



Indium

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Location of Indium in the Periodic Table

| | | | | | | | | | | | | | | | | | | |
|---|--|--|---------------------------------------|--|--|---|---|--|---|---|--|--|--|--|--|--|---|--|
| 1 | | | | | | | | | | | 13 | 14 | 15 | 16 | 17 | 18 | | |
| 1 | 1 H Hydrogen 1.008 | | | | | | | | | | | 5 B Boron 10.811 | 6 C Carbon 12.011 | 7 N Nitrogen 14.007 | 8 O Oxygen 15.999 | 9 F Fluorine 18.998 | 10 Ne Neon 20.180 | |
| 2 | 3 Li Lithium 6.941 | 4 Be Beryllium 9.012 | | | | | | | | | | | 13 Al Aluminum 26.982 | 14 Si Silicon 28.086 | 15 P Phosphorus 30.974 | 16 S Sulfur 32.064 | 17 Cl Chlorine 35.453 | 18 Ar Argon 39.948 |
| 3 | 11 Na Sodium 22.990 | 12 Mg Magnesium 24.305 | | | | | | | | | | | 31 Ga Gallium 69.723 | 32 Ge Germanium 72.631 | 33 As Arsenic 74.922 | 34 Se Selenium 78.971 | 35 Br Bromine 79.904 | 36 Kr Krypton 84.799 |
| 4 | 19 K Potassium 39.098 | 20 Ca Calcium 40.078 | 21 Sc Scandium 44.956 | 22 Ti Titanium 47.88 | 23 V Vanadium 50.942 | 24 Cr Chromium 51.996 | 25 Mn Manganese 54.938 | 26 Fe Iron 55.845 | 27 Co Cobalt 58.933 | 28 Ni Nickel 58.693 | 29 Cu Copper 63.546 | 30 Zn Zinc 65.38 | 49 In Indium 114.818 | 50 Sn Tin 118.710 | 51 Sb Antimony 121.760 | 52 Te Tellurium 127.6 | 53 I Iodine 126.905 | 54 Xe Xenon 131.294 |
| 5 | 37 Rb Rubidium 85.468 | 38 Sr Strontium 87.62 | 39 Y Yttrium 88.906 | 40 Zr Zirconium 91.224 | 41 Nb Niobium 92.906 | 42 Mo Molybdenum 95.94 | 43 Tc Technetium 98.907 | 44 Ru Ruthenium 101.07 | 45 Rh Rhodium 102.905 | 46 Pd Palladium 106.42 | 47 Ag Silver 107.868 | 48 Cd Cadmium 112.411 | 50 Sn Tin 118.710 | 51 Sb Antimony 121.760 | 52 Te Tellurium 127.6 | 53 I Iodine 126.905 | 54 Xe Xenon 131.294 | |
| 6 | 55 Cs Cesium 132.905 | 56 Ba Barium 137.327 | 57-71 * | 72 Hf Hafnium 178.49 | 73 Ta Tantalum 180.948 | 74 W Tungsten 183.85 | 75 Re Rhenium 186.207 | 76 Os Osmium 190.23 | 77 Ir Iridium 192.22 | 78 Pt Platinum 195.08 | 79 Au Gold 196.967 | 80 Hg Mercury 200.59 | 81 Tl Thallium 204.383 | 82 Pb Lead 207.2 | 83 Bi Bismuth 208.980 | 84 Po Polonium (209) | 85 At Astatine (209) | 86 Rn Radon 222.018 |
| 7 | 87 Fr Francium 223.019 | 88 Ra Radium 226.025 | 89-103 ** | 104 Rf Rutherfordium (261) | 105 Db Dubnium (262) | 106 Sg Seaborgium (266) | 107 Bh Bohrium (264) | 108 Hs Hassium (265) | 109 Mt Meitnerium (268) | 110 Ds Darmstadtium (285) | 111 Rg Roentgenium (280) | 112 Cn Copernicium (285) | 113 Nh Nihonium (284) | 114 Fl Flerovium (289) | 115 Mc Moscovium (288) | 116 Lv Livermorium (293) | 117 Ts Tennessine (294) | 118 Og Oganesson (294) |

