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Ideality and Tunneling Level Systems (TLS) in amorphous silicon films.[1]

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Heat capacity, sound velocity, and internal friction of covalently bonded amorphous silicon (a-Si) films with and without hydrogen show that low energy excitations commonly called tunneling or two level systems (TLS) can be tuned over nearly 3 decades, from below detectable limits to the range commonly seen in glassy systems. This tuning is accomplished by growth temperature, thickness, growth rate, light soaking or annealing. We see a strong correlation with atomic density in a-Si and in literature analysis of other glasses, as well as with dangling bond density, sound velocity, and bond angle distribution as measured by Raman spectroscopy, but TLS density varies by orders of magnitude while these other measures of disorder vary by less than a factor of two. The lowest TLS films are grown at temperatures near 0.8 of the theoretical glass transition temperature of Si, similar to work on polymer films and suggestive that the high surface mobility at relatively low temperature of vapor deposition can produce materials close to an ideal glass, with higher density, lower energy, and low TLS due to fewer nearby configurations with similarly low energy. The TLS measured by heat capacity and internal friction are strongly correlated for pure a-Si, but not for hydrogenated a-Si, suggesting that the standard TLS model works for a-Si, but that a-Si:H possess TLS that are decoupled from the acoustic waves measured by internal friction. Internal friction measures those TLS that introduce mechanical damping; we are in the process of measuring low T dielectric loss which yield TLS with dipole moments in order to explore the correlation between different types of TLS. Additionally, a strong correlation is found between an excess T^3 term (well above the sound velocity-derived Debye contribution) and the linear term in heat capacity, suggesting a common origin.

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