A compact device for simultaneous dielectric spectroscopy and gravimetric analysis using quartz crystal microbalance under controlled humidity

Alessia Gennaro[1], Sebastian Rosa[2], Peter Cornelis[1], Helge Pfeiffer[3], E. Anibal Disalvo[2], Patrick Wagner[1], Michael Wübbenhorst[1]

[1] Department of Physics and Astronomy, Laboratory for Soft matter and Biophysics, KU Leuven, Celestijnenlaan 200d, 3000 Leuven, Belgium

[2] Laboratorio de Biointerfases y Sistemas Biomimeticos, Centro de Investigacion y Transferencia de Santiago del Estero, Universidad Nacional de Santiago del Estero-Consejo Nacional de Investigaciones Científicas y Técnicas, Santiago del Estero, Argentina

[3] Department of Materials Engineering (MTM), Non–Destructive testing in Aerospace, KU Leuven, Kasteelpark Arenberg 44, 3001 Leuven, Belgium

In this study, a newly designed hydration cell is described, which allows setting a standardized humidity level while in parallel measuring the mass uptake/loss using a quartz crystal balance (QCM). Furthermore, simultaneously dielectric measurements are performed in such systems with a known moisture content to examine how drying and hydration processes affect the molecular dynamics in a frequency region from 0.1 Hz up to 1 MHz and in a wide temperature range.

Introduction

Hydration of natural or synthetic macromolecules is responsible for a variety of phenomena, affecting both the structure and the stability of such systems. Studying the effect of hydration enhances the understanding of many complex biological mechanisms such as protein folding, phospholipid hydration, as well as the dynamics and conformation of polymers [1-3]. Previous hydration studies, however, largely relied on the combination of separate measurements of relevant physical quantities aiming to a further refinement of e.g. the theory of hydration forces. In this study, we present a compact setup able to simultaneously quantify the film thickness while monitoring the evolution of the dynamics upon thickness variation [4].

Results and discussion

We have studied the multilamellar DMPC vesicles (MLVs) dynamics increasing dehydration stress. It was shown that at low hydration levels more pronounced lipids phase transitions are revealed and humidity affects the T-dependence of the main lipid phase transition (T_m). The data acquired by dielectric spectroscopy were supported by in situ mass uptake and loss as revealed by QCM results. The phase transition temperatures got from the two simultaneous measurements are resumed in the table below.
The two samples might present slight differences in the sample thickness and it explains the small variation in the T_m values.

RH	32%	22%	11%
QCM T_m	46	54	62
DRS T_m	49	54	61

Table 1: *DMPC vesicles phase transition temperature in Celsius degrees at three different relative humidity (RH).*

Conclusions

The combination of simultaneous DRS and gravimetric measurements allows to monitor the film dynamics upon variation of the sample mass, which is directly related to the moisture uptake/loss. The complementary results provide new insights into multilamellar lipids dynamics and viscoelastic properties at different humidity levels.

References

[1] F. Khabaz, S. Mani, and R. Khare, "Molecular Origins of Dynamic Coupling between Water and Hydrated Polyacrylate Gels", Macromolecules 2016, 49 (19), 7551–7562.

[2] E. A. Disalvo, "Membrane hydration: Membrane Hydration: the role of water in the structure and function of biological membranes", ed. Springer, Switzerland, 2015.

[3] G. Paradossi, I. Finelli, F. Natali, M.T.F. Telling and E. Chiessi, "Polymer and Water Dynamics in Poly(vinyl alcohol)/Poly(methacrylate) Networks. A Molecular Dynamics Simulation and Incoherent Neutron Scattering Investigation", Polymers 2011, 3, 1805-1832.

[4] A. Gennaro, S. Rosa, P. Cornelis, H. Pfeiffer, E. A. Disalvo, P. Wagner, M.Wübbenhorst, "A compact device for simultaneous dielectric spectroscopy and gravimetric analysis using quartz crystal microbalance under controlled humidity", IOP Measur. Sci. Techn. 2019, submitted.