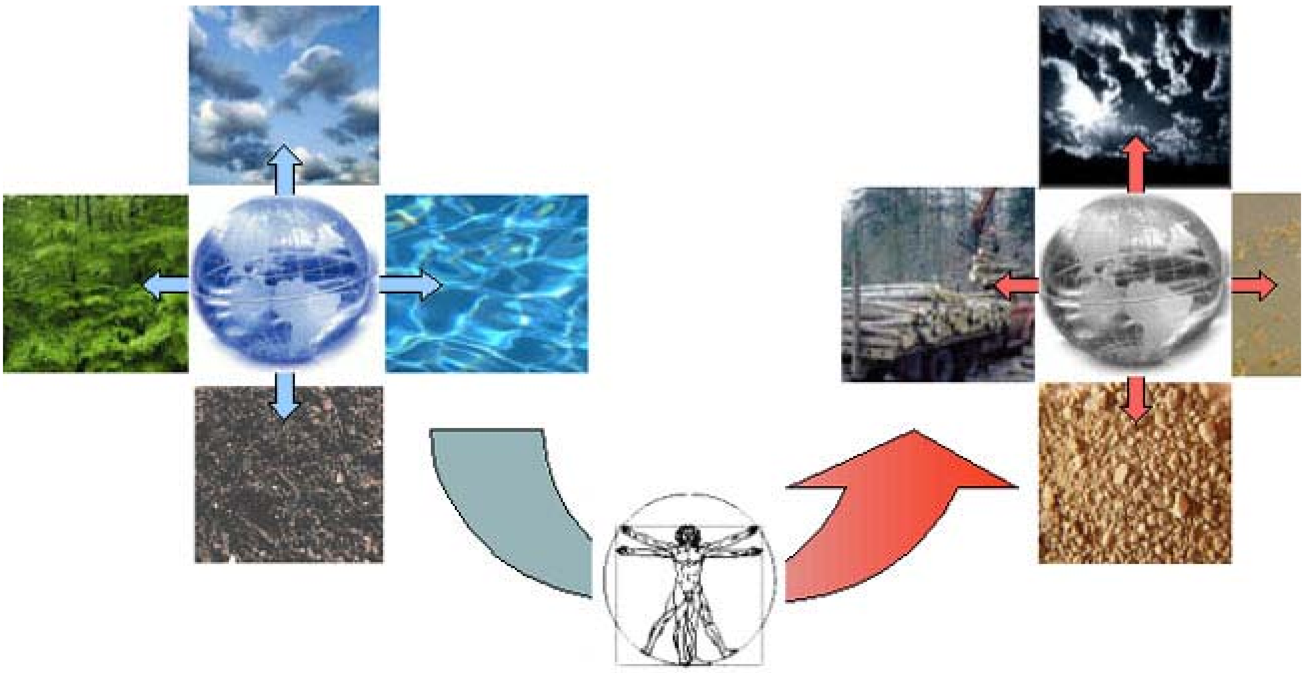
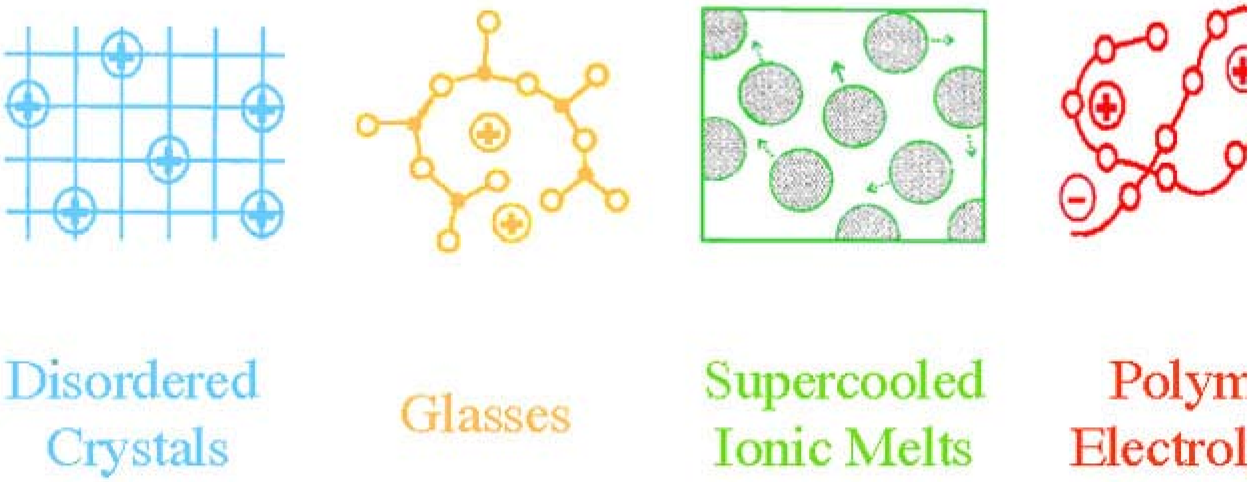
Environment, Ions and Polymers