Lanthanide Series*

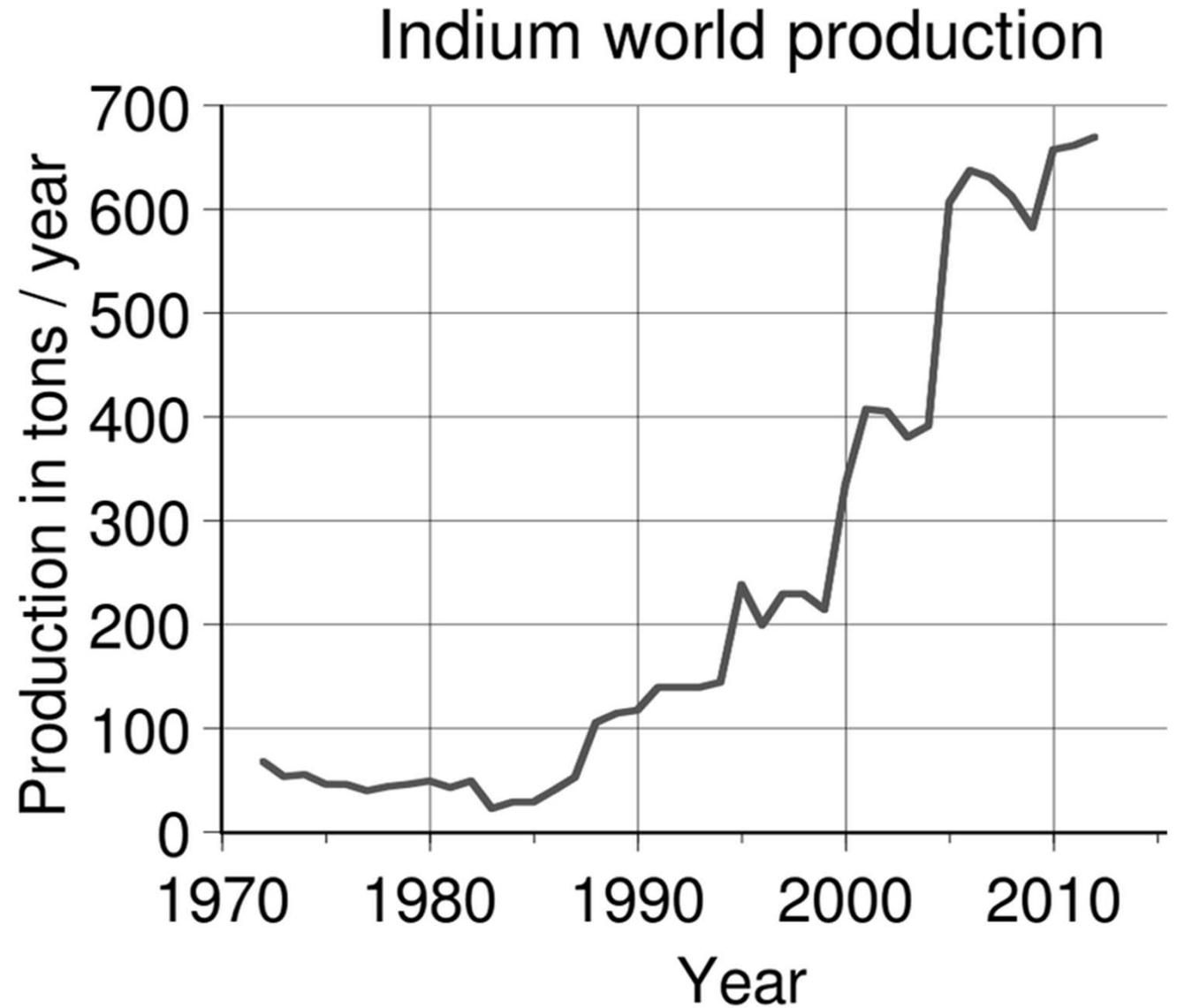
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|---|--------------------------------------|--|---|--|---------------------------------------|--|---|---------------------------------------|--|---------------------------------------|--------------------------------------|---------------------------------------|---|--|
| 57 La Lanthanum 138.905 | 58 Ce Cerium 140.116 | 59 Pr Praseodymium 140.908 | 60 Nd Neodymium 144.242 | 61 Pm Promethium 144.913 | 62 Sm Samarium 150.36 | 63 Eu Europium 151.964 | 64 Gd Gadolinium 157.25 | 65 Tb Terbium 158.925 | 66 Dy Dysprosium 162.500 | 67 Ho Holmium 164.930 | 68 Er Erbium 167.259 | 69 Tm Thulium 168.934 | 70 Yb Ytterbium 173.055 | 71 Lu Lutetium 174.967 |
|---|--------------------------------------|--|---|--|---------------------------------------|--|---|---------------------------------------|--|---------------------------------------|--------------------------------------|---------------------------------------|---|--|

