

Inductive dielectric analyzer

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Abstract

© 2017 IOP Publishing Ltd. One of the approaches to bypass the problem of electrode polarization in dielectric measurements is the free electrode method. The advantage of this technique is that, the probing electric field in the material is not supplied by contact electrodes, but rather by electromagnetic induction. We have designed an inductive dielectric analyzer based on a sensor comprising two concentric toroidal coils. In this work, we present an analytic derivation of the relationship between the impedance measured by the sensor and the complex dielectric permittivity of the sample. The obtained relationship was successfully employed to measure the dielectric permittivity and conductivity of various alcohols and aqueous salt solutions.

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Keywords

conductivity, dielectric permittivity, electrode polarization, electromagnetic induction, sensor system, spectrometer

References

- [1] Raicu V and Feldman Y 2015 Dielectric Relaxation in Biological Systems: Physical Principles, Methods, and Applications vol xix 1st edn (Oxford: Oxford University Press) p 429
- [2] Kremer F and Schonhals A 2003 Broadband Dielectric Spectroscopy vol xxi (Berlin: Springer) p 729
- [3] Ben Ishai P et al 2013 Electrode polarization in dielectric measurements: a review Meas. Sci. Technol. 24 102001
- [4] Schwan H P 1968 Electrode polarization impedance and measurements in biological materials Ann. New York Acad. Sci. 148 191
- [5] Lyklema J J and Keizer A 1995 Electric Double Layers Fundamentals of Interface and Colloid Science vol 2 (New York: Academic) pp 1-232
- [6] Bockris J O M and Reddy A K N 1973 Modern Electrochemistry: an Introduction to an Interdisciplinary Area (New York: Plenum)
- [7] Schwan H P 1992 Linear and nonlinear electrode polarization and biological-materials Ann. Biomed. Eng. 20 269-88
- [8] Grosse C and Tirado M C 2002 Low-frequency dielectric spectroscopy of colloidal suspensions J. Non-Cryst. Solids 305 386-92
- [9] Nakamura H, Husimi Y and Wada A 1981 Time domain measurement of dielectric spectra of aqueous poly-electrolyte solutions at low-frequencies J. Appl. Phys. 52 3053-61
- [10] Myers D F and Saville D A 1989 Dielectric-spectroscopy of colloidal suspensions 1. The dielectric spectrometer J. Colloid Interface Sci. 131 448-60
- [11] Hayakawa R et al 1975 New apparatus for measuring complex dielectric-constant of a highly conductive material Japan. J. Appl. Phys. 14 2039-52
- [12] Schwan H P et al 1962 On the low-frequency dielectric dispersion of colloidal particles in electrolyte solution J. Phys. Chem. 66 2626-35

- [13] Scheider W 1975 Theory of the frequency dispersion of electrode polarization. Topology of networks with fractional power frequency dependence J. Phys. Chem. 79 127-36
- [14] Kornyshev A A 2007 Double-layer in ionic liquids: Paradigm change? J. Phys. Chem. B 111 5545-7
- [15] Feldman Y et al 1998 Fractal-polarization correction in time domain dielectric spectroscopy Phys. Rev. E 58 7561-5
- [16] Wakamatsu H 1997 A dielectric spectrometer for liquid using the electromagnetic induction method Hewlett-Packard J. 48 37-44
- [17] Siano S A 1997 Biomass measurement by inductive permittivity Biotechnol. Bioeng. 55 289-304
- [18] Asami K, Gheorghiu E and Yonezawa T 1999 Real-time monitoring of yeast cell division by dielectric spectroscopy Biophys. J. 76 3345-8
- [19] Asami K 2002 Characterization of biological cells by dielectric spectroscopy J. Non-Cryst. Solids 305 268-77
- [20] Tumanski S 2011 Handbook of Magnetic Measurements (Series in Sensors vol xiv) (London: Taylor and Francis) p 390
- [21] Wachtman J B et al 1969 Mechanical and thermal properties of ceramics Proc. National Bureau of Standards Special Publication 303 vol vii (Washington: US Department of Commerce, National Bureau of Standards; for sale by the Supt. of Docs., US Government Printing Office) p 268
- [22] Kaatze U and Feldman Y 2006 Broadband dielectric spectrometry of liquids and biosystems Meas. Sci. Technol. 17 R17-35
- [23] Kaatze U 2007 Reference liquids for the calibration of dielectric sensors and measurement instruments Meas. Sci. Technol. 18 967-76
- [24] Clarke R N et al 2003 A Guide to the Characterisation of Dielectric Materials at RF and Microwave Frequencies (London: Institute of Measurement and Control/National Physical Laboratory) (www.npl.co.uk/publications/a-guide-to-the-characterisation-of-dielectric-materials-at-rf-and-microwave-frequencies)
- [25] Akhadov I I 1972 Diélektricheskie Svoistva Chistyx Zhidkosti (Moscow: Izdatelstvo Standartov)
- [26] Chen T, Hefter G and Buchner R 2003 Dielectric spectroscopy of aqueous solutions of KCl and CsCl J. Phys. Chem. A 107 4025-31
- [27] Kulkarni S V and Khaparde S A 2013 (Transformer Engineering: Design, Technology, and Diagnostics vol xx) 2nd edn (Boca Raton: CRC Press) p 730