TOUGHNESS ENHANCEMENT OF NANOSTRUCTURED POLYMERS AND NANOCOMPOSITES

Goerg H. Michler

Institute of Physics, Martin Luther University Halle-Wittenberg, 06099 Halle/S., Germany
E-mail: goerg.michler@physik.uni-halle.de

ABSTRACT

The mechanical properties and in particular toughness of all materials are controlled by the morphology and the structures down to the nm-level. In polymers precondition of any ductility and toughness is a minimum of free volume, the free space between the macromolecular segments in the scale of 0.1 nm and in the range of a few per cent of the whole volume. For a high stiffness and strength of the material the free volume should not be too large. On the other side, nanovoids in the size of some 10 nm up to some 100 nm with a volume content of a few 10% can contribute to a remarkable increase of toughness of otherwise brittle polymers.

Many polymers and particularly polymer combinations reveal formation of voids due to processing or after mechanical loading. If the voids possess sizes below a critical value, they do not initiate premature or brittle fracture, but they can play a very positive role in increasing toughness. Next to the sizes of voids, the distances between voids, i.e. the thicknesses of the polymeric strands between voids possess a decisive influence.

In this talk the role of nanovoids and nanoparticles of different sizes on mechanical properties and particularly on toughness in several polymers is discussed. With decreasing void sizes and intervoid distances, the influence of the interphase material around the voids becomes more important and characteristic changes in the nano- and micro-deformation mechanisms appear. These mechanisms in dependence on the local morphology have been revealed by several techniques of electron microscopy, including scanning electron microscopy, transmission electron microscopy and atomic force microscopy (so-called *in-situ microscopy*) [1]. In this way, detailed structure-property-correlations could be determined [2, 3].

Different groups of nanostructured polymer combinations have been studied, including [2, 3]

- rubber modified polymers with nanosized core-shell particles (SAN and PMMA modified with PBA particles, PP modified with EPR particles),
- nanocomposites (PMMA/SiO_2 nanocomposites, PS/Al_2O_3 nanocomposites) and
- nanofibres nanocomposites (PMMA/Na-MMT), respectively.

Several nanoscopic toughness enhancing mechanisms are described in detail: *local stress concentrations*, *surface drawing mechanism*, *nanovoid-modulated craze-formation*, and the *core flattening mechanism*. The effect of these mechanisms to enhance toughness is connected with the *thin layer yielding mechanism* [3]. The action of these mechanisms in nanostructured polymers constitutes a distinct advantage of *nano*voids over *micro*voids [4].

References

1. G.H. Michler: Electron Microscopy of Polymers, Springer-Verlag Berlin, 2008
2. G.H. Michler, F.J. Baltá-Calleja (Eds.): Mechanical Properties of Polymers Based on Nanostructure and Morphology, Taylor & Francis, Boca Raton, 2005
3. G.H. Michler, F.J. Baltá-Calleja: Nano-and Micromechanics of Polymers: Structure Modification and Improvement of Properties, Carl Hanser Verlag, München, 2012
4. G.H. Michler, H.H. Kausch: Feature article in Polymer 54 (2013) 3131-3144