Effects of Electric Fields on Forces between Dielectric Particles in Air

Ching-Wen Chiu

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Chemical Engineering

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Description of item under review for fair use: Figure 1-1. Schematic of a digital active feedback controlled DEP levitation system. Source: Tombs, T. N.; Jones, T. B., DIGITAL DIELECTROPHORETIC LEVITATION. Review of Scientific Instruments 1991, 62 (4), 1072-1077.

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Description of item under review for fair use: Figure 1-2 Schematic of an apparatus for measuring electric field-induced force between two particles with a computer-controlled elevator to adjust the separation between the particles. Source: Wang, Z. Y.; Peng, Z.; Lu, K. Q.; Wen, W. J., Experimental investigation for field-induced interaction force of two spheres. Applied Physics Letters 2003, 82 (11), 1796-1798.

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Description of item under review for fair use: Figure 1-3 The principal of measuring an external force on a particle by an optical trap. (A) There is no external force acting on the particle so the particle is at its equilibrium position and the net force from the optical trap is zero. (B) The particle deviates from its equilibrium position due to an external force (Fext) and the force of the optical trap (Fopt) acting the same force with opposite direction to balance the external force. -Fext=Fopt=-kopt•Δx , where kopt is the optical trap stiffness. Source:Jonas, A.; Zemanek, P., Light at work: The use of optical forces for particle manipulation, sorting, and analysis. Electrophoresis 2008, 29 (24), 4813-4851.

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Description of item under review for fair use: Figure 1-4 (A) Scheme of Mizes' setup to study the electrostatic adhesion of microparticles. Source: Mizes, H. A., ADHESION OF SMALL PARTICLES IN ELECTRIC-FIELDS. Journal of Adhesion Science and Technology 1994, 8 (8), 937-951.; (B) The modified setup based on Mizes' setup to study DC electric field-induced force of a microparticle between the parallel condenser electrodes. Source: Kwek, J. W.; Vakarelski, I. U.; Ng, W. K.; Heng, J. Y. Y.; Tan, R. B. H., Novel parallel plate condenser for single particle electrostatic force measurements in atomic force microscope. Colloids and Surfaces a-Physicochemical and Engineering Aspects 2011, 385 (1-3), 206-212.

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Description of item under review for fair use: Figure 2-1. Real and imaginary parts of complex permittivity and dielectric dispersion of a heterogeneous lossy dielectric versus the applied frequency. Source: Hao, T.; Kawai, A.; Ikazaki, F., Mechanism of the electrorheological effect: Evidence from the conductive, dielectric, and surface characteristics of water-free electrorheological fluids. Langmuir 1998, 14 (5), 1256-1262.

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Description of item under review for fair use: Figure 3-1 Schematic of the polarization of an uncharged particle under an electric field when (a) the polarizability of the particle is greater than the suspending medium or (b) the polariability of the particle is less than the suspending medium. Source: Morgan, H.; Green, N. G., AC Electrokinetics: colloids and nanoparticles. Research Studies Press: Philadelphia, PA, 2003.

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Description of item under review for fair use: Figure 3-10 An equivalent circuit for formulating the interparticle force of a one-diemensional particle chain in AC-DC fields. Source: Colver, G. M., An interparticle force model for ac-dc electric fields in powders. Powder Technology 2000, 112 (1-2), 126-136.

Report generated on: 06-05-2013 at : 04:12:58

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Description of item under review for fair use: Figure 3-2 Numerically calculated electric field lines of four different situations: (a) the particle is more polarizable than the medium and the field is uniform; (b) the particle is less polarizable than the medium and the field is uniform; (c) the particle is more polarizable than the medium and the field is non-uniform; (d) the particle is less polarizable than the medium and the field is non-uniform. Source: Morgan, H.; Green, N. G., AC Electrokinetics: colloids and nanoparticles. Research Studies Press: Philadelphia, PA, 2003.

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Description of item under review for fair use: Figure 3-3 Two dimensional electric field distributions around two identical particles align with an axis connecting the centers of the particles parallel to the direction of an applied uniform electric field: (a) particles are more polarizable than the medium so positive DEP occurs; (b) particles are less polarizable than the medium so negative DEP occurs. Source: Morgan, H.; Green, N. G., AC Electrokinetics: colloids and nanoparticles. Research Studies Press: Philadelphia, PA, 2003.

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Description of item under review for fair use: Figure 3-4 Two dimensional electric field distributions around two identical particles align with an axis connecting the centers of the particles perpendicular to the direction of an applied uniform electric field: (a) particles are more polarizable than the medium so positive DEP occurs; (b) particles are less polarizable than the medium so negative DEP occurs. Source: Morgan, H.; Green, N. G., AC Electrokinetics: colloids and nanoparticles. Research Studies Press: Philadelphia, PA, 2003.