Actinide Series**

| | | | | | | | | | | | | | | |
|--|---------------------------------------|--|--------------------------------------|---|---|---|--------------------------------------|---|---|---|--|--|---|---|
| 89 Ac Actinium 227.028 | 90 Th Thorium 232.038 | 91 Pa Protactinium 231.036 | 92 U Uranium 238.029 | 93 Np Neptunium 237.048 | 94 Pu Plutonium 244.064 | 95 Am Americium 243.061 | 96 Cm Curium 247.070 | 97 Bk Berkelium 247.070 | 98 Cf Californium 251.080 | 99 Es Einsteinium (252) | 100 Fm Fermium 257.080 | 101 Md Mendelevium 258.1 | 102 No Nobelium 259.103 | 103 Lr Lawrencium (262) |
|--|---------------------------------------|--|--------------------------------------|---|---|---|--------------------------------------|---|---|---|--|--|---|---|

Overview

- [Element symbol In, element number 49, Group 13 post-transition p-block metal]
- Discovered in 1863 by Richter and Reich in Germany from a mineral sample of sphalerite
- Named after the indigo blue color of the flame
- Relatively rare: abundance of about 50 ppb
- Price of 210€/kg

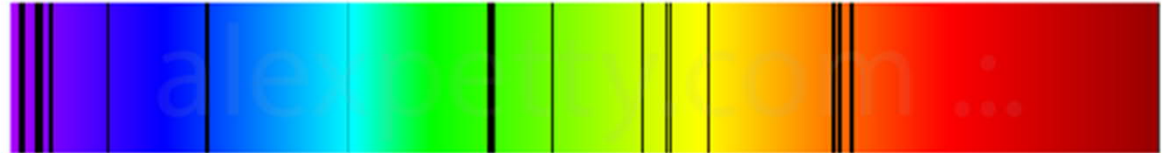


General properties

- Extremely soft (Mohs hardness 1,2)
- Low melting point (156,6 degrees C)
- Density 7.31 g/cm³
- No major role in biology, low toxicity; compounds very toxic



absorption



emission



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Chemical properties

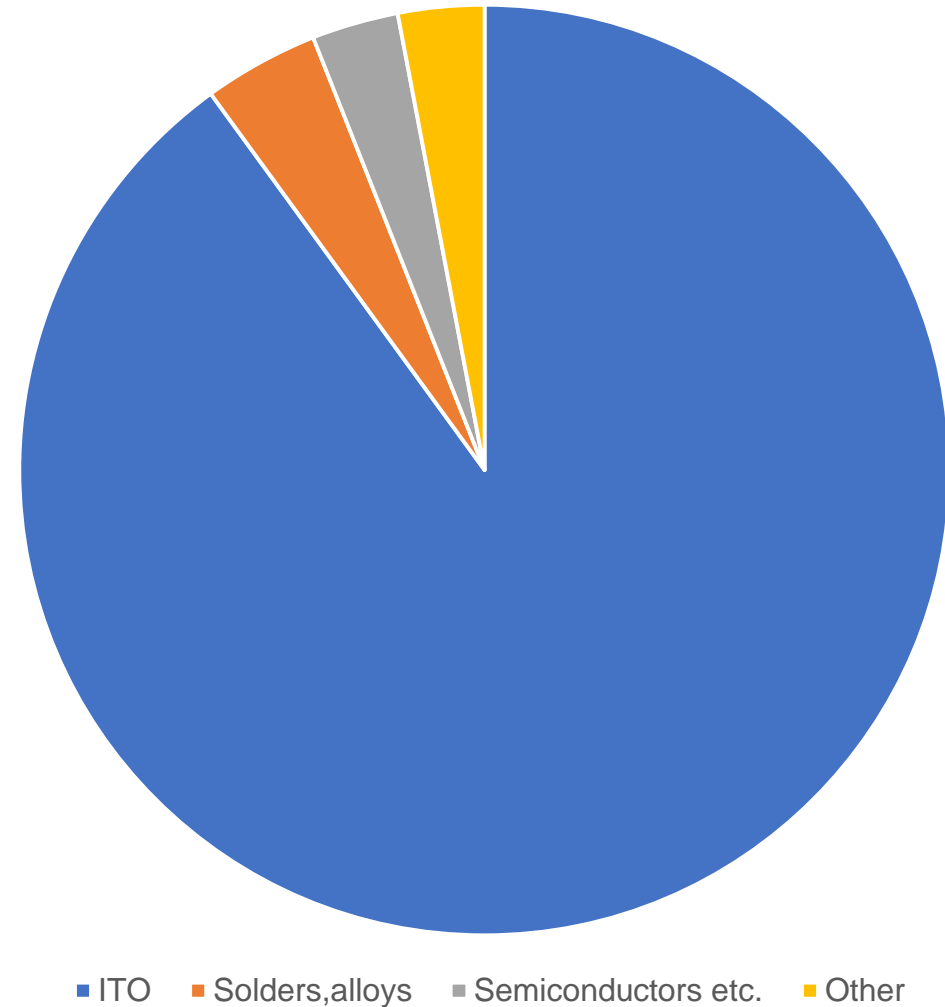
- $[\text{Kr}]4d^{10}5s^25p^1$
- Relativistic effects stabilize 5s orbital, and thus oxidation state +I is possible, though much rarer than +III
- Intermediate properties between other group 13 metals (gallium and thallium)
- 39 different known isotopes, the most common being In-115 (radioisotope)

