Mechanical behaviour of glassy polymers: experiments and modelling

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Polymers, colloquially referred to as the plastic, are commonly used in many everyday products as well as in industrial applications. In order to make better use of the material and to reduce the amount of material needed in load bearing applications, it is of great importance to understand and be able to foresee how the material behaves when it is deformed. This is also important in order to reduce the time and cost to develop new and to more sustainable products. To increase the knowledge and to be able to predict the behaviour, practical experimental work as well as theoretical models are important tools. The main goal of this research project is to develop new theoretical models that better predicts the behaviour of polymers.

During this research project, we have developed a method to investigate the mechanical response of different materials by combining several advanced experimental techniques. By combining the different techniques, a large amount of information is provided from a single experiment; from the deformation of the test specimen in whole all the way down to the deformation of single molecules. The reason for doing the experiments is to gain more knowledge of the origin of the deformation on different length-scales in the material. This information is then used to explain different deformation phenomena and to establish more accurate theoretical models that can predict the mechanical behaviour of the material.

The developed experimental method is very general and in addition to polymers, paper based materials and biomedical materials has been investigated. During this research project, the main focus is on polymers in the glassy state and in particular polycarbonate. Using the developed method, it has been seen that the molecules in polycarbonate are reorganised during the deformation. The reorganisation of the molecules is present after the test specimen is unloaded, i.e. the material is permanently deformed by a reorganisation of the molecular structure.

In order to study the deformation of the molecular structure, we are using different X-ray techniques when deforming the test specimen. Using X-rays, we are able to look inside the material and study objects that are much to small to be visible by the naked eye. Simultaneously as the X-ray measurements are made, the deformation at the surface of the test specimen is measured using an optical technique called “digital image correlation”, or DIC for short. This technique gives detailed information about how the surface is deformed.

The novel information provided using the method described above are currently being used to develop a theoretical model to predict the mechanical behaviour of polycarbonate. The model includes the reorganisation of the molecules that was found in the experiments. By including the permanent reorganisation of the molecules, the model is able to accurately predict the mechanical response of the material; from the overall behaviour of the material down to the behaviour of the microstructure.