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Study of Some AC Electrical Properties of the AL/AgI/AL Junction

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Abstract

Investigation in the AC conductivity of the solid electrolyte AgI in the structure Al/AgI/Al that prepared as thin film have been presented. The results show that the conductivity increases with frequency, while the capacitance and the permittivity is nearly constant at high frequency but change significantly at low frequency. Interpretations of the results have been presented by proposing an equivalent circuit and deriving its corresponding theoretical equations that fit our experimental data.

Keywords: AgI thin films; Thermal evaporation; Complex conductivity; Capacitance; Dielectric constant.

Introduction

The interest of scientists in the solid electrolyte has rapidly accelerated because of the possible applications of these electrolytes in advanced electrochemical devices and because of basic consideration related to the microscopic diffusion mechanism. The composite electrolytes are, therefore, candidates for applications in batteries, switching, sensors, memory device and fuel cells [1-3]. The solid electrolytes are solid materials which proses an electric conductivity partially or wholly due to ionic displacements [4]. The chemical and physical properties of an ideal electrolyte would be invariant. It should at the same time provides a path for ionic transport, and serves as a mechanical separator for electrodes. In alkali halide crystals, the electrical conductivity usually depends on the movement of ions rather than electrons. This is proven by comparing the transport of mass with transport of charge that is measured by the material plated out on electrodes in contact with crystals [5]. Usually the ion related Ac conductivity σ_{ac} is written as [6,7].

$$\sigma_{ac} = (d/a)\, G = \sigma_{dc} + \sigma_{(w)} = \sigma_{dc} + Aw^{s}. \quad \text{...............}(1)$$

where σ_{dc} is the dc conductivity, $\sigma_{(w)}$ the high - frequency dispersion of σ_{ac}, d the sample thickness, a the effective area and A and s are the parameters with value $0 < s < 1$.

AgI is a solid electrolyte has successfully been tested in combined structure with for galvanic cell applications [8] with low electrical conduction. The equivalent circuit of metal / insulator / metal (MIM) has been studied by many authors, see for example the excellent reviews by Jonscher [9] and Shaila [10]. It is usually assumed as composed of two interfaces potential barriers one on each side, of the electrolyte layer between them. MacDonald [11] suggested a model for the equivalent circuit of (MIM) as composed of three series - parallel circuit in which the diffusion effect has been considered as one of the parallel C-R combination. In this research, we suggested a model for Al / AgI / Al to fit our data.

Experimental

The thin films that were used in this research have been prepared by thermal evaporation method using Blazer coating unite (model 450) with builtin thickness monitor and Edward vacuum chamber (model 306) with Al evaporation electrodes. The better vacuum was 10^{-5} torr. The Al/AgI/Al structure has been deposition on a glass substrate. The thickness of Layer was about (600) nm. Special care was required to obtain a homogeneous thin film of AgI solid electrolyte. For a.c. measurements HP-RLC units models (4274 A and 4275 A multi - frequency LCR Meter) have been used to find the impedance and the capacitance of the structure. All measurement were achieved at room temperature.

Results and Discussion

The experimental data which give the cole-cole diagram where the cole-cole diagram was suggested by American physicits Kenneth S. Cole and Robert H. Cole. When similar diagrams are constructed with the real and imaginary value of dielectric constant they are known as cole-cole plots. The cole-cole diagram have been used to determine the distribution parameter a and the molecule relaxation time τ, and this method can give more valuable information on the local motion of ion [12].

Provided information concerning the total equivalent circuit that consist of the total resistance and total capacitance figure (1-a). Our model for the theoretical equivalent circuit for all the studied range of frequencies is they system shown in figure (1-b).
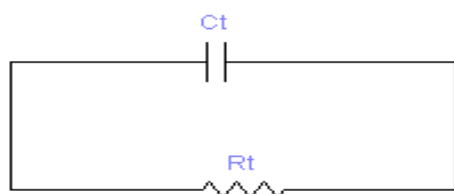
(a)
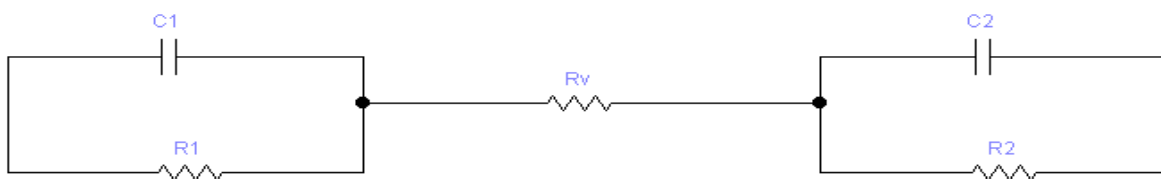
(b)

