N Type Diamond Semiconductors

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Diamond Semiconductor- Why?

- High carrier mobility- 4500 $cm^2\ V^{-1}s^{-1}$ for electrons and 3800 $cm^2\ V^{-1}s^{-1}$ for holes measured at room temperature
- Thermal conductivity 2000 - 2500 W/(m·K)
- High breakdown voltage
- Wide Bandgap

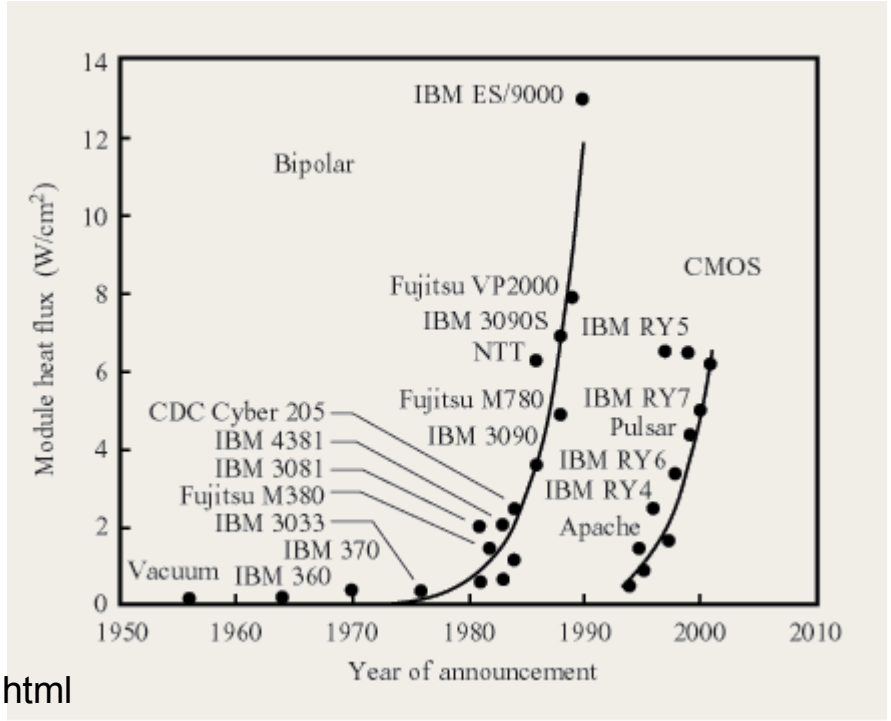
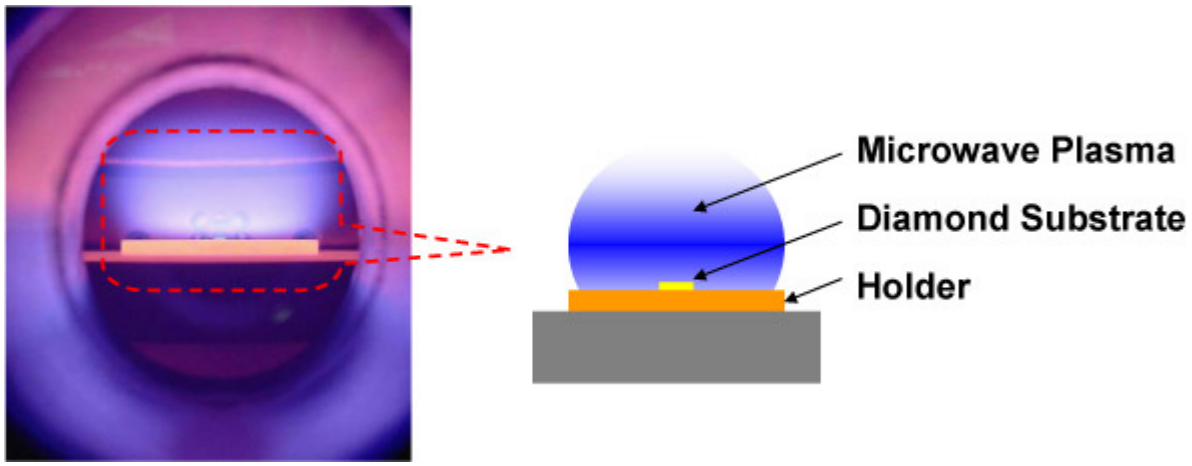


