Open Topics

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Quo Vadis, Transmission Electron Microscopy?

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Over the last two decades impressive progress has been made in all areas of transmission electron microscopy. A major advancement was the theoretical design and experimental realisation of correctors for the omnipresent aberrations of electron lenses. Instrumentation could profit from technological advancements: magnetic materials with excellent properties are available nowadays, the high voltage of the instruments as well as the currents of the lenses and correctors can be stabilised with extremely high accuracy. However, any technological progress will sooner or later push against the physical limits of the instruments. It seems likely that the physical limits will be reached soon.

Also the understanding of contrast phenomena made progress and is now also close to the limit, as summarized in a recently published book [1]. In that book microscopy at high resolution is called "nanoscopy". This suggestion follows the present trend to identify many phenomena as "nano". In principle, this new name is not necessary but may be important for political reasons.

Microscopy as a field of science is, of course, of great importance. The main contributions of microscopy will be expected in areas of materials science, solid state physics, solid state chemistry, Revealing the microstructure of the materials may lead to an understanding of the relationship between the microstructures and properties of the materials or materials systems.

It looks like everything is available from an instrumentation point of view to determine positions, compositions, and bonding of individual atoms in a solid, in 3 dimensions and as a function of time. Major problems have to be solved in achieving the goals.

One important challenge is to determine all data quantitatively (numbers with error bars) not just images. The precision of the data has to be evaluated.

Other challenges for quantitative microscopy are:

- Determination of the 3D structure of the materials. Tomography with high accuracy is needed.
- 4D electron microscopy by ultrafast microscopy by which stroboscopic images can be made at (nano-, femto-) second time intervals [2]. These studies will yield insight on the dynamics of various chemical as well physical processes.
- Reduction of radiation damage by applying lower high voltages of the instrument (as low as possible) with aberration-corrected lenses.
- Specimen preparation techniques have to be improved. This is a long-standing problem. The quality of the (best) specimen influences the data obtained by TEM.
- Non-conventional imaging extracting the phase of the waves will lead to information on the fields inside a specimen.
- It is presently not quite clear what the contributions of TEM will be with regard to revealing the structure of amorphous materials.

Concerning amorphous materials progress has been made by "fluctuation electron microscopy FEM" in combination with phonon scattering [3].

The mechanical properties of metallic glasses (MG) depend strongly on their structural ordering at the nanoscale. Many studies have been completed on the short-range order of metallic glasses, indicating a preference for icosahedral-type short-range order. However, the prevalent nanostructure present at medium-range length scales in most metallic glasses remains open to debate. Cu-Zr binary metallic glasses are good glass formers over a large composition range and serve as a useful model system to study medium-range structural order in metallic glasses. Investigations have been performed so far for different Cu-Zr MGs (Wochner et al [3], Bogle et al [4]).

There are great challenges ahead in the area of microscopy of materials. These can be overcome by improving present day analysis techniques with higher and better accuracy or by developing new techniques. New techniques can be achieved either by deep thinking or/and by serendipity.

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