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Dynamic Mechanical Analysis of Supercooled Water in Nanoporous Confinement and Biological Systems

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Abstract : In the present work, we show that Dynamic Mechanical Analysis (DMA) with a measurement frequency range f= 0.2 - 100 Hz is a rather powerful technique for the study of phase transitions (freezing and melting) and glass transitions of water in geometrical confinement. Inserting water into nanoporous host matrices, like e.g. Gelsil (size of pores 2.6 nm and 5 nm) or Vycor (size of pores 10 nm) allows one to study size effects occurring at the nanoscale conveniently in macroscopic bulk samples. One obtains valuable insight concerning confinement induced changes of the dynamics by measuring the temperature and frequency dependencies of the complex Young's modulus Y* for various pore sizes. Solid-liquid transitions or glass-liquid transitions show up in a softening or the real part Y' of the complex Young's modulus, yet with completely different frequency dependencies. Analysing the frequency dependent imaginary part of the Young´s modulus in the glass transition regions for different pore sizes we find a clear-cut 1/d-dependence of the calculated glass transition temperatures which extrapolates to Tg(1/d=0)=136 K, in agreement with the traditional value of water. The results indicate that the main role of the pore diameter is the relative amount of water molecules that are near an interface within a length scale of the order of the dynamic correlation length x. Thus we argue that the observed strong pore size dependence of Tg is an interfacial effect, rather than a finite size effect. We obtained similar signatures of Y* near glass transitions in different biological objects (fruits, vegetables, and bread). The values of the activation energies for these biological materials in the region of glass transition are quite similar to the values of the activation energies of supercooled water in the nanoporous confinement in this region. The present work was supported by the Austrian Science Fund (FWF, project Nr. P 28672 – N36).

Keywords : biological systems, liquids, glasses, amorphous systems, nanoporous materials, phase transition
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