The generally accepted age of the Earth is approximately 4.5 billion years. The oldest rocks which have been found on Earth date back approximately 3.9 billion years. The Earths biosphere (pictured below) consists of the atmosphere, the hydrosphere, the lithosphere and the ecosphere. The exact origin of the biosphere is unclear, however, scientists suggest that water first precipitated 4.4 billion years ago, whilst the first thermophilic bacteria and blue green algae existed 3.5 to 4 billion years ago. The ozone layer began to function as a UV screen approximately 600 million years ago which lead to a huge explosion of life. The first plants appeared on land approximately 400 million years ago with reptiles thriving approximately 100 million years later. Our biosphere evolved over a long period of time to form the delicate balance it is today. In contrast to this, man (homo sapiens) is only 150-200 thousand years old. Although much of the biosphere has survived and evolved over hundreds of millennia, today it is under threat from us. Humanity currently poses the greatest long term threat to our biosphere. Since the industrial revolution we have grown an insatiable appetite for natural resources to fuel our needs.



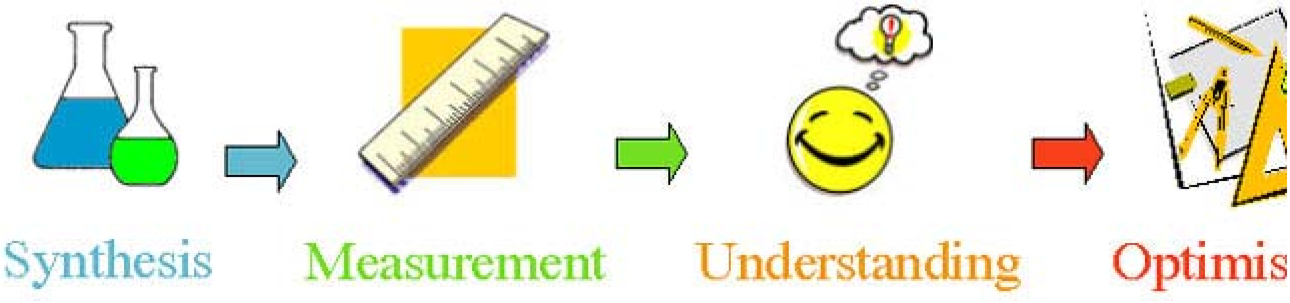
The power we consume generally comes from harnessing the energy obtained when burning fossil fuels or from physical and chemical processes. Generally, obtaining fossil fuels (mining) and their use (carbon dioxide production) causes irreparable damage to the environment. Further, the reserves of fossil fuels are finite. Currently, the best way to combat these factors is to rely on chemists, physicists and materials scientists to develop new technologies which produce energy cleanly (e.g. fuel cells), efficiently store energy from renewable sources such as solar power (e.g. batteries and capacitors) and help us reduce energy consumption (e.g. electrochromic windows).

All of these technologies currently under development owe their importance to the movement of charged particles or ions. Of all the materials currently studied, the most promising and most technologically relevant are materials with disordered structures. These include:

