Disorder induced Localization in crystalline Phase Change Materials

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Few properties have provided such a wealth of information on solids as measurements of charge carrier transport. The electrical resistivity in particular is highly valuable to characterize solids, since it varies by more than 32 orders of magnitude. Two different types of solids can be distinguished based upon the temperature dependence of their resistivity, or the reciprocal quantity, the electrical conductivity. While the conductivity of insulators vanishes as T goes to 0 K, metals reveal a finite conductivity. This immediately raises questions on the nature of the transition from the metallic to the insulating state and the existence of a minimum conductivity for metals.

Several concepts to explain a metal-insulator transition (MIT) have been established. According to Mott, a metal-insulator transition can be achieved if the electron correlation exceeds a critical value. A second route to insulating behavior has been identified by Anderson, who showed that increasing disorder turns a metal with delocalized electronic states at the Fermi energy into an insulator with localized states. In this talk the implications of these two pathways to charge localization will be discussed. Particular emphasis will be put on a discussion of phase change materials, where an MIT is observed in some materials that can solely be accounted to a varying degree of disorder (Anderson localization). The experimental data enabling this conclusion will be discussed in detail. It will be demonstrated, that electron – electron interactions are very weak. This is a direct consequence of resonance bonding and lattice instabilities, which lead to a large static dielectric constant. The high value of this constant leads to very small electron – electron interactions and hence marginal electron correlations. The disorder in some crystalline phase change materials, on the contrary, is very pronounced. The origin of this disorder will be presented and compared for different phase change materials. As a consequence of the small electron correlation, yet pronounced disorder, disorder effects are significantly more important than correlation effects. This unusual situation leads to unconventional properties. Implications regarding both the application potential as well as related scientific opportunities will be presented.