Influence of impurities on two level systems in amorphous ice

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Low temperature far infrared absorption by two level systems (TLS) is studied in two amorphous ice phases which are produced by pressure amorphization of regular ice and subsequent thermal cycling of the sample. When the amorphous sample is heated above 120 K the high density amorphous (HDA) phase is transformed to the low-density amorphous (LDA) phase so that a precise spectroscopic comparison of the two phases is possible in the mm-wave region. We find that HDA ice has a TLS optical density of states with strength comparable to that found in many conventional glasses whereas in the LDA phase the TLS strength is thirty times smaller. Isotopic substitution resulting in 50% of molecules having lower symmetry (HOD) fails to change this strength ratio suggesting that the observed difference is not due to a breaking of the tetrahedral selection rule in the HDA phase. The lack of an isotope effect also severely limits what exactly can be tunneling to produce the TLS. By doping the samples with different concentrations of LiCl, methanol, HF, NaCl, LiOH, and NaOH we have explored both the TLS optical density of states and the glass transition characteristics in the LDA ice phase. For LiCl and methanol we find that the doping changes the TLS optical density of states and the glass transition temperature T_g while for all other impurities the effects on both quantities are negligible. Two types of correlations have been observed between the high and low temperature properties of the glass. One correlation is represented by an activation form, relating the TLS optical density with T_g for both impurities. A second, only observed with LiCl, is a qualitative correspondence between fragility of the liquid phase and the TLS optical density.
*Supported in part by NSF-DMR and by NASA.