Electrical impedance spectroscopy (EIS) as a tool to investigate the complexation process of Gum Arabic and Chitosan solution: a review

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ABSTRACT

Electrical impedance spectroscopy (EIS) is a powerful technique to investigate the electrical properties of a large variety of materials. This technique has been used by Yadav et al. [1] to study the complexation process between gum Arabic and chitosan in bulk solution. EIS data were obtained for different GA/Ch mass ratios (R= 1:1–10:1) at frequencies ranging from 1Hz to 1000 Hz. Randles circuit was used to fit experimental data and to estimate resistance and capacitance parameters as a function of RGA/Ch. These parameters showed sharp changes at the isoelectric point of the complex coacervates. The capability and accuracy of the EIS were compared with that obtained via traditional potential measurements. The results indicated that the EIS technique can be used at specific frequency ranges as a practical method for monitoring the complexation process between biopolymers

However; it seems that the analysis of the impedance data was limited only to the complex impedance function. Therefore; this paper presents a review for a deep investigation on various electrical properties such as complexes impedance; modulus; admittance and capacitance. In this study; a simulation was performed in order to generate impedance complex data using electrical parameters extracted from the equivalent circuit since this latter showed a good fit for the experimental data. Moreover; an extrapolation in the low-frequency region was carried out to further investigate the behavior of the relaxation and the diffusion process. The analysis of impedance data using the bode plot allowed us to the identification and the de-convolution of a different process. Other electrical functions such as complex conductivity and permittivity were investigated using the Bode plot to further investigate the different processes. This review could provide considerable information about the user and guidance for the analysis of various electrical complexes functions as well as for monitoring the complexation process between biopolymers.

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INTRODUCTION

The study of the complexation and formation of electrostatic complexes between poly-ions has become a technology that has attracted great interest in the scientific community and several journals have been published on the association of chitosan with dextran sulfate or heparin. The formation of polyelectrolyte complexes (CPEs) results from attractive electrostatic interactions between a polyanion and a polycation in aqueous solution.

Impedance spectroscopy is a simple and easy method and it becomes a practical alternative for monitoring the evolution of biopolymer complexation. EIS is also useful in the study and analysis of other systems such as protein-protein, protein-polysaccharide, polysaccharide-polysaccharide complexation.

In this study; a simulation was performed to generate impedance complex data using electrical parameters extracted from the equivalent circuit. The analysis of impedance data using the bode plot allowed us to the identification and the de-convolution of a different process. An extension and extrapolation in the frequency range to further investigate the behavior of the relaxation process in the impedance data in the low-frequency region. Other electrical functions such as complex admittance, permittivity and dissipation factor were investigated using bode plot to extract the different processes.

In This Poster, Just The Results Of Impedance And Complex Admittance Are Presented.

METHODS AND MATERIALS

Electrical impedance spectroscopy measurements were obtained for $R_{GA/Ch}$ ranging from 1:1 to 10:1 under nominal open-circuit conditions (i.e., zero DC bias voltage) by scanning the exciting potential frequency from 1 to 1000 Hz.

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RESULTS AND DISCUSSION

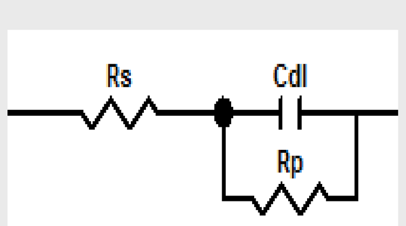

Figure 1. Equivalent circuit

	R_m(KΩ)	R_{dl}(KΩ)	α	τ_Z(s)	ω_{max} (rad/s)
Chitosan	0.48	44.01	0.89	16.86	5.93E-2
Gum Arabic	3.23	64.02	0.83	9.37	1.07E-1

Table 1. Parameters of the circuit used.

