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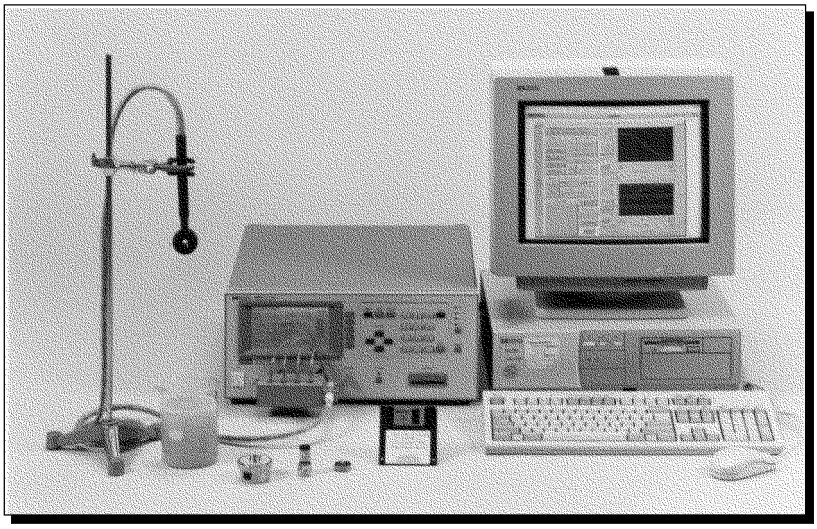
Sample Permittivity Data of Colloidal Liquids Using the HP E5050A Colloid Dielectric Probe

Product Note

HP E5050A
Colloid Dielectric Probe



Introduction

The growing importance of on-line monitoring in the food, chemical and biochemical industries has lead researchers to look beyond traditional analytical tools. Many key parameters of colloids such as structure, consistency and concentration are directly related to permittivity or conductivity.

This note introduces the basic concepts of dielectric spectroscopy and offers researchers some ideas to stimulate investigations into using permittivity measurements for colloid characterization in the lab and for process monitoring in production.

The HP E5050A Colloid Dielectric Probe is suitable for real-time in-situ process monitoring in a tank, pipeline, or fermentor. The technique is non-destructive and no sample preparation is required before analysis.

HP E5050A Overview

The HP E5050A Colloid Dielectric Probe provides easy and reliable permittivity and dielectric relaxation evaluation of ionic colloidal liquid materials from 200kHz - 20MHz with the HP 4285A Precision LCR Meter and the HP Vectra Personal Computer.

The new measurement technique of the HP E5050A solves the electrode polarization problem which has hindered the progress of research into permittivity evaluation of materials with bulk conductive properties.

Easy and simple probing with the HP E5050A helps on-line monitoring experiments and improves efficiency of permittivity measurements. Conductivity, another important parameter for ionic liquid material evaluation, can also be measured simultaneously.

Permittivity and Dielectric Relaxation

Permittivity is an electrical parameter which expresses the dielectric polarization of positive and negative charges or ions in a material. Polarization occurs when a material is subjected to an electric field. Frequency characteristics of permittivity (also known as dielectric dispersion) give useful information on the molecular or colloidal structure of materials.

Figure 1b. shows an electric field applied to a colloidal material with dispersed phase(s) having free charges or ions such as a water/oil (W/O) emulsion, microcapsule or yeast suspension. Interfacial polarization occurs at the boundaries between the dispersed phase and the dispersion medium resulting in the material exhibiting higher permittivity compared to molecular solutions.

This typically occurs at low frequencies, kHz or MHz. Figure 1a. shows that this effect is not observable at higher frequencies, such as with optical techniques. Permittivity decreases because the free charges in the dispersed phase cannot follow the fast polarity changes at higher frequencies and the resulting interfacial polarization decreases. This phenomenon is termed dielectric relaxation. Because of the speed with which these measurements can be made, this technique holds promise for on-line process monitoring and control of colloidal products.

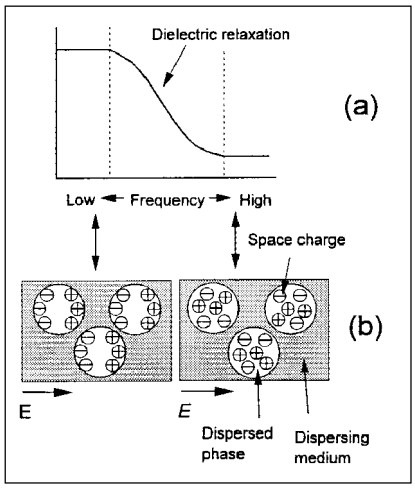


Figure 1. Dielectric dispersion properties provide insight into the nature of colloids: structure, purity and concentration are often related to permittivity.

