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Amorphous Materials: Exotic Physics and Practical Applications Arising from Disorder

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Virtually all textbooks of solid state physics start from the premise of a perfect crystal, from which the properties and characteristics of the material are derived, such as electrical resistance, superconductivity, optical properties, etc. Yet, few real materials have that perfect crystal structure, and in many cases the disorder actually improves the properties, sometimes significantly. Disorder comes in different forms: structural or chemical defects, grain boundaries, even surfaces. In some cases, the structural disorder is so strong that it is impossible to consider the disorder in terms of defects, and the material is called amorphous. This is for example the state that is created by rapidly quenching a liquid such as molten silicon dioxide, which is the basis for window glass. It is also possible to create amorphous or glassy materials by vapor deposition techniques, and in some particular cases, to create a disordered material that has low entropy and enthalpy, much like a crystal has. This is partially because the material can have short or even medium range order, without having long range order. Superconductivity is an example of an exotic property that can arise in an amorphous material, despite the fact that the original theory of superconductivity relied on crystalline symmetry. Other examples exist, some with very practical applications, and these challenge both theorists and experimentalists to think more deeply about the underlying physics of the phenomenon they are describing, and not to only rely on the simpler mathematics of the crystalline structure.