Image from http://www.research.ibm.com/journal/rd/446/allen.html

Diamonds- Manufactured

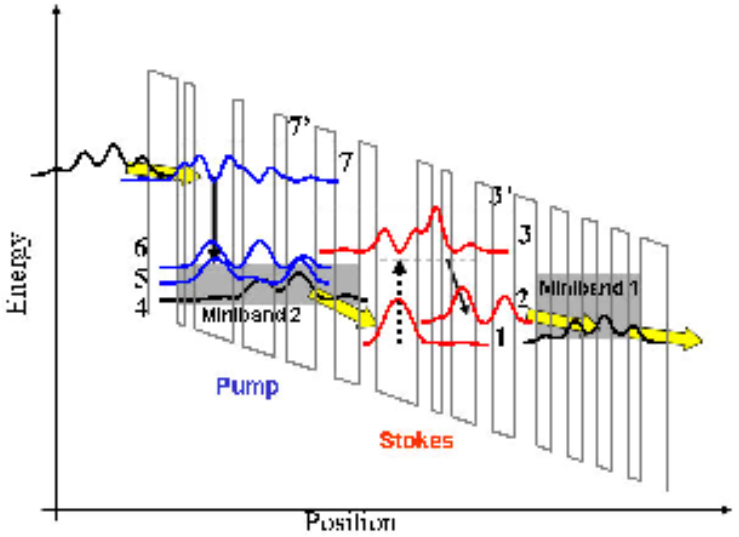
- Cultured diamonds
- Gemesis and Apollo Diamond
- Single crystal diamonds using CVD

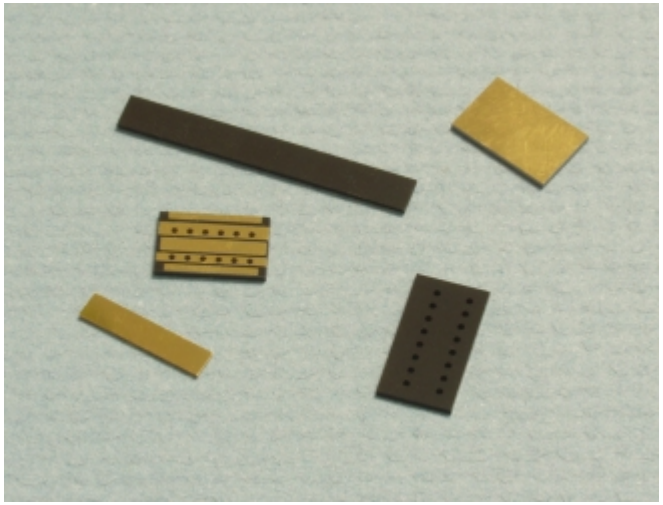


Images from http://www.aist.go.jp/aist_e/latest_research/2005/20050615/20050615.html

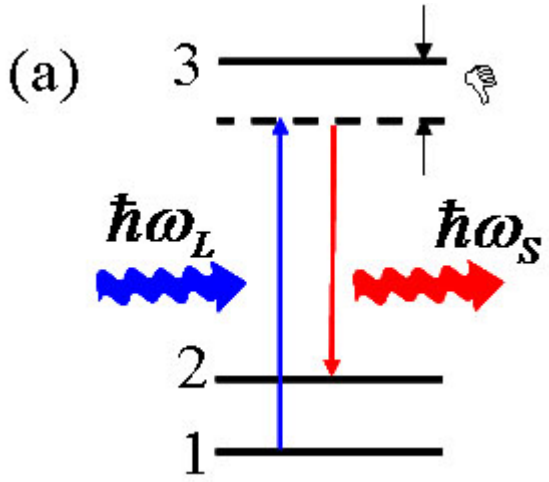
Diamonds- Applications

- Heat Spreaders
- High power Raman lasers
- Ultrafast transistors
- High power electronics