| | |
|-------------------------------|--|
| Oxidation states | +I, +II, +III |
| Electronegativity | 1,78 |
| Atomic radius | 1,55 Å |
| Effective ionic radius (+III) | 0,80 Å |
| Main isotopes | In-115, In-113 (95.7% and 4.3% respectively) |
| Electron affinity | 28.9 kJ/mol ⁻¹ |

Main compounds

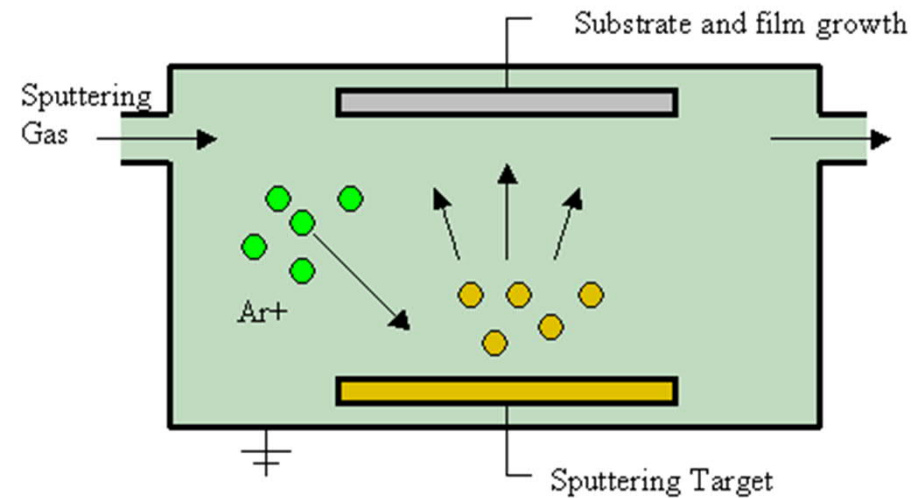
- Pure indium
 - *Solders, sealings, gaskets, thermal conductors*
- Indium tin oxide
 - *Degenerate semiconductor, optoelectronics*
- Indium phosphite
 - *Semiconductors, optics*
- Indium antimonide
 - *Narrow-gap semiconductor*

