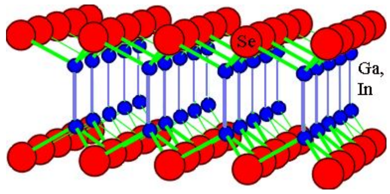
Layered Semiconductors

Advanced

- Compounds like **InSe**, **GaSe** or **Bi_2Se_3** are called "**layered semiconductors**" .
  - The reason is shown in the picture below. Considering the bonding situation, the two elements will form two-dimensional layers if the average number of bonds is three (= (**4** (**Ga**, **In**) + **2** (**Se**)**/2**). A **GaSe** or **InSe** layer as shown below thus has no "**dangling bonds**" and no urgent reason to form a three-dimensional crystal.
  - Note that there is a certain degree of polytypie with regard to the arrangement of the layers, but we won't go this deeply into the matter here.



Structure of **III-Se** (**III = Ga**, **In**, ...)
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- A crystal is formed by stacking the layers; the bonding between the layers can only be weak and of the van-der-Waals (**vdW**) type
  - Accordingly, mechanical properties will be extremely non-uniform. It is easy to shear the crystal in the **vdW** plane, but not in strongly bonded planes and so on.
- Since the **vdW** bonded plane has a low density of dangling bonds, but still a perfectly ordered arrangement of atoms, it is ideal for growing epitaxial films of other materials.
  - The atoms of the film to be grown, upon striking the surface of the layered semiconductor substrate, are not strongly bounded and can move around, but their arrangement will still be influenced by the ordered array of atoms "below" - and they might follow this order, forming a single crystal.
  - A single-crystal layer growing on a substrate formed by some other crystal usually experiences increasing strain with increasing thickness because the lattice constants never match perfectly. A relaxation of this misfit stress is necessary at some critical thickness and misfit dislocations are commonly introduced. With **vdW** bonded planes this may not happen - the growing layer "simply" shears of the substrate, expanding or contracting; whatever is as required to release the stress, because it is only loosely bound to the substrate. Coherency to the substrate is lost in this case, but that may not be important since the layer can keep growing to considerable thickness as a single crystal
- As far as semiconducting properties go, here are a few numbers:

Type	Lattice	Band Gap	Remarks
GaSe	hex.	2-2.1 eV, direct	
InSe	hex.	1.2-1.3 eV, direct	