Seminar on the Nonlinear Dynamics of Chemical Reactions, Processes, and Reactors

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DOI: 10.1134/S0040579510020156

The regular seminar held on May 21, 2009, was devoted to the role of size effects in the behavior of electrorheological liquids (ERLs), which are dispersions whose properties are controllable by an electric field. The application of an external electric field dramatically increases the viscosity of such a dispersion and brings the system from the liquid state to the solid state. This makes ERLs promising for mechanical applications, such as oscillation damping and torque transfer, and for some areas of robotics. Participants of the seminar discussed experimental evidence of the possibility of controlling the electrorheological response of ERLs based on various liquid and solid phases in order to obtain materials with preset performance characteristics.

Doctor of Chemistry, Professor A.G. Zakharov (Director of the Institute of Solution Chemistry, Russian Academy of Science, Ivanovo) delivered a report entitled “Electrorheologically Active Nanosized Materials: Sol–Gel Synthesis and the Nonlinear Rheological Response of Their Suspensions in Electric Fields.” He presented a promising approach to preparation of electrorheological dispersions with improved properties from nanoparticles of titanium dioxide and titania-based hybrid materials as the starting components. A sol–gel procedure was developed for obtaining these titanium dioxide–based nanosized materials. By varying synthetic conditions in this procedure (pH, introduction of a modifier, and ultrasonication parameters), it is possible to prepare solid phases with various particle sizes, structures, and compositions. Silicone oils with various molecular weights were mainly used as the dielectric liquid. The strongest electrorheological response is shown by titanium dioxide–containing systems synthesized in the presence of cellulose derivatives as the modifier. According to X-ray diffraction data, this method yields not simple mixtures of titanium dioxide and the modifier, but organohybrid composites consisting of highly amorphous particles 10 to 70 nm in size. These particles are more polarizable than unmodified titanium dioxide particles, and their small size imparts the ERL better strength properties upon application of an electric field and enhances the sedimentation stability of the ERL in the absence of a field. According to the author of the report, the good prospects for use of these systems are demonstrated by the performance of model damping

devices in which the change in the shear stress upon the application of a 4-kV/mm field to the ERL raises the yield strength by a factor of 200.

In the discussion of the report, the audience expressed greatest interest in the nonlinear phenomena observed in the study of ERL fluidity as a function of the field strength. These phenomena proved to take place in a variety of systems; however, they remain unexplained in terms of conventional models and mathematical formalism (e.g., the Bingham–Shvedov equation). Many speakers discussed the possible size factor in these phenomena. In this connection, issues were raised concerning the optimal size of titanium dioxide particles (I.V. Melikhov, V.N. Rudin), their morphology and degree of crystallinity (O.A. Shlyakhutin), and the effects of interparticle interaction and the composition of the dielectric liquid on the electrorheological response (P.E. Kazin, A.O. Shapfev). Another topic was control of the properties of ERLs by varying the character of the external electric field. A.L. Nikolaev suggested employing variable fields. A.G. Zakharov replied that there had been experiments along this line and, like the relevant data available from the literature, they had not indicated any significant improvement of the electrorheological response. A.G. Zakharov and some other participants of the seminar advocated S.S. Berdonosov's proposal to use a nonuniform electric field, which can make different parts of a homogeneous system differ in rheological properties. A.L. Nikolaev also noted that electrorheological response data can likely be used in solving the inverse problem of gaining additional information about the composition and morphology of nanosystems. However, lack of well-developed physiochemical and mathematical models of the electrorheological effect makes it impossible to interpret relevant experimental data unambiguously (A.G. Zakharov).

Concluding the seminar, Cochairman I.V. Melikhov said that the phenomena considered in the report were very interesting and further accumulation of detailed experimental data in the framework of the reported study would make possible predictive simulation of electrorheological processes.

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