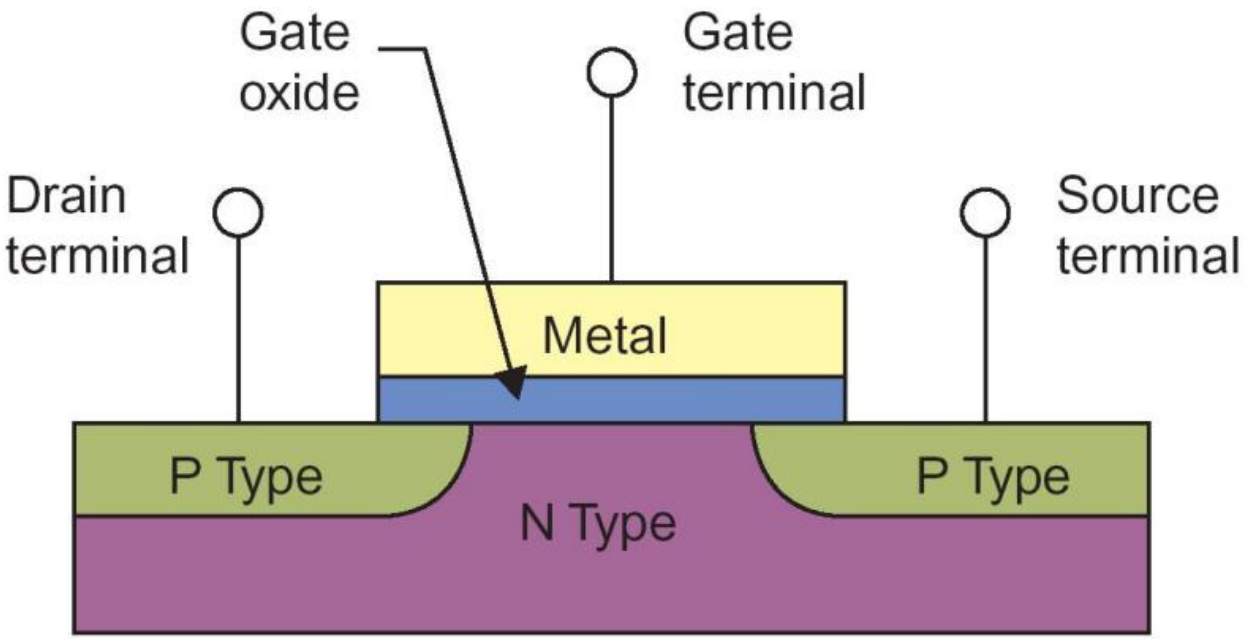


http://www.sp3inc.com/spreader.htm



Diamond Transistors

- Pure diamond is not conductive
- Need to create N and P type doped regions with sufficient conductivity



P Type

- Boron doping creates a p-type diamond semiconductor
- Boron doping exists in nature as blue colored diamonds
- Boron doped diamonds

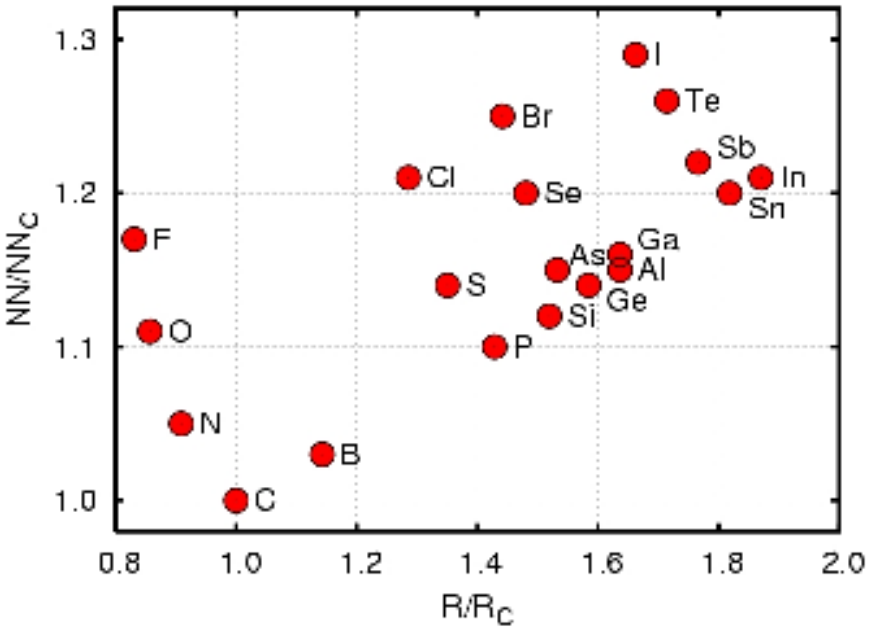
can be grown with CVD, ion implantation, or high temperature and pressure processes