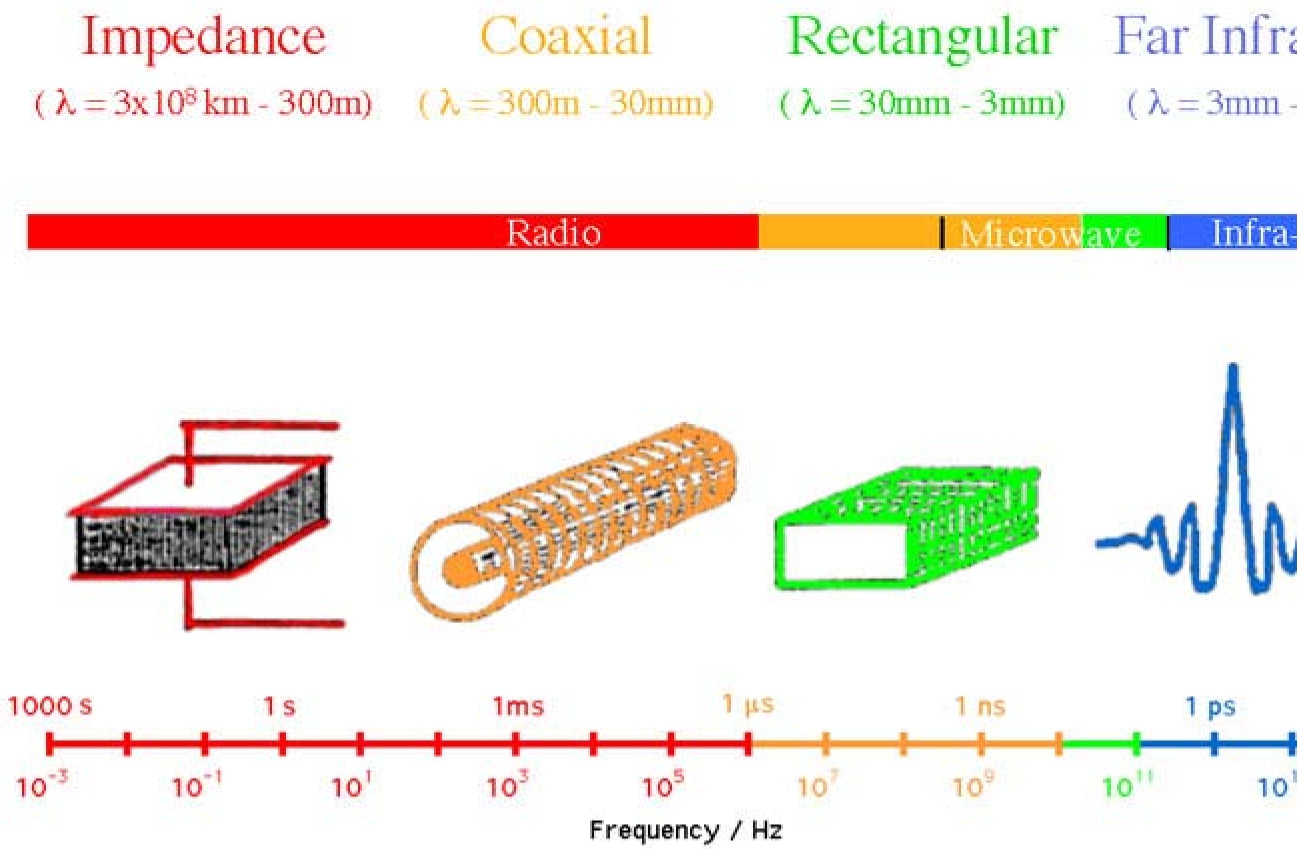


In order to develop such promising materials it is important to understand how the mobile ions move and interact with each other and their surroundings. Such understanding is also important in other fields of research, such as bioactive glasses (which help grow new bone tissue in the body) and nuclear science (how radioactive ions produced in nuclear power stations will behave over many centuries).

