



Contribution ID: 64

Type: Oral Presentation

Water diffusion in cellulose nanopores

Thursday, 25 May 2023 10:00 (15 minutes)

Cellulose, the world's most abundant natural, renewable, biodegradable polymer, is a major component of plants, wood, paper, textiles or other industrial materials. A remarkable property of cellulose-based materials is that they can absorb huge amounts of water (typically 25% of the dry mass) from ambient vapor, in the form of bound water confined at a nanoscale in the amorphous regions of the cellulose structure. The control of the dynamics of sorption and desorption of bound water is a major stake for the reduction of energy consumption and material or structure damages. This dynamics relies on the ability of bound water to be transported through the material, but in the absence of direct observations this process is still poorly known. Here we present straightforward internal observations of bound water transport through a cellulose fiber piling filled with oil, which prevents vapor transport. Thanks to NMR relaxometry and MRI measurements we show that the bound water is transported along the fibers and throughout the network of fibers in contact. This process may be well described by a constant diffusion coefficient. The dependence of this diffusion coefficient on the fiber density and orientation is then analyzed to deduce the (elementary) diffusion coefficient of bound water along a cellulose fiber axis. Surprisingly, although the bound water molecules are confined in nanometric pores between cellulose microfibrils, the diffusion coefficient is in the order of the coefficient of self-diffusion of water. This constitutes fundamental physical data which may be compared with molecular simulations, and opens the way to the prediction and control of sorption dynamics of all cellulosic materials or other hygroscopic materials.

Participation

In-Person

References

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Session Classification: MS13

Track Classification: (MS13) Fluids in Nanoporous Media