The Electrode Polarization Problem

Traditionally, permittivity is measured with parallel metal electrodes and this technique can be used to measure non-conducting solutions such as oils and alcohols. However, in the case of salt or ionic solutions or other liquids with bulk conductivity, this method results in large measurement errors. Figure 2a shows the electrical double-layer formed between the metal electrodes and the liquid. This interaction is called electrode polarization. Figure 2b shows how this effect masks the actual permittivity values of the material, thus limiting its usefulness. Since many food and chemical materials contain ions, it is difficult or impossible to accurately characterize permittivity with a parallel metal electrode fixture.

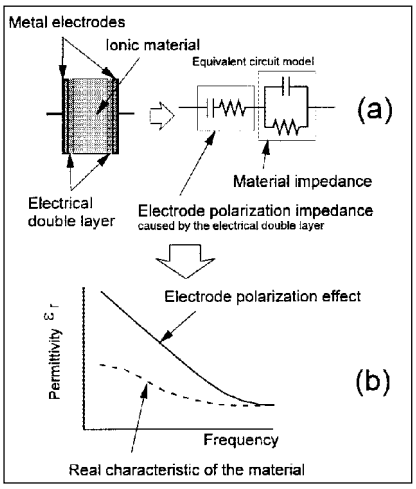


Figure 2. The electrode polarization problem has so far limited the use of permitivitty measurements.

The measurement technique of the HP E5050A is based on electromagnetic induction using non-metal electrodes thus solving the electrode polarization problem for ionic liquid materials.

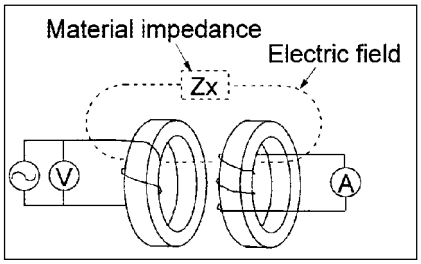


Figure 3. The design of the HP E5050A eliminates electrode polarization, allowing measurement of actual material behavior.

Measurement Examples

Examples of permittivity and conductivity measurements of 1) yeast suspension, 2) detergent, and 3) liquid car wax using the HP E5050A are shown below.

Measurement conditions :

Frequency range : 200kHz-20MHz
Number of points :26
Sweep type : LOG sweep
Meas. parameter : εr' - κ'

The measurements were performed at 22±1 degree C in a 500cc beaker.

1. Yeast Suspension

A sample of a yeast suspension in 0.1% salt water using dry baking yeast was measured. Figure 4 shows the dielectric relaxation characteristics to be in the kHz to MHz range, with permittivity values proportional to yeast concentration observable in the lower frequency region. Figure 5. shows the well-behaved and linear relationship between ε' and yeast concentration and suggests that permittivity measurements may be used for on-line or process monitoring.

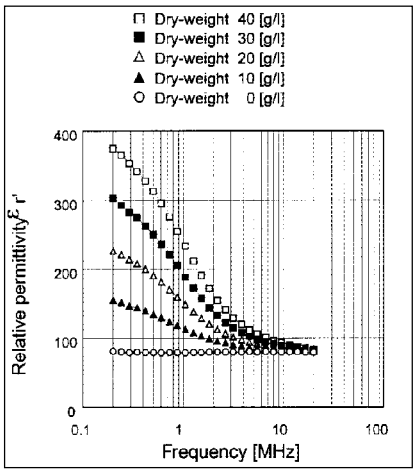


Figure 4. Relative permittivity of yeast suspension

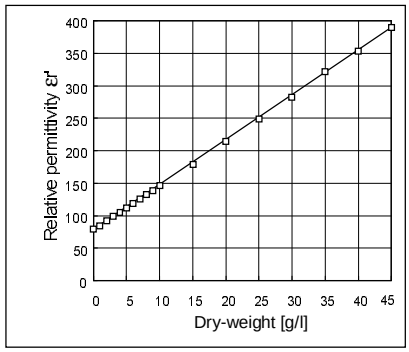


Figure 5. Relative permittivity (@300kHz) vs. yeast concentration (dry-weight)

2. Detergent

Various compounds with surface active agents, in this case four detergents, were measured as shown in Figure 6. The ε' of the detergents differ indicating the possibility that permittivity can be used to characterize and monitor them in real-time. The relatively high conductivity, as shown in Figure 7 makes obtaining the data shown in Figure 6 impossible with the traditional metal electrode method due to electrode polarization. With the HP E5050A, however, permittivity characteristics without electrode polarization are easily obtained.