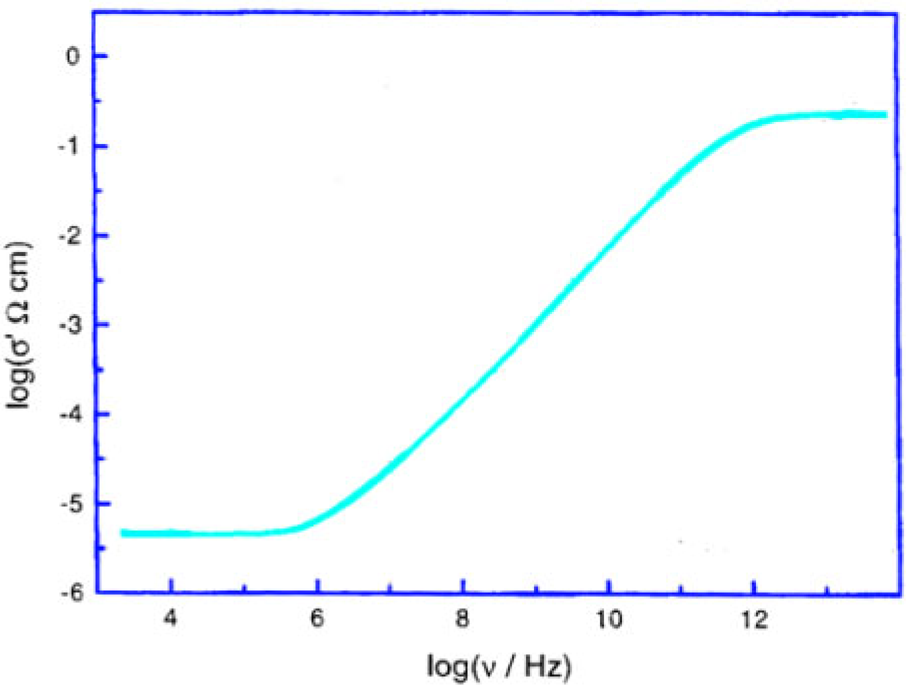
Of all the materials with disordered structures polymer electrolytes are the most promising. They find application in batteries or capacitors (e.g. in mobile telephones), as membrane electrolytes in fuel cells, and as thin film electrolytes in electrochromic windows. Polymer electrolytes are simply a salt (similar to salt on the dinner table) dissolved into a polymer. Their main advantages are the ability to be made into any shape and their mechanical and electrochemical strength. This means very small, very light and very powerful devices can be produced. Polymer electrolytes have not yet been used in high impact applications, such as electric vehicles, as ionic motion in these systems is poorly understood. This is in part due to research in this field being focused on the application of these materials rather than understanding them. My work at the University of Münster, is to understand how ions move and interact in polymer electrolytes. This will help in the optimization of polymer electrolytes for use in the production, storage and saving of energy, which has important environmental applications. To achieve this, we follow a simple scheme:



This scheme tells us that we need to measure and understand the materials we make before we can optimise them. What do we measure? The best method to capture all the characteristics of mobile ions in materials is the measurement of frequency dependent conductivity. Here, we measure how electromagnetic radiation (over 17 decades of frequency) interacts with the electrical properties of the material which are determined by the dynamics of the mobile ions. This is achieved by using several different techniques as sketched below:



The University of Muenster is one of only two laboratories in the world which has both the equipment and the expertise to measure frequency dependent conductivity over the full 17 decades (as shown), making this a centre of both excellence and importance. After taking these measurements we obtain a spectrum similar to that shown below:



The low frequency side of the spectrum (left side) tells us about the dynamics of ions carrying charge forward with time. In the middle of the spectra (slope) we measure more and more ions moving backward and forward as we go up in frequency. At high frequency (right side) we measure the dynamics of all ions. These properties and the temperature dependence of this spectrum, how it changes in shape and how it moves on each axis, teaches us invaluable lessons about the underlying microscopic characteristics of ions within the material. By making some simple assumptions, and describing the spectra with rate equations, we learn much more about the dynamics of mobile ions (see week 52 **"Wie hüpfen Ionen"** for more details). The fundamentals of the model described therein has already helped us understand how ions behave in disordered crystals, glasses and ionic melts. This project, therefore, is both very exciting, promising and important. This was one of the major factors when deciding to pursue my Ph.D. studies in Muenster.

Other than an exciting project, and having the opportunity to work with a distinguished scientist (**Prof. Dr. Klaus Funke**), my decision to further my studies in Münster was supported by the world class research environment established at the **Institute of Physical Chemistry** at the **University of Muenster** through both the **NRW International Graduate School of Chemistry** and **Sonderforschungsbereich 458**. The Graduate School is a school of excellence which offers a Ph.D. program in English which is limited to three years to ensure students are at a competitive age upon completing their studies. The Graduate School provides a competitive stipend, as well as comprehensive funding for opportunities to attend conferences and workshops, to buy text books and scientific equipment, as well as supporting other educational and social activities. I saw the SFB 458 as an opportunity to be part of a collaborative network of notable scientists with first class instrumentation and expertise, with a friendly environment, which induces a spirit to work and succeed together.

Through this environment I have had the opportunity to collaborate not only with members of my own institute and the **Institute for Materialphysik** here in Muenster, but also with **Prof. Malcolm D. Ingram** at the **University of Aberdeen** where I have already spent one month undertaking experiments. Furthermore, I continue to maintain collaborations with **Dr. Anita J. Hill** at **CSIRO** and Professors **Douglas R. MacFarlane** and **Maria Forsyth** at **Monash University** both for my Ph.D. studies and within the framework of SFB 458.

Since arriving in the beautiful city of **Münster** my expectations have been well surpassed. Not only was the decision to further my studies in Germany the best decision to make for my career but has also presented me with many more opportunities to develop myself both as a scientist and as a person than if I had remained in Australia.