The liquid-glass transition in sugars and sugar mixtures

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The glass transition in sugars is important for several reasons. First, sugar glasses are very effective materials for cryopreservation and anhydrobiosis. Second, biochemists commonly use sugars to suspend biomaterials in a glassy matrix for spectroscopic studies. Third, the glass transition in sugars is important in the food industry. The texture of candies or cookies mainly depends on the glass transition temperature of sugars. Forth, sugars are useful material to study the glassy dynamics such as the secondary relaxation process and aging phenomena.

In this presentation, we studied a number of sugars and sugar mixtures including Glucose, Galactose, Sucrose, Trehalose, Glucose/Sucrose, Sucrose/Trehalose, using calorimetry (DTA and DSC), photon correlation spectroscopy, Brillouin scattering, dielectric spectroscopy, and X-ray diffraction.

We measured the glass transition temperatures of glucose-water mixtures by using Brillouin scattering and differential scanning calorimetry (DSC). The measured glass transition temperatures from both experiments were consistent with each other, indicating that the Brillouin scattering technique can be used to determine the glass transition temperature. We also measured the glass transition temperatures of monosaccharide mixtures, disaccharide mixtures and monosaccharide-disaccharide mixtures by using DSC technique. We found that the volume compression effect from the molecule size and shape played an important role in determining the glass transition temperature.

We have studied the relaxation dynamics of mono-saccharide(Glucose and Galactose)/water and disaccharide(Trehalose and Sucrose)/water mixtures by using dielectric loss spectroscopy in the frequency range from 0.1 Hz to 10 MHz. We found that dielectric loss spectroscopy has not yet provided useful information on the α-relaxation dynamics in disaccharide-water mixtures because the low frequency dielectric loss is apparently dominated by a strong dc-conductivity of unknown origin. However, evidence of temperature dependent secondary relaxation at higher frequency has been observed.

On the other hand, in the case of mono-saccharide/water mixtures, we could observe the α-relaxation and the secondary relaxation in our measurement window [1]. As shown in Fig. 1, we clearly observed that as the water content or temperature decreased the relaxation time difference between the α- and the secondary relaxations increased and the relative relaxation strength between the α and the secondary relaxations decreased. We found that the effects of adding water or increasing temperature on the secondary relaxation are qualitatively similar to that of decreasing the rotation-translation (RT) coupling in the schematic mode-coupling theory [3].

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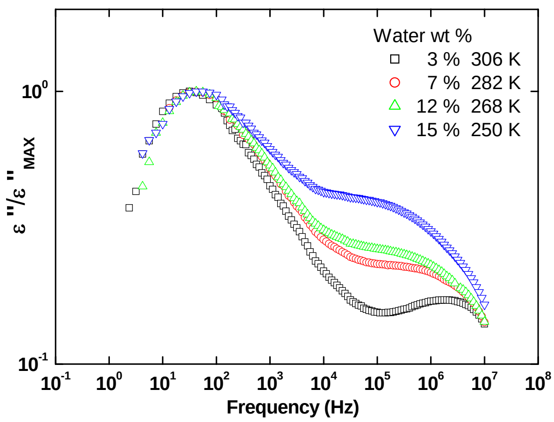

Fig. 1 The dielectric loss spectra of glucose-water mixtures with different water contents at the same effective temperature.

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