Cleaving Semiconductors for (Blue) Lasers Diodes

Advanced

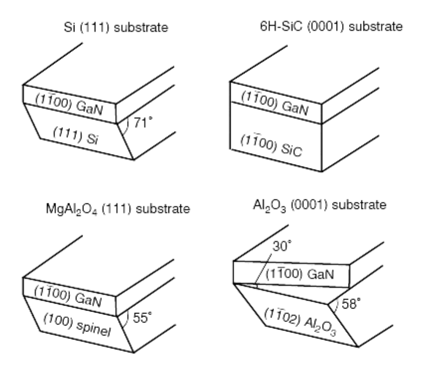
- The module is based on the paper of Kuramta et al: in FUJITSU Sci. Tech. J. **342** (1998). p.191. The authors provide data about **cleavage planes in semiconductors**.
  - The preferred cleavage planes of a semiconductor are not as clear-cut as it seems. As everybody know who just once dropped a **{100}** Si wafer knows, the fracture plans are the **{110}** planes; a large part of the literature, however, including the paper given above, insists that it should be **{111}**.
  - Be that as it may, here we take the planes given in the article.

Material	Crystal structure	Effective lattice mismatch (%)	Difference in thermal expansion coefficient ($\times 10^{-6}$)	Cleavage	Stability
Si	Diamond	20.1	-2.0	(111)	Good
GaAs	Zinc blende	25.3	0.4	(110)	Fair
GaP	Zinc blende	20.7	-0.9	(110)	Fair
MgO	Rock salt	-6.5	4.9	(100)	Fair
MnO	Rock salt	-1.4		(100)	Bad
CoO	Rock salt	-5.4		(100)	Bad
NiO	Rock salt	-7.6		(100)	Bad
$MgAl_2O_4$	Spinel	-10.3	1.9	(100)	Good
$NdGaO_3$	Perovskite	-1.2	1.9		Fair
ZnO	Wurtzite	2.0	-2.7	(1-100) (11-20) (0001)	Fair
6H-SiC	ZnS 6H	-3.4	-1.4	(1-100) (11-20) (0001)	Good
$LiAlO_2$	β-$NaFeO_2$	1.7	1.7	(001)	Fair
$LiGaO_2$	β-$NaFeO_2$	-0.1	1.9	(010)	Fair
Al_2O_3	Corundum	-13.8	1.9	(1-102)	Good
$LiNbO_3$	Ilmenite	-6.7	9.9	(1-102)	Bad
$LiTaO_3$	Ilmenite	-6.8	10.6	(1-102)	Fair

From the Ref. given above

Comparison always to **GaN**

- **GaN** as a semiconductor technology material only comes as a thin layer on a substrate other than **GaN** since there simply are no usable **GaN** single crystals
  - As we know, if we grow thin layers with different lattices, we have to watch out for misfit dislocations. It is important to look for substrates with a lattice constant as similar as possible to that of the thin layer to be grown. The table above shows the lattice mismatch of prospective substrates to **GaN** and thus gives a guideline.
- If we want to make a Laser diode form the thin film, we have a few more requirements besides "just" avoiding misfit dislocations as best as we can:
  - The substrate should have a high electrical and thermal conductivity. The first property would make it easier to supply the large current densities we need to operate a Laser diode, the second to remove efficiently the heat generated during operation.
  - The whole stack of substrate and layers should cleave nicely on a well-defined and very flat plane because the two relevant surfaces obtained by cleavage will serve as the mirrors of the Faby-Perot resonator we need for a Laser. Now look at the possible cleavage relations:



From the Ref. given above

- Summing up: There is no ideal substrate - you have to find the optimal compromise once more if you wan to make the blue Laser diode.