A MODEL FOR THE ULTRASONIC DISPERSION OF NANOPARTICLES IN EPOXY RESIN

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Nanoparticles in polymer matrices might lead to completely new material properties compared to conventional composites, e.g. an improved mechanical, electrical or optical behavior [1]. Several properties of the material can be enhanced simultaneously, i.e. the fracture toughness and the stiffness [2]. However, therefore a separation and homogeneous distribution of the particles in the matrix material is required in order to profit from the high specific surface of the nanoparticles, that hence can interact as an interphase with the polymer matrix.
In the present project the dispersion of nanoscale titanium dioxide (TiO_2) and barium sulfate ($BaSO_4$) particles in a high viscos epoxy resin by means of ultrasonic waves was studied systematically. The dispersion parameters, e.g. the ultrasonic amplitude and the dispersion time, were optimized to achieve a best possible dispersion. To be able to describe the development of the particle sizes in dependence on the dispersion parameters the dispersion model from Winkler for bead mills [3] was advanced and applied to the ultrasonic process. Thus, the particle size X in dependence on the sonication time t can be calculated by the following expression:

$$X(t) = \left(X_A - e^{-\frac{a^* \cdot P}{\sigma \cdot V_T}} - X_P \right) \cdot e^{-k \cdot \frac{V_{eff}}{V_T} \cdot t} + e^{-\frac{a^* \cdot P}{\sigma \cdot V_T}} + X_P$$

X_A ist he initial and X_P the primary particle size provided by the manufacturer. P describes the power input into the mixture, a* is a coupling constant, that describes the transference of the power to the agglomerates, and σ is the agglomerat's strength. V_{eff} describes the effective volume, where dispersion occurs and V_T is the total volume of the mixtura. The constant k describes te mixing in the prepolymer during sonication.
With the help of the developed model the developement of the particle size during sonication can be described in dependence on different parameters, as can be seen from Figure 1 for the dispersion of TiO_2 in epoxy resin. The transferability of the model to other particle systems was tested and approved by sonication of $BaSO_4$ nanoparticles in the liquid polymer.

References:

[1] Thostenson, Erik T.; Li, Chunyu; Chou, Tsu-Wei, Composites Science and Technology, **65** (2005) 491.
[2] Wetzel, Bernd; Haupert, Frank; Zhang, Ming Qui, Composites Science and Technology, **63** (2003) 2055
[3] Winkler, Jochen, Farbe und Lack, **2** (2006) 35

Figures:

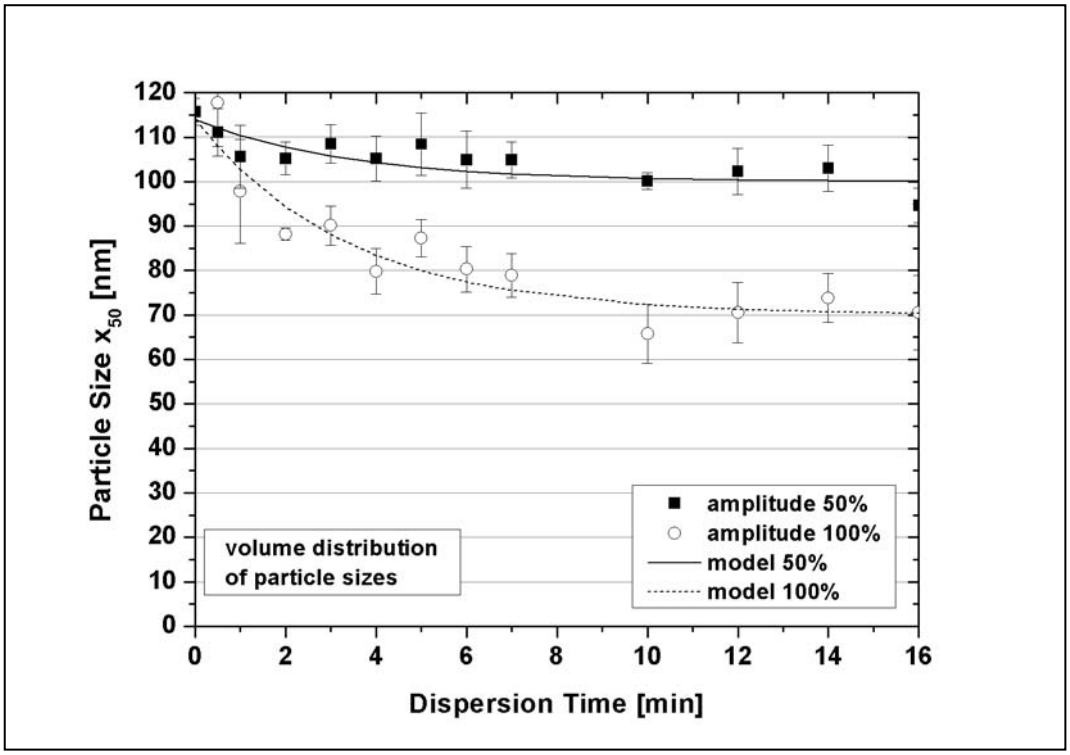

Figure 1: Experimental values and model curve for the ultrasonic dispersion of TiO_2 in epoxy resin at sonication amplitudes of 50 and 100%