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Electrodeless Investigation of Conductivity of Liquid in Capillaries with due Regard for Skin Effect

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Abstract—Processes occurring in the setup for contactless measurement of conductivity of liquids have been considered. The experimental study of the relationship of the oscillating circuit Q-factor as a function of the specific resistance of liquid was performed using the electrode and electrodeless methods of measurements. Frequency relationships of additional attenuation d in the oscillating circuit caused by the presence of liquid with specific resistance ρ in inductively coupled capillary solenoid were investigated in the frequency range 2.2–8.8 MHz. It was shown that the impact of skin effect was significant for the considered values of ρ and the additional attenuation was described by formula $d = -a_0(f) + a_1(f)\rho^{-1/2}$, where function $a_1(f)$ is proportional to $f^{3/2}$, while function $a_0(f)$ is proportional to f^2. Owing to different frequency dependences of functions $a_1(f)$ and $a_0(f)$, the frequency relationship of the relative depth of skin layer in liquid electrolyte was obtained in explicit form: $h / r_{cp} = A(f)\rho^{1/2} = af^{1/2}\rho^{1/2}$, where a is the constant that does not depend on frequency and specific resistance of liquid.

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INTRODUCTION

Electrodeless studies of conductivity in liquid are topical for many sectors of science and production, including technological processes using both chemically pure and chemically aggressive liquids. The study of properties of aqueous solutions of electrolytes for a large range of concentrations is of considerable interest both for practice and for the development of theoretical concepts [1]. The current state of investigations of electrophysical parameters of liquids enables us to obtain information about the behavior and structure patterns of different solutions [2, 3].

Conductivity measurements in solid bodies and liquids are usually performed by using, respectively, contacts and electrodes. Therefore, the corresponding measurement techniques are often called contact and electrode.

At present, the electrode and electrodeless methods of measurements of electrically conducting media are utilized for investigating the specific conductance of liquid. The majority of these methods [4–8] are based on the analysis of transients and steady-state processes with participation of the object under study. The emergence of these processes is caused by eddy currents generated in the object under study that depend on the object configuration and conductivity. The measurement of weak eddy currents by using additional inductive sensors leads to a significant rise of the measurement error. Therefore, it is advisable to get rid of such techniques and use the high-frequency resonant methods.

The dependence of characteristics of measuring oscillating circuit, such as L, C, R, ω_0, and Q on the properties of environment is often employed in electrodeless methods. Simpler methods involve the use of an empirical relationship of resonant frequency ω_0 of oscillating circuit as a function of specific conductance σ of tested object in a specific configuration. More exact methods are also forced to use an empirical relationship of the oscillating circuit Q-factor caused by eddy currents as a function of specific conductance σ of object especially at minor changes of resonant frequency ω_0 of measuring oscillating circuit.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ADDITIONAL INFORMATION

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