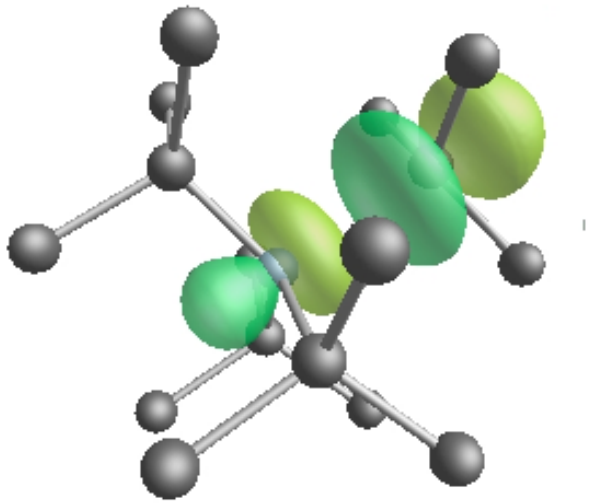


Image from http://www.leifels.ch/diamonds/

N Type

- Difficult
- Obvious potential donors, such as Nitrogen, distort the crystal and create deep donors



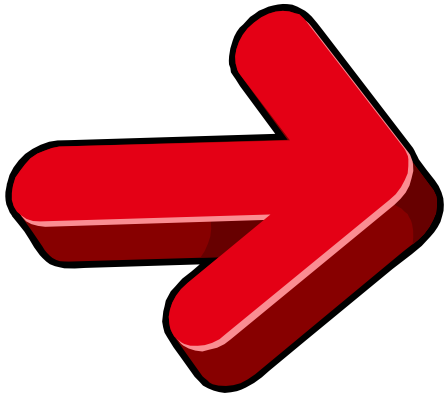


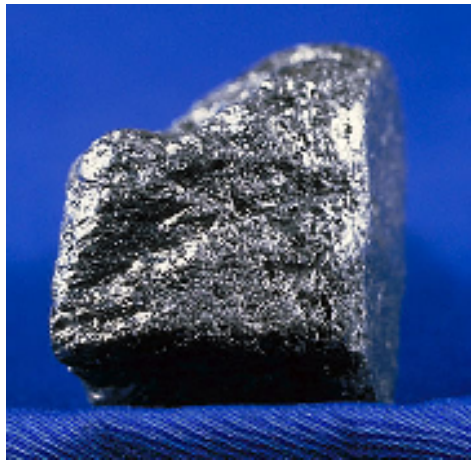
Images from http://www.staff.ncl.ac.uk/j.p.goss/Research/NtypeDiamond/

Phosphorus

- Shallower donor, ~.1-.4 eV
- Most successfully doped donor
- Can be incorporated with CVD or HTHP processes
- Ion implantation can cause graphitization

