Effective Thermal Conductivity of Nanofluids: Measurement and Prediction

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Nanofluids representing dispersions of solid particles on the nanometer scale with a liquid continuous phase are of interest in many applications of heat and energy engineering. Examples are the miniaturization of electronic devices by efficient cooling or the design of new working fluids for energy storage and transport. One key property characterizing nanofluids is their effective thermal conductivity. Many experimental and theoretical investigations in literature report that adding a small amount of nanoparticles to liquids can significantly increase the effective thermal conductivity of nanofluids relative to the base fluid. Other studies do not observe any significant enhancement. Until today, the relevant mechanisms affecting thermal conduction in nanofluids are controversially discussed.

In this work, the recent research activities at AOT-TP aiming at an improved understanding of the effective thermal conductivity of nanofluids are presented. For this property, our theoretical model accounts for the heat transfer mechanisms caused by thermal conduction of the base fluid and the particles and by microconvection due to the particle Brownian motion. The consideration of the latter effect was found to limit the enhancement of the effective thermal conductivity. For a test of our theoretical model, a steady-state parallel-plate method was used to measure the effective thermal conductivity of nanofluids with particle volume fractions up to 0.3. For the same systems, dynamic light scattering was applied to analyze the collective translational diffusion coefficient of the dispersed particles, which provides information on their size as an essential parameter for the effective thermal conductivity. Measurement results for water-based nanofluids with TiO_2, SiO_2, or polystyrene particles show only moderate changes in the effective thermal conductivity. These changes are positive or negative for particles with larger or smaller thermal conductivities than the base fluid and agree with the predictions from the model.