Indium end-uses



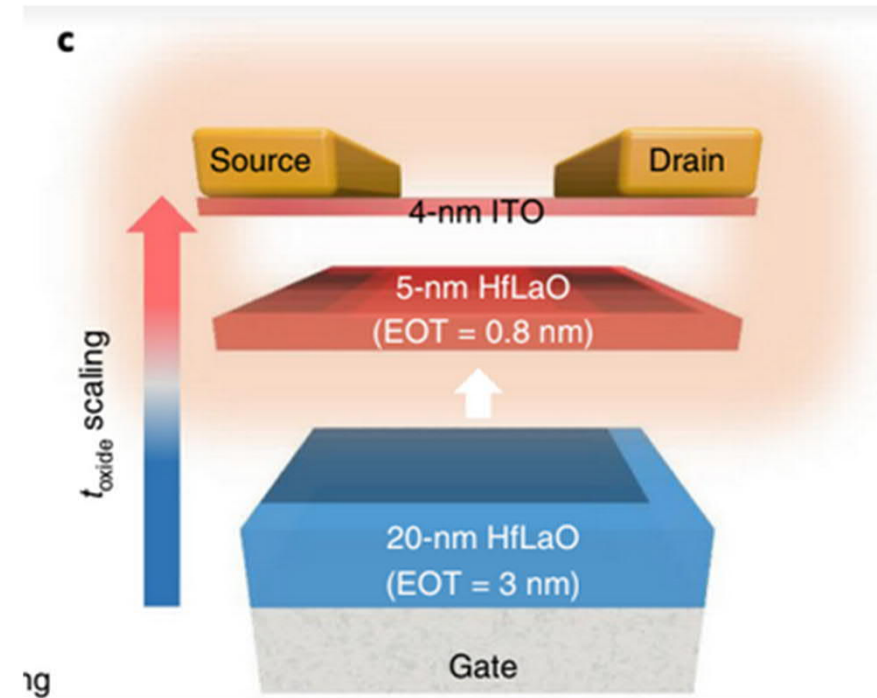
Indium tin oxide

- In_2O_3 doped with SnO_2
- Rare combination of transparency and conductivity: very commonly used in displays
- N-type semiconductor, band gap of 4 eV: tin oxide doping gives near metallic-like conductance
- Thin films easily made with physical vapor deposition methods



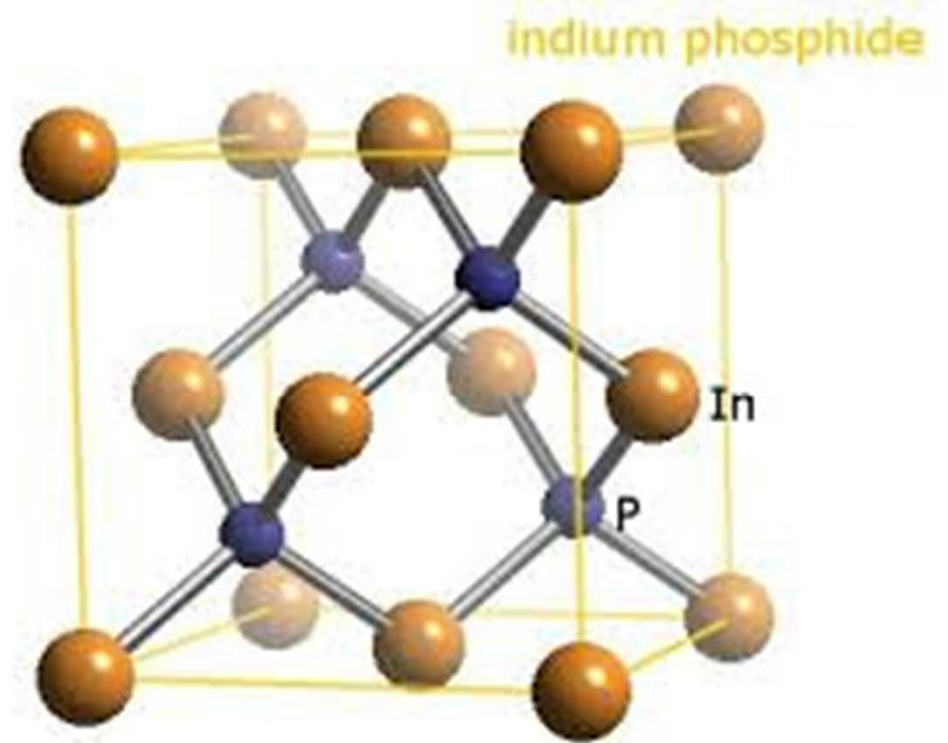
Indium tin oxide

- Jung et al (2019): Wearable electronics and sensors
- Li et al (2019): ultrathin ITO with HfLaO used to manufacture fast transistors
- High resistance to heat -> strain gauges, sensors etc for high temperature applications
- Coatings to reflect infrared radiation, defrosting