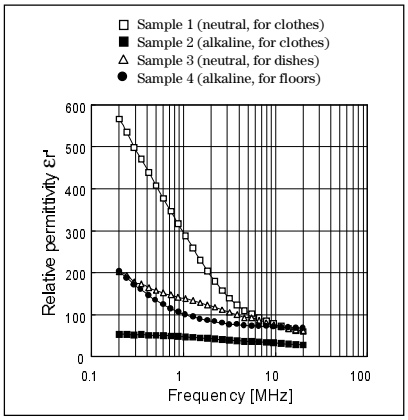


Figure 6. Permittivity of various detergents

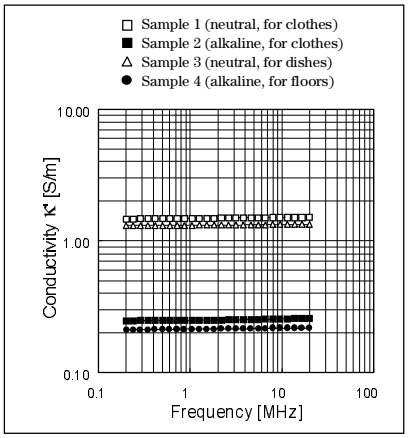


Figure 7. Conductivity of detergents

3. Liquid Car Wax

Wax is an oil-base colloid with dielectric relaxation characteristics dependent on the colloidal structure as shown in Figure 8. When measurement results with the HP E5050A are unstable due to low permittivity and very low conductivity like Samples 3 and 6 of Figure 9, it is recommended that the HP 16452A Liquid Test Fixture be used. The HP 16452A is a parallel-plate metal electrode test fixture which is suitable for low conductivity liquid materials, because low conductivity materials do not exhibit the electrode polarization

Yeast concentrations above values shown can be measured.

problem even in the presence of metal electrodes.

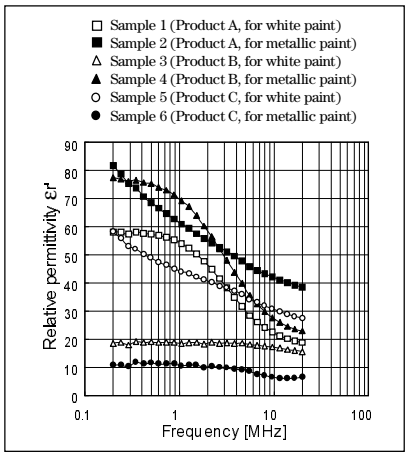


Figure 8. Relative permittivity of liquid car wax

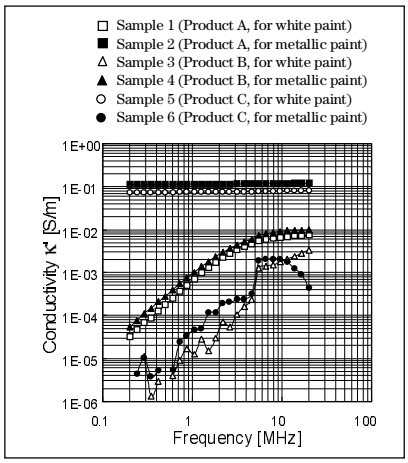


Figure 9. Conductivity of liquid car wax

Conclusion

The HP E5050A Colloid Dielectric Probe realizes permittivity measurements without electrode polarization problem even for ionic materials with bulk conductive properties. It is an effective tool for research into future on-line monitoring application development using dielectric measurements.

For more information

Request the following literature from you local HP Test and Measurement Representative:

HP E5050A Colloid Dielectric Probe Inquiry Form
HP P/N 5964-0093E

Technical Data Sheet:
HP E5050A Colloid Dielectric Probe, Product Overview
HP P/N: 5963-6635E

Solution Note E5050-2: *Yeast Concentration Measurement Using HP E5050A with Option 001*
HP P/N: 5963-6632E

Application Note Number 380-3: *Evaluation of Colloids by Dielectric Spectroscopy*
HP P/N: 5963-6634E

Contact us with your inquiry and for the latest list of available literature.

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For more information on Hewlett-Packard Test and Measurement products, applications, or services please call your local Hewlett-Packard sales office. A current listing is available via the Web through AccessHP at http://www.hp.com. If you do not have access to the internet, please contact one of the HP centers listed below and they will direct you to your nearest HP representative.

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