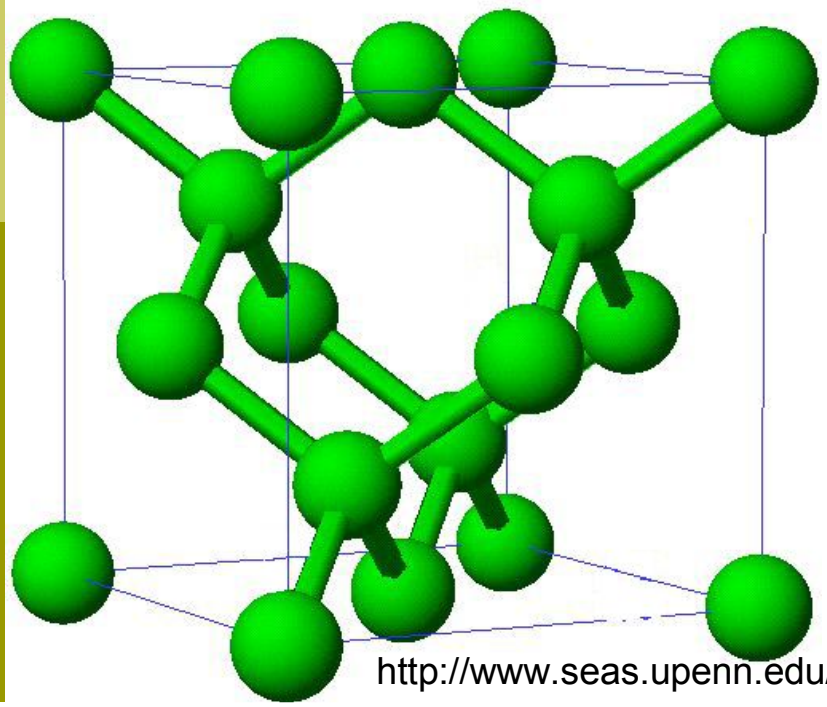






Li and Na

- Lithium and Sodium have been considered
- Interstitial dopants
- Small, so many can fit in the crystal

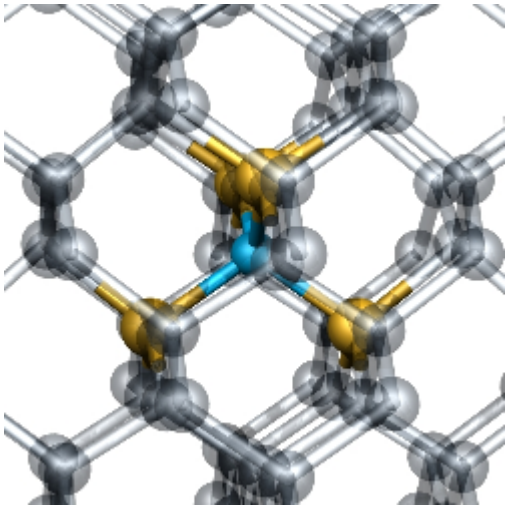


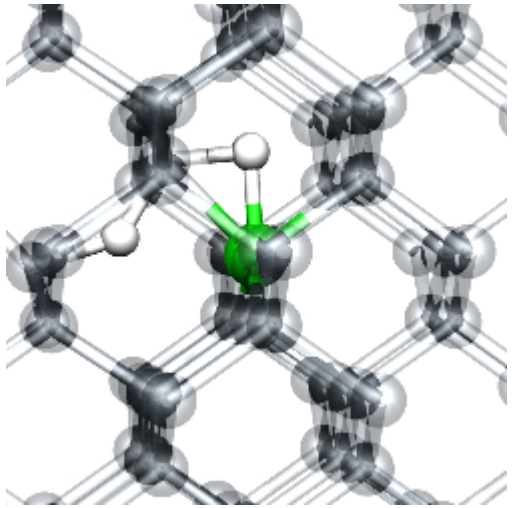
http://www.seas.upenn.edu/~chem101/sschem/diamond.jpg

- Two electrons left in the inner shell causes a preference for a linear bond

Potential Workarounds

- Co-doping- using a combination of donors and acceptors can create shallow donor sites
- Boron-hydrogen complexes





http://www.staff.ncl.ac.uk/j.p.goss/Research/NtypeDiamond/

Phosphorus Doping

- Phosphorus doping with vapor deposition on a 001 oriented substrate has been demonstrated by Japanese researchers.
- Used to create a p-n junction that radiates light at 235 nm.
- Getting enough phosphorus into the diamond is difficult- saturation of the phosphorus in the material leads to higher defect generation.

References

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