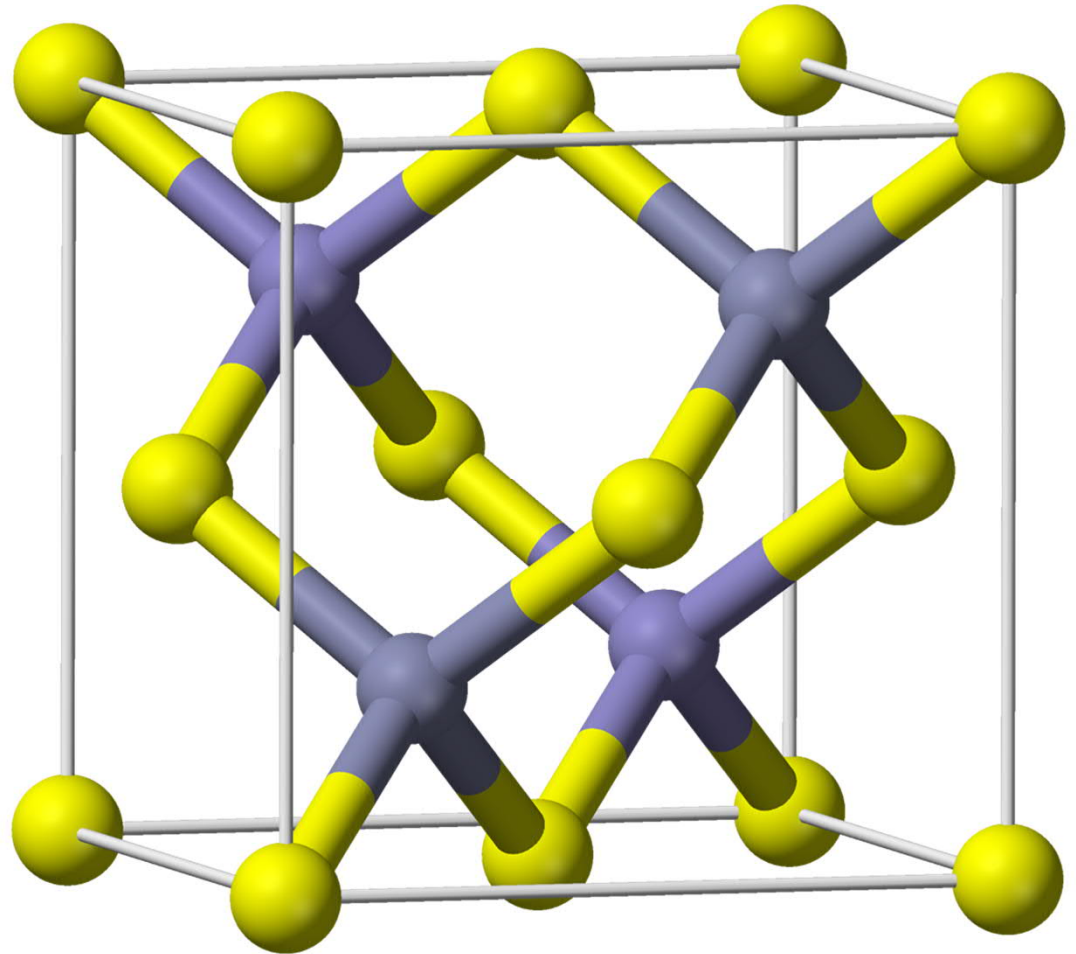
Indium phosphide

- Binary semiconductor, band gap of 1.344eV
- Direct bandgap
- Active and passive optical devices, communication devices due to emission range etc.
- Suitable for high-frequency electronics due to high electron velocity



Indium antimonide

- InSb, narrow gap semiconductor
- 0.17 eV (300 K), 0.23 eV (80K)
- Very high electron velocity, low thermal coefficient
- Low-power, high frequency transistors
- Thermal vision due to IR-range photovoltaics



Future prospects

- Bonaccorso et al (2010): Graphene replaces as a optoelectric material
- Increased use as high-performance semiconductor
- Very limited supply due to rarity and being a side product: price evolution
- Recycling increases from current >1% (USGS)

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