with impurity atoms being in solid solution or existing as complexes during the production processing steps challenges our ability to model complex relationships. However, it is being claimed that numerical simulation is used as a valuable tool to optimise the crystallisation and cooling processes at plants. This is the kind of work that certainly will develop during the coming years.