For the equivalent circuit, the complex impedance of such a circuit can be written as:

$$Z^*(\omega) = R_s + \frac{R_p(1+\tau^\alpha \cos(\alpha\frac{\pi}{2})\omega^\alpha)}{1+2\tau^\alpha \cos(\alpha\frac{\pi}{2})\omega^\alpha + \tau_z^{2\alpha}\omega^{2\alpha}} + i\frac{R_p\tau^\alpha \sin(\alpha\frac{\pi}{2})\omega^\alpha}{1+2\tau^\alpha \cos(\alpha\frac{\pi}{2})\omega^\alpha + \tau_z^{2\alpha}\omega^{2\alpha}}$$

$$Z'(\omega) = R_s + \frac{R_p(1+\tau^\alpha \cos(\alpha\frac{\pi}{2})\omega^\alpha)}{1+2\tau^\alpha \cos(\alpha\frac{\pi}{2})\omega^\alpha + \tau_z^{2\alpha}\omega^{2\alpha}}$$

$$Z''(\omega) = \frac{R_p\tau^\alpha \sin(\alpha\frac{\pi}{2})\omega^\alpha}{1+2\tau^\alpha \cos(\alpha\frac{\pi}{2})\omega^\alpha + \tau_z^{2\alpha}\omega^{2\alpha}}$$

With Z'(ω) : reel part and Z''(ω): imaginary part

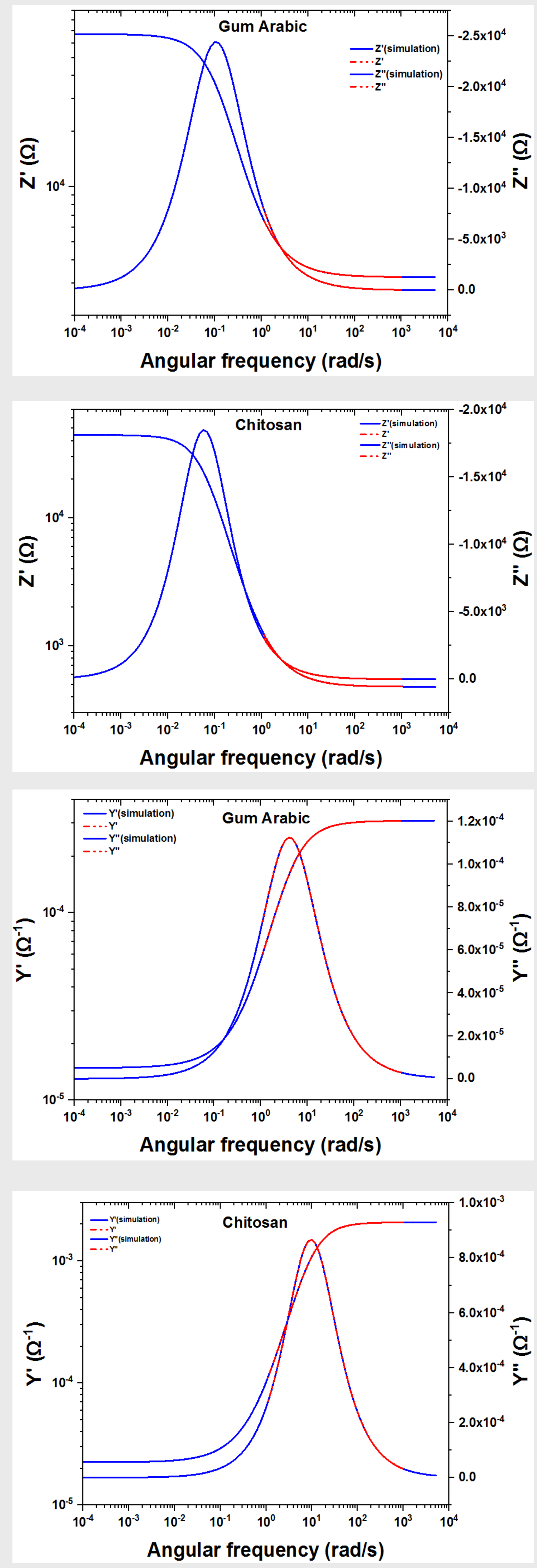

Figure 2. reel and imaginary part of impedance and admittance as a function of angular frequency of Chitosan and Gum Arabic

