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Signal processing and recognition of true kinetic equations containing non-integer derivatives from raw dielectric data

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Abstract

Signal processing in dielectric spectroscopy implies that it is necessary to find a 'true' fitting function (having a certain physical meaning), which describes well the complex permittivity and impedance data. In dielectric spectroscopy for description of complex permittivity/impedance data researches usually use the empirical Cole–Davidson (CD) and Havriliak–Negami (HN) equations that contains one relaxation time. But the parameters figuring in CD and HN equations do not have clear physical meaning as well as fitting parameters entering into linear combination of several CD or HN equations. For description of dielectric (especially asymmetric) spectra we suggest the complex permittivity functions containing two or more characteristic relaxation times. These complex susceptibility functions correspond in time domain to new type of kinetic equation containing non-integer (fractional) integrals and derivatives. We suppose that these kinetic equations describe a wide class of dielectric relaxation phenomena taking place in heterogeneous substances. To support and justify this statement the special recognition procedure has been developed that helps to identify this new kinetic equation from raw dielectric data. It incorporates the *ratio presentation* (or RP) format and separation procedure. Separation procedure was turned out to be helpful in detection of number of relaxation processes (each process is described by a characteristic relaxation time) taking place in the dielectric material under consideration. We suppose that this procedure can be applicable also for identification of fractal noises.

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Keywords: Dielectric spectroscopy; Ratio presentation; Kinetic equations; Fractional integrals; Fractional derivatives

1. Introduction

Signal processing in dielectric spectroscopy implies description of a complex permittivity function and impedance in terms of an analytical function. Most of the experimental studies show that the dielectric ac response in many dielectric materials especially for glass-forming materials is hardly being explained by the "classical" Debye dielectric function [3,7–11,21,23–25]

$$\varepsilon(\mathrm{j}\omega) = \varepsilon'(\omega) - \mathrm{j}\varepsilon''(\omega) = \varepsilon_\infty + \frac{\varepsilon(0) - \varepsilon_\infty}{1 + \mathrm{j}\omega/\omega_\mathrm{p}}. \qquad (1)$$

Generally, the experimentally observed non-Debye ac response of glass-forming hydrogen-bonded substances as well as that of a variety of solid dielectric materials in a remarkable wide range of frequencies have been found to exhibit much more broadening in

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