

The solid state in-between

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What is a crystal? This question again and again causes discussions in the crystallographic community. However, having in mind the solid state in general, materials scientists are usually confronted with something in-between two extreme, ideal states of solids: The perfect crystal and the perfectly amorphous state.

The ideal crystal, the definition of which is still being argued about (especially when aperiodic or quasicrystalline solids are given to us by nature), shows perfect long range order (LRO). Either points or real atoms filling space have to be considered, the situation may or may not be clear.

The ideal amorphous state: When we consider an ideal amorphous state, points are scattered randomly in space. They have no correlations, no structure at all: $\alpha\mu\omicron\rho\phi\omicron\varsigma$ - meaning “no form”. This has to be adapted for real atoms with no shorter than minimum distances allowed. So if we deal with *e.g.* real glasses, a short range order (SRO) does exist.

This constraint, as well as deviations from the other extreme of perfect crystallinity (different degrees of disorder are possible), already calls our attention to the state “in-between”:

In the last years, there is more and more evidence for “amorphous” materials exhibiting

- different kinds of SRO, *e.g.* Santoro *et al.* (2006)
- poly-amorphism, *e.g.* McMillan (2004)
- “medium-range” order, *e.g.* Bates *et al.* (2006), or Brühne *et al.* (2007)
- partial crystallinity, *e.g.* Petkov *et al.* (2000), or Paglia *et al.* (2006)
- nanocrystallinity, *e.g.* Gilbert *et al.* (2004), or Page *et al.* (2004)

Are for these substances the diffraction patterns still “discrete”? They definitely are something in-between and should be part of the discussion. Experimentally, total scattering techniques begin to help us to elucidate this situation in a growing number of cases (Kanatzidis & Billinge, 2004; Egami & Billinge, 2004). For a „nanocrystallographic“ website, where nanocrystallinity is even dealt with in bulk crystals, see <http://nirt.pa.msu.edu/index.php>. A pending issue of *Zeitschrift für Kristallographie* 2007 is on “Nanocrystallography”.

We expect for the future next years an increase of experimental data and thus new knowledge on the state in-between order and disorder. The properties of many materials often are distinctly governed by correlations on the nano-scale (Billinge & Levin 2007).

A scientific goal will be a new and comprehensive definition which incorporates all the terms used today: *ideal crystal*, *disordered crystal*, *real crystal*, *perfect crystal*, *imperfect crystal*, *nanocrystal*, *paracrystal*, *metacrystal* (Steurer 2007), and moreover terms like *amorphous*, *ideally amorphous*, *glassy*, *semicrystalline*, *partially crystalline*, *partially amorphous*, *poly-amorphic*, ..., and so on. Synonymous to the desired definition is the intellectual insight of these varieties of the solid state. Steps towards a ‘holistic’ approach can be seen in the mathematical understanding of Faraday waves (Lifshitz & Petrich 1997) or in the crystal formation of monoatomic model systems with a simple parametrized interaction potential (Engel & Trebin 2007).

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Being non-mathematicians and non-theoretical crystallographers, we would welcome – alongside the definition of “crystal” – definitions of all the other terms necessary to describe the solid state(s). The extension of the problem may complicate the situation. But probably (and hopefully!) a change in perspective will feed back on the given problem “What is a crystal” and therefore may help to clarify the situation.

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