Effect of surface modification of silica particles on the interaction forces and dipsersibility in suspension

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The performance of polymer composite materials in which dispersed inorganic or organic particles is significantly affected by their dispersion conditions. In order to obtain stable quality for such materials, homogeneous dispersion of particles is required in solutions, which contain a various kind of solvent and polymers. Although surface modification of particles using silane coupling agents has proven to be effective for modulating the dispersibility in each solution, it is still difficult to control the dispersibility of dense solution and/or nano-size particles. Qualitative and quantitative analysis of dispersion/aggregation property is challenging, because they are complex phenomenon, which are determined based on the sum of several interactions. We have been studying colloidal probe AFM method, which enables direct measurement of such forces acting on the particles in solutions. This methodology is promising to estimate the dispersibility in terms of repulsive or attractive forces between the particles. In the present work, the effect of surface modifications of silica using silane coupling agents with different molecular structure and amount on dispersion behavior was assessed from the viewpoint of interaction forces by using colloidal probe AFM method.

3-glycidyloxypropyltrimethoxysilane (GPTMS) and vinyltrimethoxysilane (VTMS) were used as model silane coupling agents. The coupling reactions of silica (mean diameter 2.0 μm, specific surface area 4.2 g/m^2) were carried out in xylene at 40-100 ^oC for 24 h. The loading of the surface-modified silica was determined by TG-DTA at 1000 ^oC.

To confirm the difference of dispersion behavior depending on the surface modifications, each silica particles were dispersed in toluene (1.0% weight fraction) with sonication and agitation for 30 min. In the case of silica modified with GPTMS, aggregation and sedimentation were observed independent on the amount of loading. On the other hand, silica modified with VTMS showed loading amount-dependent dispersibility. In order to analyze the difference of these dispersion behavior, surface interaction forces were measured by colloidal probe AFM in toluene. As results, repulsive force was observed between a VTMS modified-probe silica particle and a mica plate, whose intensities were good correspond to the loading amount. In contract, GPTMS modified-probe silica did not show repulsive force toward the plate, while attractive force was observed under the short separation distance. It can be concluded that colloidal probe AFM method is effective tool to assess dispersion/aggregation property of surface modified silica based on the repulsive and/or attractive forces, leading to the understanding of dispersion behavior.