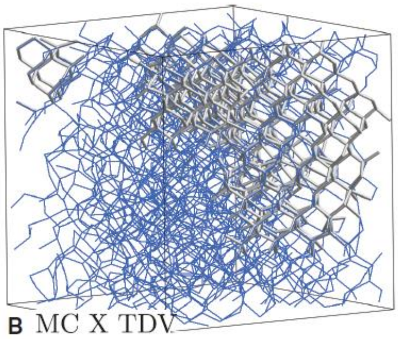
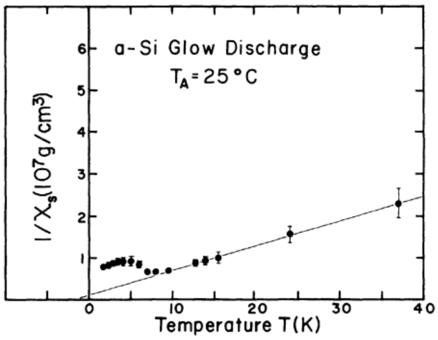
Amorphous Solid-State Physics

Almost all research in the field of solid-state physics is still dealing with the physics of crystals. However most solids in Nature and more and more in technological applications are amorphous, or topologically disordered. Let us just think of glasses and all their ubiquitous uses. Yet these materials (and related organic solids) still represent a formidable challenge for studying their properties at the microscopic level, progress being slow but steady thanks to simplifications occurring at low temperatures. Degrees of freedom called Tunneling Systems exist at low-T and can be used as probes for investigating the real structure of these materials at the intermediate-range atomic level. The great surprise from this research (theoretical, but matched by the available experimental data) is that the amorphous solid appears to be a new type of solid, namely heterogeneously disordered and cell-like organized, different from the crystal (even when defect ridden) and that ought to be no longer thought of as a dynamically arrested liquid as is commonly believed. The images below refer to the case of a-Si structure and mysterious data (mag. suscept. χ).





A paracrystal in the atomic structure of a-Si (left), and the puzzling magnetic response of non-magnetic a-Si.

Are they related?

Much has been done in the past 15 years to understand the silicate glasses at low-T, with a model that is now being tested for the understanding of amorphous Si and Ge (films). Especially a-Si is a material of great technological significance, but as mysterious as ordinary SiO_2-based glasses. Yet the experimental data – still unexplained – available at low-T show the very same phenomenology as discovered for the silicate glasses in the presence and absence of a magnetic field. Work is being done to adapt the model to these systems and to then infer on the real atomic structure and its relevance for useful research projects like the improvement of efficiency of a-Si based solar cells.

Research on a more fundamental level is also being carried out in order to elucidate the main assumptions (and consequences) of the phenomenological tunneling model. For example lightly Li-doped KCl single crystals are considered as model systems that can be treated – to an extent – in a truly microscopic way and that show at low-T similar phenomenology as the cold glasses. The challenge is to see if the model for a-SiO_2, a-Si etc. can also be employed, and better understood, for KCl:Li. In parallel, the consequences of said model for a new description of the glass transition are being investigated., always comparing theory to available experiments.

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References:

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