Electrical characterization of suspensions with microcapsules

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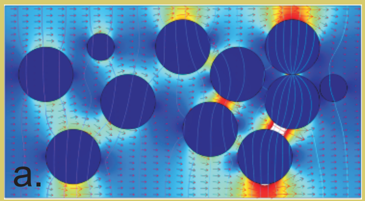
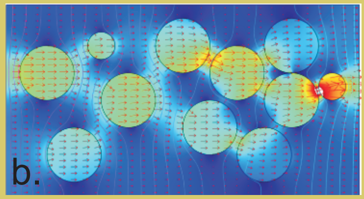
Microcapsules in a suspension polarize when subjected to imposed electric field. The current flow through the suspension depends on the electrical material properties of the microcapsules and the suspension and their concentration. This can be evaluated by dielectric spectroscopy. Two, three of four probe measurement is used. The influence of electrode/suspension resistance can be taken into account using a measurement cell with varying distance between the electrodes. Miniaturization is achieved using semicoductor technology to develop electrodes on top of a nonconduction substrate.

Numerical modeling of current flow through the particles

Particles (for instance microspheres) have different electrical material parameters than the surrounding solution. Due to difference in the resistivity and permittivity of the particles than the suspension, the current flows predominantly around the particles at low frequencies (a.) of the applied signal and through the particles at higher frequencies (b.).
The magnitude of the current on the electrodes connected to an AC voltage source depends on the concentration and electrical material properties of the suspension and the particles and the frequency of an applied signal.


a.

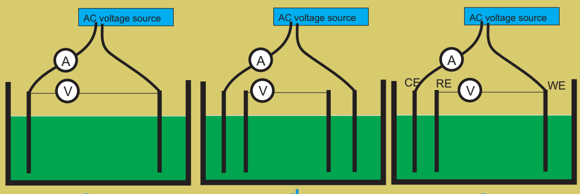

b.

(Electrical) impedance spectroscopy

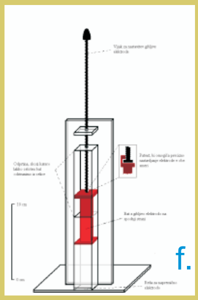
Impedance between the electrodes (c.) is determined from measured voltage and current between the electrodes connected to an AC voltage source. In complex notation it is composed of an amplitude and a phase difference between the signals:

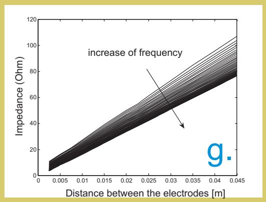
$$\underline{Z} = \frac{\underline{U}_V}{\underline{I}_A} = \frac{U_V}{I_A} e^{\varphi_U - \varphi_I} = Z e^{j\varphi}$$

When electrodes are submersed into the solution a double layer is formed resulting in electrode/solution electrical resistance. The influence of this resistance on measured impedance can be quite significant. As a consequence, three or four point probe measurement is required (d., e.). In electrochemistry, three point probe measurement is frequently used where the electrodes are named WE (working electrode), CE (counter electrode) and RE (reference electrode). In all cases one has to take into account the effects of stray capacitances, inductances and noninfinite impedances of measuring circuitry.
Another type of measurement cell can be made where the spacing between the electrodes is varied (f.). Assuming that the electrode/solution resistance does not change with variation of the distance between the electrodes the influence of the electrodes on the measured impedance can be subtracted from the measured impedance. A linear increase of the real as well as imaginary part of the impedance is obtained (g.) by increasing the distance between the measuring electrodes.



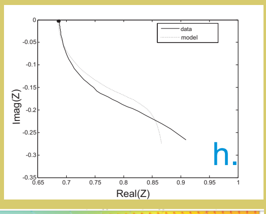
c. d. e.


f.

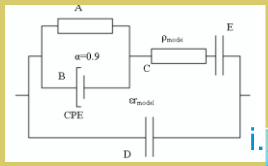


g.

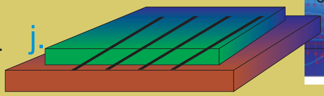
The extracted impedance of a suspension is presented in a complex (Warburg) plane (h.) where it can be fitted with an appropriate electrical lumped model (i.). A model shown has been found most suitable for describing the impedance of a suspension with parrafine microcapsules. For better fit it comprises a so called Fricke's constant phase element. Assuming a model of a parallel plate capacitor, electrical parameters such as permittivity and conductivity of the sample can be identified. A certain model is necessary in order to extract conductivity and permittivity of a single cell from a suspension. For this purpose a Maxwell-Wagner model or a Hanai mixure exquiation etc. can be used.
The system of electrodes can be developed using semiconductor technology where the electrodes are set as conducting stripes over the non-conducting semiconductor (or oxidized) surface (j.). In this case a cell parameter needs to be established first. This can be done by either using a solution of known electrical properties or by numerical simulation (k.).

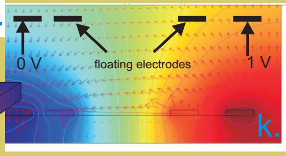


h.



i.


j.

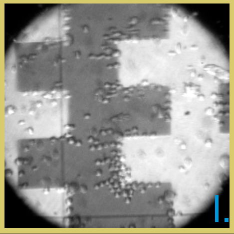


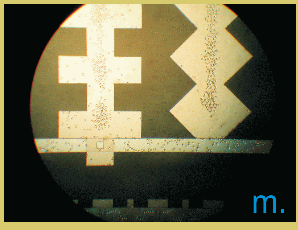
k.

Dielectrophoresis and electrorotation

Microspheres polarize in electric field. Force acting on a polarized sphere enables its manipulation by subjecting it to a non-homogeneous electric field: ***F*** = (***p***.)***E***.
Dielectrophoresis can be used to attract microspheres toward regions of high electric field (toward the electrodes,(l.)) or toward regions of low electric field (away from the electrodes (m.)). Since this depends on the frequency of the applied AC signal it is possible to extract the electrical parameters from the frequency of the signal.
Microelectrodes can be designed in such a way that polarized particles rotate in a rotational electric field between the electrodes: ***T*** = ***p*** x ***E***.

Dielectrophoresis and electrorotation together with traveling wave dielectrophoresis can be also used to concentrate, trap or transfer microparticles.


l.


m.

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Research interests: (bio)impedance spectroscopy, manipulation of particles in electric and magnetic field and numerical simulation of electromagnetic phenomena.

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