Figure (1): Illustrates the total equivalent circuits system (a) Measured circuit (b) Calculated circuit

The variation of dielectric loss factor with the frequency is shown in figure (2), where the capacitance (C) is drown as a function of the angular frequency (ω).

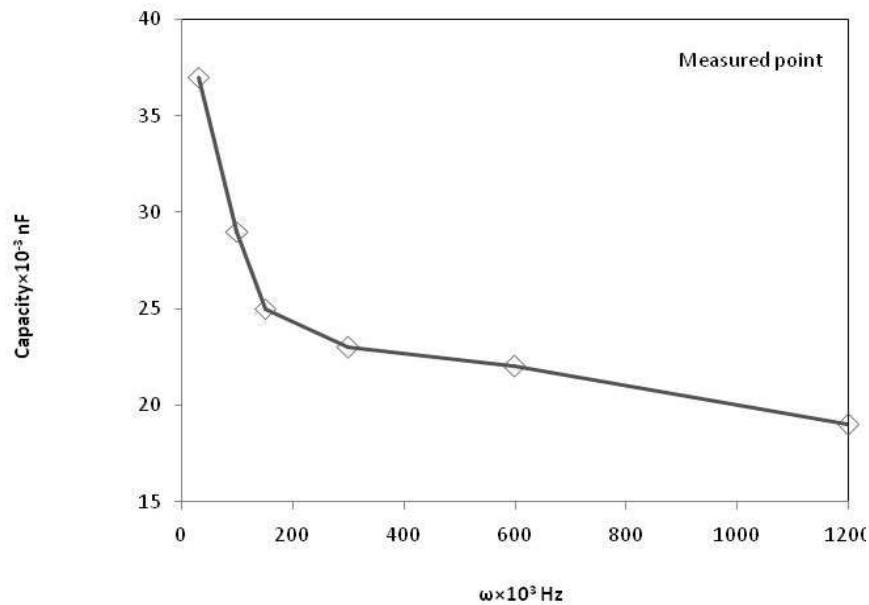$$C(\omega) = C_1(\omega) - j\, C_2(\omega) \ldots\ldots(2)$$

Figure (2): variant of capacitance versus angular frequency.

The abrupt change in capacitance (C) and consequently in permittivity ϵ took place at low frequency within narrow range, after that we observed a slow decrease in capacitance (C) for a wide range of high frequency. In the low frequency region, the ion mobility may be partially blocked across the interface [10]. While at high frequency, the space charge fluctuating across the electrodes showing intrinsic conduction. The variation of the complex permittivity ϵ^* with frequency is shown in figure (3).

