広帯域誘電分光法によるポリエチレングリコールの水和特性評価

Characterization of Hydration State of Polyethylene Glycol based on Broadband Dielectric Spectroscopy.

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The storage and wearing comfort of contact lenses (CLs) has always been a concern. The CLs package solution, which stores and dispenses CLs, employs PEG to prevent CLs from dehydration and maintain the high-water content for its ready-to-wear condition[1]. The PEG used tends to be of relatively low molecular weight (Mw), Mw of 2000 Da and less and most preferably from about 100 Da to about 500 Da. Nevertheless, this Mw preference not fully understand, and thus characterizing the hydration state of PEG in aqueous phase will make it possible to describe a comprehensive picture of the moisturizing effect of PEG in CLs preservation.

The aim of this study is to elaborate the application prefer of PEG with various Mw in the CLs package solution from the aspect of hydration state. Therefore, a broadband dielectric spectroscopy covering the microwave-terahertz (THz)-far infrared (FIR) range (Fig. 1), 0.1 GHz to 18 THz, was performed to characterize PEG solutions with different molecular weights at room temperature. The moisturizing effect of PEG can be described by the number of water molecules restricted by PEG molecules and the degree of the caused dynamical slowing down of water molecules. Fig. 2 shows that with the increasing Mw, the ratio of hydration water decreases, which proves that longer chains make it harder to ensure each monomer to interact with the maximum number of water molecules. The PEG with larger Mw can restrict water molecules tighter with the retardation factor $\xi = \tau_{H2}/\tau_{slow}$ from 2.09 to 2.25. The effect of Mw on the structural disorder of hydrogen bond networks is not significant, which should be attributed to the offset between the increase of local forces in the hydration layer and the decrease of hydration water proportion. The obtained characterization of the hydration effect of PEG in the dependence of Mw quantitatively describes better moisturizing effect of CLs package solution with lower-Mw PEG, but also is beneficial to other biological and medical preservation techniques.

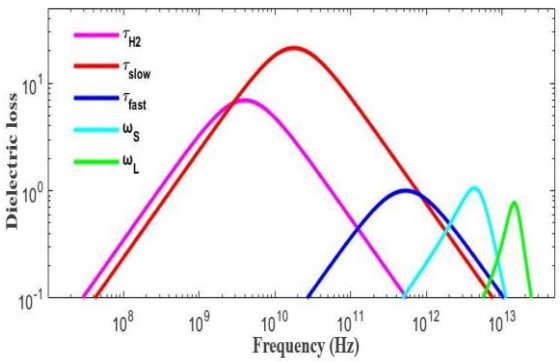

Fig. 1. Dielectric loss spectrum in Micro-THz-FIR range. τ_{H2} component: the relaxation of 2nd hydration water; τ_{slow} component: the slow relaxation of bulk water; τ_{fast} component: the fast relaxation of free water, ω_S component: the intermolecular stretching vibration of water; ω_L component: the libration of water.

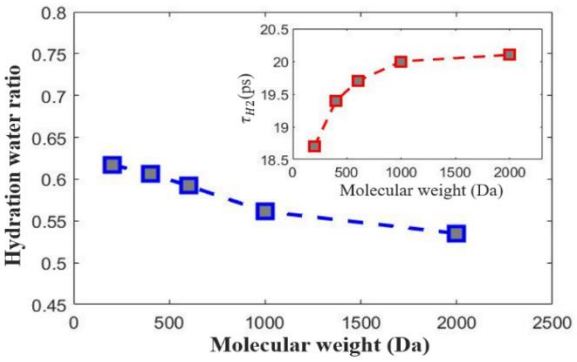

Fig. 2. Molecular weight dependence of the ratio of hydration waters of PEG solutions with concentration of 20 wt.% at 23℃. The inset is the relaxation time of 2nd hydration waters (τ_{H2})

Reference

[1] Jones L, et al. The TFOS International Workshop on Contact Lens Discomfort: Report of the Contact Lens Materials, Design, and Care Subcommittee. Invest Ophthalmol Vis Sci. 2013;54:TFOS37–TFOS70. DOI:10.1167/iovs.13-13215.