

Crystal Structure

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The spatial distribution of atoms in a solid, or in other words its crystallographic structure, significantly influences its electronic and photonic properties. In this regard distinction is made between crystalline solids, or crystals, and non-crystalline solids also referred to as amorphous (Fig.1). Crystals display highly periodic distribution of atoms featuring long-range order. In contrast, in amorphous materials atomic arrangement exhibits no periodicity or long-range order. Among crystals, single-crystal and polycrystalline materials are distinguished. As shown in Fig. 1 in the former case, periodic long-range order is maintained throughout the entire piece of material while in the latter such order is maintained only within limited in volume grains randomly connected to form a solid and separated by grain boundaries.

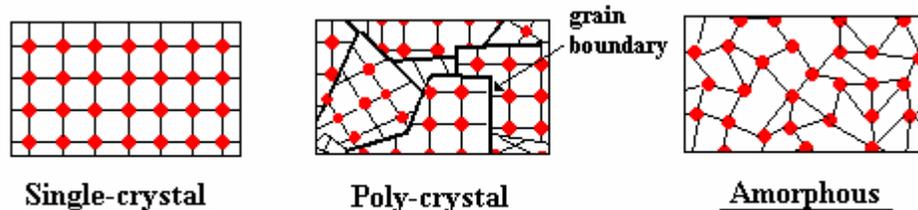


Fig. 1

Key characteristics of semiconductors, e.g. carrier mobility and diffusion length, degrade as crystal structure changes from single-crystal to amorphous. All substrate wafers used in semiconductor device processing are single-crystals. Poly-crystal and amorphous semiconductor thin films are used in the variety of applications as well. All dielectrics used in semiconductor device manufacturing (e.g. SiO_2 and Si_3N_4) are amorphous.

In crystalline solids the crystal lattice is comprised of elemental cells which for various crystals appear in a variety of different forms. Most of semiconductor crystals belong to the cubic class of crystals, and more specifically, they represent two different variations of the same face centered cubic (f.c.c.) cell (Fig. 2a where a represents lattice constant). The most common f.c.c. sublattices are diamond lattice and zinc

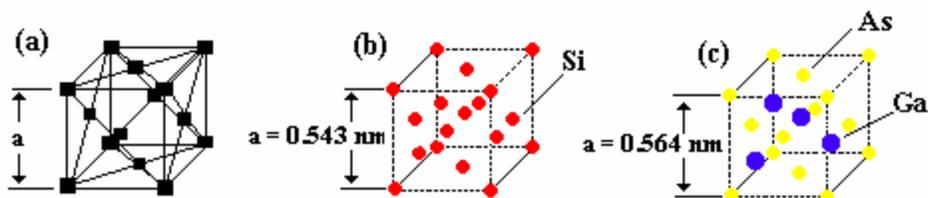


Fig. 2

blend lattice. Crystals of group IV semiconductors (Si, Ge, Sn, C) have a diamond lattice while common III-V semiconductors, for instance GaAs and GaP, crystallize in the zinc blend crystal lattice. The difference arises from the different nature of bonds in group IV and III-V semiconductors. The covalent bonds in for instance silicon, have strong directional properties not displayed by bonds in gallium arsenide which are only partially covalent (68% covalent bonds 32 % ionic bonds). What results is a slightly different distribution of atoms in f.c.c. cell in the case of silicon (diamond sublattice -Fig. 2b) and GaAs (zinc blend sublattice -Fig.2c) and a slightly different lattice constant a in these two cases.