Impurity-Induced mm-Wave Absorption in Amorphous Ice

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The temperature dependant mm-wave absorption of amorphous solids is dominated by a broad distribution of two level systems (TLS) at low temperatures. The TLS absorption coefficient has a unique temperature dependent signature in that it becomes weaker with increasing temperature up to about 15 K. At higher temperatures the absorption coefficient again increases due to a phonon assisted tunneling relaxational mechanism. Such changes in the absorption coefficient produce a temperature dependent spectral index. [1]

The mm-wave properties of amorphous ice are particularly interesting because there are two amorphous phases. For the pure system we illustrate that the high-density amorphous (HDA) phase has a large mm-wave absorption coefficient with strong temperature dependence, whereas the low-density amorphous (LDA) phase has an absorption coefficient smaller by a factor of 5, and it is practically temperature independent. [2]

We have examined the effect of three different kinds of impurities (ionic, molecular and carbon grains) on the spectral properties of the two amorphous ice phases. The HDA phase samples doped with LiCl (ionic), methanol (molecular) or carbon (charcoal) impurities are produced at 77 K by pressure amorphization at 1.5 GPa and are later converted into the LDA phase by warming the sample to 135 K. In this way the absorption coefficient can be measured for both phases in the same sample. Methanol impurities in the range 1 to 7 mol% and LiCl in the range 0.5 to 5 mol% do not alter the temperature dependence of the absorption coefficient in the HDA phase, but greatly increase its value in the LDA phase. For carbon impurities it is observed that at 5 wt% charcoal in the ice, the HDA phase becomes unstable and the characteristic HDA to LDA exothermic transition at $\sim$ 120 K disappears. As a result, only the LDA phase is stable for concentrations above 5 wt%. The temperature dependence of the absorption coefficient monotonically increases with temperature from 3 to 30 cm^1 for all of these charcoal doped samples.

The general findings of our study are that: (1) doping with ionic (LiCl) or molecular (methanol) impurities decreases the difference in the mm-wave absorption coefficient between the HDA and LDA ice phases so that the HDA spectrum can be used for impure ice; (2) a mixture of amorphous ice with charcoal stabilizes the LDA phase so the mm-wave absorption coefficient is completely dominated by the carbon grain properties.

References:

[1] N. I. Agladze, A. J. Sievers, S. A. Jones, J. M. Burlitch, and S. V. W. Beckwith, *AstrophysicalJournal* **462**, 1026 (1996).
[2] N. I. Agladze and A. J. Sievers, *Phys.Rev.Lett.* **80**, 4209 (1998).

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