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Description of item under review for fair use: Figure 3-5 The two charges in a dipole experiences different forces in magnitudes of a non-uniform electric field. Source: Jones, T. B., Electromechanics of Particles. Cambridge University Press: New York City, NY, 1995.

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Description of item under review for fair use: Figure 3-6 A dielectric particle with radius R and permittivity εp suspending in a fluid with permittivity εm under a uniform electric field E0 in z direction. Source: Jones, T. B., Electromechanics of Particles. Cambridge University Press: New York City, NY, 1995.

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Description of item under review for fair use: Figure 3-7 Calculated DEP spectra of homogeneous dielectric spheres with ohmic loss but no dielectric loss when (a) εm/ε0=2.5, εp/ε0=10.0, σm=4x10-8 S/m, σp=10-8 S/m and R=5 μm, and (b) εm/ε0=10.0, εp/ε0=1.0, σm=10-8S/m, σp=10-7 S/m and R=5 μm. Source: Jones, T. B., Electromechanics of Particles. Cambridge University Press: New York City, NY, 1995.

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Description of item under review for fair use: Figure 3-8 (a) Schematic of the replacement of multilayered spherical particle with an equivalent homogeneous sphere of the same radius but with the effective permittivity. Source: Jones, T. B., Electromechanics of Particles. Cambridge University Press: New York City, NY, 1995. (b) The DEP spectrum of the tow-layered spherical particle. The solid line represents Re[K] and the dot line represents Im[K]. Source: Morgan, H.; Green, N. G., AC Electrokinetics: colloids and nanoparticles. Research Studies Press: Philadelphia, PA, 2003.

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Description of item under review for fair use: Figure 3-9 (a) Electric field-induced interaction between two identical spheres i and j in an electric field. rij is the separation between the centers of the particles and θij is the angle between the line-of-center and the electric field. (b) Calculated square of the effective relative polarizability βeff2 versus dimensionless frequency in terms of the Maxwell-Wagner relaxation time: (I) βd=10βc; (II) βd=0.1βc. Source: Parthasarathy, M.; Klingenberg, D. J., Electrorheology: Mechanisms and models. Materials Science & Engineering R-Reports 1996, 17 (2), 57-103

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Description of item under review for fair use: Figure 4-1 (a) The behavior of the cantilever in an AM mode. Source: Melitz, W.; Shen, J.; Kummel, A. C.; Lee, S., Kelvin probe force microscopy and its application. Surface Science Reports 2011, 66 (1), 1-27. (b) Scheme of an AFM setup in the AM mode. Source: Schirmeisen, A.; Anczykowski, B.; Hölscher, H.; Fuchs, H., Dynamic Modes of Atomic Force Microscopy. In Nanotribology and nanomechanics. Volume 1, Measurement techniques and nanomechanics, Bhushan, B., Ed. Springer: Berlin ; Heidelberg ; New York 2011; pp 307-353.

Report generated on: 06-05-2013 at : 04:14:00

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Name: Ching-Wen Chiu

Description of item under review for fair use: Figure 4-2 (a) The behavior of the cantilever in an FM mode. Source: Melitz, W.; Shen, J.; Kummel, A. C.; Lee, S., Kelvin probe force microscopy and its application. Surface Science Reports 2011, 66 (1), 1-27. (b) Scheme of an AFM setup in the FM mode. Source: Schirmeisen, A.; Anczykowski, B.; Hölscher, H.; Fuchs, H., Dynamic Modes of Atomic Force Microscopy. In Nanotribology and nanomechanics. Volume 1, Measurement techniques and nanomechanics, Bhushan, B., Ed. Springer: Berlin ; Heidelberg ; New York 2011; pp 307-353.

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Name: Ching-Wen Chiu

Description of item under review for fair use: Figure 4-3 Scheme of the operation principle of a KPFM. Source: Sadewasser, S., Experimental Technique and Working Modes. In Kelvin probe force microscopy: measuring and compensating electrostatic forces, Sadewasser, S.; Glatzel, T., Eds. Springer-Verlag Berlin Heidelberg: Heidelberg ; New York, 2012; pp 7-24.

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Description of item under review for fair use: Figure 4-4 On the left, a typical raw data diagram of the deflection of the cantilever (i.e., the deflection of the laser beam for the catnielver) vs. the piezo position (i.e., the displacement of the piezo) from a force measurement by AFM is shown. On the right, the scheme of the behaviors of a cantilever with respect to a flat sample in a force measurement is illustrated. Source: Ralston, J.; Larson, I.; Rutland, M. W.; Feiler, A. A.; Kleijn, M., Atomic force microscopy and direct surface force measurements - (IUPAC technical report). Pure and Applied Chemistry 2005, 77 (12), 2149-2170.

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