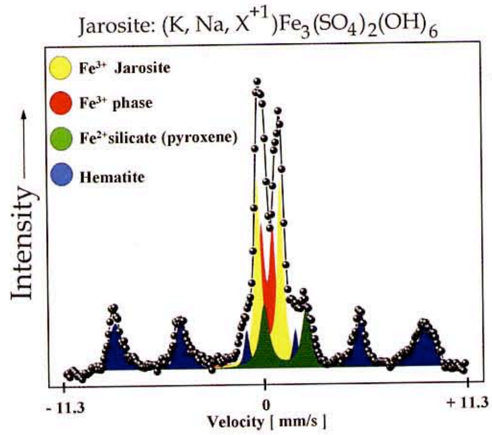
www.ima-mineralogy.org

International Mineralogical Association



Mössbauer spectrum of El Capitan: Meridiani Planum

^{57}Fe Mössbauer spectrum taken in situ from the Mars surface [Klingelhöfer et al. (2004) Science 306: 1740-1745].

COMMISSION ON PHYSICS OF MINERALS

Georg Amthauer

The Commission on Physics of Minerals (CPM) was established by IMA to promote the application of modern solid state physics to minerals and their physical properties as a function of temperature and pressure, even those occurring under the extreme conditions of the deep Earth. Many Earth processes can be understood only on the basis of a profound knowledge of the physical properties of the minerals involved, so research in mineral physics is fundamental in Earth sciences. One recent example is the discovery of the relation between deep earthquakes and the phase transition of olivine minerals under very high pressures in the upper mantle. In addition, many mineral groups, for example garnets, perovskites, spinels and zeolites, have physical properties that are very important for various technological applications. The development of innovative photovoltaic devices based on natural sulfosalts exemplifies the close relationship between mineral physics and materials science.

In both types of applications of mineral physics, the connection between crystal structure or phase transformations and the related physical properties plays a decisive role in the understanding of phenomena. For the determination of crystal structure (on the subnanometer scale) and its dependence on temperature and pressure, several diffraction methods using X-rays, neutrons, electrons, and synchrotron radiation are available. With these methods, not only the positions of ions on lattice sites, but also electronic distributions around the nuclei may be derived. Transformations of structure (phase transitions) can be detected with high accuracy using special calorimetric methods. The physical properties measured comprise scalar quantities, such as density and specific heat, and tensor quantities, like elasticity/ compressibility, thermal and electrical conductivity, refraction coefficient, magnetic susceptibility, and electric field gradient. Here, classical methods, such as calorimetry, magnetometry and refractometry can be used, but spectroscopic tools, like infrared, Raman, Mössbauer spectroscopy, ESR and NMR are preferable. The latter have the great advantage of providing direct information at an atomic or even nuclear scale.

To develop a sophisticated interpretation and deep understanding of the physics of minerals, however, we need not only experimental data from structure solution and solid state physics, but also the important contribution of quantitative methods, such as density functional theory based on quantum mechanics. This relatively recent mighty tool connects structural parameters, like ionic distances and symmetries in the crystal structure, with physical properties, such as specific heat, magnetic moment structures, and electric field gradient. Thus, it is possible to create or control physical models for the intrinsic mechanism of the orientation of magnetic moments or electronic conduction in specific minerals. New or revised mineral-like materials with predicted properties can be "designed," of eminent importance for materials science.

Recent developments in mineral physics show that the most significant advances are obtained at the "boundary regions" between mineralogy and other disciplines:

- In the field of planetary mineralogy, spectacular identifications and analyses of minerals on the surface of Mars were obtained by the NASA rover using a miniaturized Mössbauer spectrometer (MIMOS II) in combination with in situ X-ray fluorescence analysis (see diagram).
- Innovative photovoltaic devices have been synthesized and produced, based on naturally occurring sulfosalts.
- The use of ferrofluids (mostly a suspension of magnetite nanoparticles) in cancer therapy represents a recent application in medicine.
- The development of the famous perovskite high-temperature superconductors resulted from a close interaction between mineralogy and physics. One of the inventors was Nobel Prize winner in physics J. Georg Bednorz, who has a diploma in mineralogy and crystallography.
- New findings in the field of nanotubes as a tool for ultrahigh-density data storage in computer technology are based on exact knowledge of crystal-growth conditions, obtained from study involving a close collaboration between mineralogy, chemistry, and physics.
- Outstanding progress has been made in the field of ultrahigh-pressure and ultrahigh-temperature mineral physics, by in situ measurements and experiments, and by computer simulations and calculations of the electronic and magnetic structure of minerals based on quantum mechanical principles.

The next few years may well bring similar progress in mineral physics through development of new analytical and experimental methods, by the improvement of old ones, by making databases more complete and accessible, and through computational mineral physics. However, who can predict where really important progress in science will come? My personal opinion is that, despite all the progress in computer science, it is still very important to perform reliable experiments and make exact measurements, and I want to encourage younger scientists to work in this field.

The main task of CPM is to promote all the different branches of mineral physics. However, there is no sharp boundary between mineral physics on the one hand and crystal chemistry and mineral thermodynamics on the other. CPM will keep promoting better communication between the different groups working in the field. During the last few years, the CPM has organized workshops and symposia during the IMA meeting in Edinburgh, UK (2002) and during the International Geological Congress in Florence, Italy (2004). The IMA meeting in Kobe, Japan, in July 2006 will feature exciting symposia on mineral physics. I hope to meet many mineral physicists there.

Georg Amthauer
University of Salzburg
Chairman, Commission on Physics of Minerals