- It was observed that the parameters characterizing the EIS were modified as a function of the frequency and mass ratio of the polysaccharides.
- The change in frequency reflects the attenuation of the polarization process induced by an alternating excitation potential (experiment). On the other hand, at low frequencies, a peak appeared in the imaginary part of the complex impedance, that reflects a relaxation, which is important to enlarge the frequency range of our study, but the imaginary part of the complex admittance has a peak in the range selected for manipulation.
- Concerning the real part of the admittance, it gives information on the conductivity of the studied system.
- The changes as a function of the mass ratio are due to variations in the active electrolytic species due to the formation of biopolymer complexes.

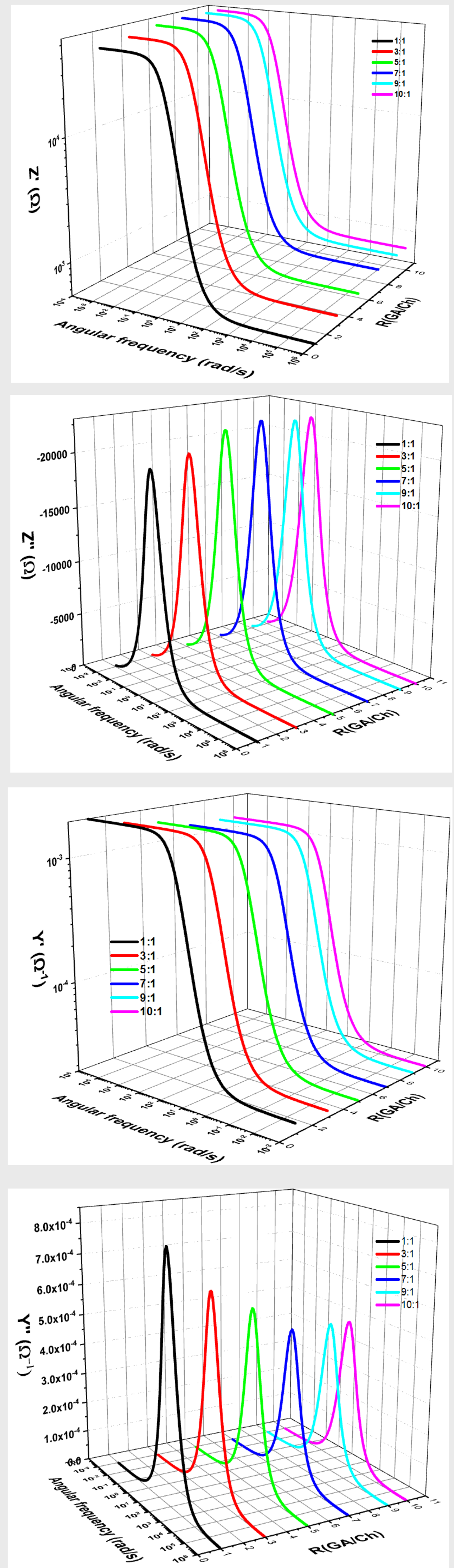

Figure 3. reel and imaginary part of impedance and admittance as a function of angular frequency for different ratio

CONCLUSIONS

The objective of this study is the analysis in-depth the complexation of both polymers, Chitosan and Gum Arabic, based on the equivalent circuit with the best fit using an extrapolation to study the different formalisms. As expected, all the electrical functions give the existence of a single relaxation process in the low frequencies, which justify the large range of frequencies used in this study.

REFERENCES

1. Roldan-Cruz et al. Colloids and Surfaces A: Physicochem. Eng. Aspects 495 (2016) 125–135