$$\epsilon^*(\omega) = \epsilon_1(\omega) - j\,\epsilon_2(\omega) \ldots(3)$$

where $\epsilon_1(\omega)$ and $\epsilon_2(\omega)$ are real and imaginary parts of permittivity respectively. We observe that the similarity in the trend of variation of ϵ^* verses. ω with that of the capacitance in figure (2).
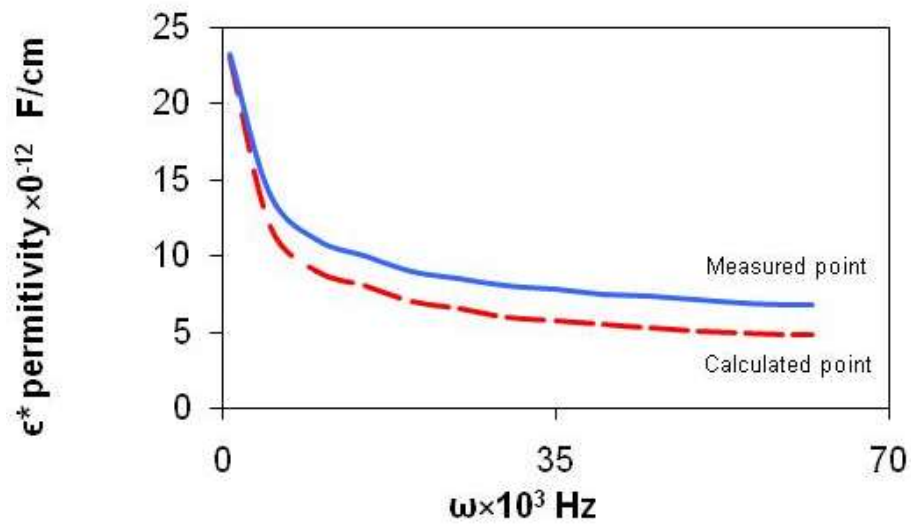
Figure (3): A comparative between calculated and measured permittivity

The dependence of the complex A.C. conductivity (σ^*) is given by

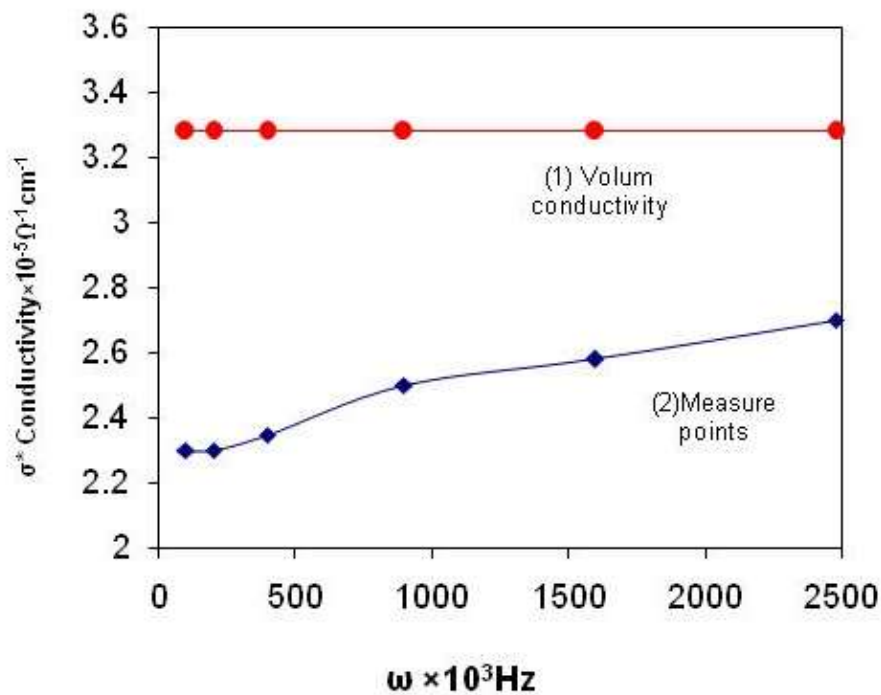$$\sigma^*(\omega) = \sigma_1(\omega) + j\,\sigma_2(\omega)\text{.........(4)}$$

Figure (4): The changing of complex conductivity (σ^*) with angular frequency (ω) for (1) volume conductivity (σ_V) and (2) experimental data.

where $\sigma_1(\omega)$ and $\sigma_2(\omega)$ are real and imaginary parts of conductivity respectively. The volume conductivity (σ_v) is shown in fig. (4). This figure exhibits that (σ_v) is independent on (ω) . While the total complex conductivity (σ^*) increases with (ω). This character shows that after the d.c. Component saturates, the a .c component of the conductivity does not change at high frequencies, this may means less ionic polarization and more ionic mobility at the metal / electrolyte interface indicating what we called before intrinsic conduction.

Conclusion

At low frequency, the capacitance and the permittivity change significantly. The suggested theoretical equations have a good fit to our experimental results. The conductivity versus frequency showed two stages phenomena confirming our data interpretation.

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