# Manipulation of aerosol particles with nonlinear polarizability

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In the non-uniform alternating electric field (NAEF), the redistribution of electric charges and polarization take place, and the induced dipole moment is formed within the entire volume of the particle (including bacteria, cells, viruses and nanoparticles). From the theoretical point of view, linear and nonlinear charge redistribution reflects the peculiarities of the dynamics of electric charge motion over the entire volume of the particle. Anyway, this is due to the physical and chemical properties and inhomogeneity of all its structures such as the walls, core and capsid. It should be noted that each of them has also significant differences in electrical properties, the dielectric constant, capacitance, conductivity and water content. In the non-uniform electric field, the dipole particle is affected by the time-averaged force vector, which causes its forward motion (Hughes, 2003).

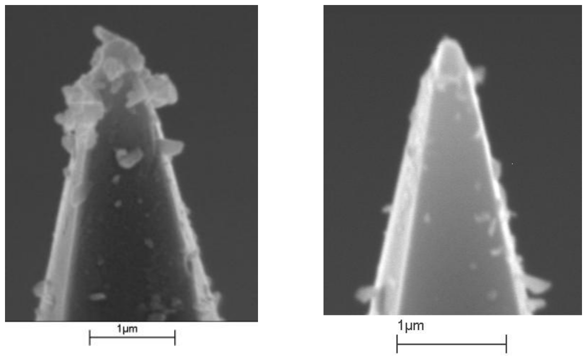
$$\langle \vec{F}_p \rangle = \langle 2\cdot\pi\cdot\varepsilon_{cp}\cdot\varepsilon_o\cdot r_p^3\cdot\left[\frac{\varepsilon_p-\varepsilon_{cp}}{\varepsilon_p+2\cdot\varepsilon_{cp}}\right]\cdot\nabla E_{cp}^2\rangle \quad (1)$$

where: $\varepsilon_{cp}$ ~1, is the dielectric constant of air;
$\varepsilon_0$ is the dielectric constant;
$\varepsilon_p$ is the dielectric constant of the particle;
$r_p$ is radius of the particle;
$\nabla E_{cp}^2$ is the gradient of the square of the electric field of air.

Expression (1) represents the polarizability of $a_p$ particle in an expanded form

$$\alpha_p = 4\cdot\pi\cdot r_p^3\cdot\varepsilon_{cp}\cdot\frac{\varepsilon_p-\varepsilon_{cp}}{\varepsilon_p+2\cdot\varepsilon_{cp}} \quad (2)$$

Two forces emerge as a result of the interaction of the induced dipole moment of each particle with the voltage gradient of the electric field. The first force causes forward motion of the particle to the nearest electrode where the gradient of the square of the electric field is maximal. The second force determined by the vector product of the induced dipole moment and the gradient of the square of the electric field that makes it rotate around its own axis. It is well known that the dielectric constant $\varepsilon_p$ of a substance (particle) depends on the frequency of the external electric field (Physical …., 1991). The frequency dependence of the difference $\varepsilon_p$ - $\varepsilon_{cp}$ will have a significant impact on the behavior and translational velocity of the particle to the nearest electrode. Our own simulations performed in water showed that particles were rotating around their own axis with a frequency greater than 1 Hz in NAEF, which is indicative of the non-linear polarization effect. All this results in pronounced, individual characteristics of their behavior in NAEF, Foto 1. The force acting on the particle with a relative permittivity $\varepsilon_p \sim 2\cdot\varepsilon_{cp}$ close to 1 (which is typical for air) is negligible. The force acting on the particle with a relative permittivity hundreds or even thousands of times greater than 1 $\varepsilon_p \sim 10^{(2\div3)}\cdot\varepsilon_{cp}$ increases proportionally. The list of materials with similar properties is very long (Physical …, 1991). Thus, this opens new opportunities to manipulate aerosol particles based on subtle differences related to their dielectric constant and nonlinear polarizability.




a) b)

Foto 1. Vaccinia virus on an electrode.
a) – probe after exposure in viral suspension with voltage; b) – probe after exposure in viral suspension with no voltage.

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