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Enhanced Water Vapor Flow in Silica Microtubes Explained by Maxwell's Tangential Momentum Accommodation and Langmuir's Adsorption

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Abstract : Recent findings of anomalously high gas flow rates in carbon nanotubes show smooth hydrophobic walls can increase specular reflection of molecules and reduce the tangential momentum accommodation coefficient (TMAC). Here we report the first measurements of water vapor flows in microtubes over a wide humidity range and show that for hydrophobic silica there is a range of humidity over which an adsorbed water layer reduces TMAC and accelerates flow. Our results show that this association between hydrophobicity and accelerated moisture flow occurs in readily available materials. We develop a hierarchical theory that unifies Maxwell's ideas on TMAC with Langmuir's ideas on adsorption. We fit the TMAC data as a function of humidity with the hierarchical theory based on two stages of Langmuir adsorption and derive total adsorption isotherms for water on hydrophobic silica that agree with direct observations. We propose structures for each stage of the water adsorption, the first reducing TMAC by a passivation of adsorptive patches and a smoothing of the surface, the second resembling bulk water with large TMAC. We find that leak testing of moisture barriers with an ideal gas such as helium may not be accurate enough for critical applications and that direct measurements of the water leak rate should be made.

Keywords : water vapor flows, silica microtubes, TMAC, enhanced flow rates
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