Cadmium telluride

From Wikipedia, the free encyclopedia
(Redirected from CdTe)

Cadmium telluride (CdTe) is a stable crystalline compound formed from cadmium and tellurium. It is used as an infrared optical window and a solar cell material. It is usually sandwiched with cadmium sulfide to form a p-n junction photovoltaic solar cell. Typically, CdTe photovoltaic cells use a n-i-p structure.

Cadmium telluride

Other names	Irtran-6
Identifiers	
CAS number	1306-25-8 ✓
PubChem	91501
ChemSpider	82622 ✓
RTECS number	EV3330000
Jmol-3D images	Image 1 (http://chemapps.stolaf.edu/jmol/jmol.php?model=%5BCd%5D%3D%5BTe%5D)
SMILES	
InChI	
Properties	
Molecular formula	CdTe
Molar mass	240.01 g mol^{-1}
Density	5.85 g·cm^{-3}[1]
Melting point	1041 °C [2]
Boiling point	1050 °C
Solubility in water	insoluble
Solubility in other solvents	insoluble
Band gap	1.44 eV (@300 K, direct)
Refractive index (n_D)	2.67 (@10 µm)
Structure	
Crystal structure	zincblende (cubic) (space group $F\bar{4}3m$
Hazards	
EU Index	048-001-00-5
EU classification	Harmful (**Xn**) Dangerous for the environment (**N**)
R-phrases	R20/21/22, R50/53
S-phrases	(S2), S60, S61
Related compounds	
Other anions	Cadmium oxide Cadmium sulfide Cadmium selenide
Other cations	Zinc telluride Mercury telluride

Contents

Applications

CdTe is used to make thin film solar cells, accounting for about 8% of all solar cells installed in 2011.[3] They are among the lowest-cost types of solar cell,[4] although a comparison of total installed cost depends on installation size and many other factors, and has changed rapidly from year to year. The CdTe solar cell market is dominated by First Solar. In 2011, around 2 GW_p of CdTe solar cells were produced;[3] For more details and discussion see cadmium telluride photovoltaics.

CdTe can be alloyed with mercury to make a versatile infrared detector material (HgCdTe). CdTe alloyed with a small amount of zinc makes an excellent solid-state X-ray and gamma ray detector (CdZnTe).

CdTe is used as an infrared optical material for optical windows and lenses and is proven to provide a good performance across a wide range of temperatures. [5] An early form of CdTe for IR use was marketed under the trademarked name of *Irtran-6* but this is obsolete.

CdTe is also applied for electro-optic modulators. It has the greatest electro-optic coefficient of the linear electro-optic effect among II-VI compound crystals ($r_{41}=r_{52}=r_{63}=6.8\times10^{-12}$ m/V).

CdTe doped with chlorine is used as a radiation detector for x-rays, gamma rays, beta particles and alpha particles. CdTe can operate at room temperature allowing the construction of compact detectors for a wide variety of applications in nuclear spectroscopy.[6] The properties that make CdTe superior for the realization of high performance gamma- and x-ray detectors are high atomic number, large bandgap and high electron mobility ~1100 cm^2/V·s, which result in high intrinsic μτ (mobility-lifetime) product and therefore high degree of charge collection and excellent spectral resolution.[7] Due to the poor charge transport properties of holes, ~100 cm^2/V·s, single-carrier-sensing detector geometries are used to produce high resolution spectroscopy; these include coplanar grids, frish-collar detectors and small pixel detectors.

Physical properties

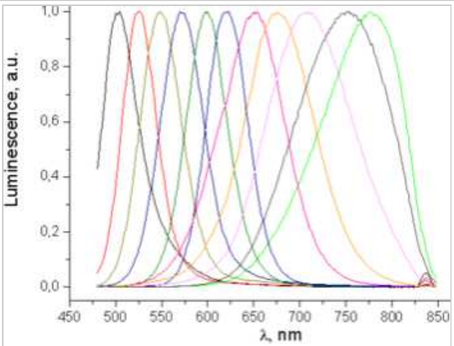
Except where noted otherwise, data are given for materials in their standard state (at 25 °C (77 °F), 100 kPa)
✓ (verify) (what is: ✓/✗?)
Infobox references

- Lattice constant: 0.648 nm at 300K
- Young's modulus: 52 GPa
- Poisson ratio: 0.41

Thermal properties

- Thermal conductivity: 6.2 $W \cdot m/m^2 \cdot K$ at 293 K
- Specific heat capacity: 210 J/kg·K at 293 K
- Thermal expansion coefficient: 5.9×10^{-6}/K at 293 K[8]

Optical and electronic properties



Fluorescence spectra of colloidal CdTe quantum dots of various sizes, increasing approximately from 2 to 20 nm from left to right. The blue shift of fluorescence is due to quantum confinement.

Bulk CdTe is transparent in the infrared, from close to its band gap energy (1.44 eV at 300 K,[9] which corresponds to infrared wavelength of about 860 nm) out to wavelengths greater than 20 µm; correspondingly, CdTe is fluorescent at 790 nm. When the size of CdTe crystal is being reduced to a few nanometers and below, thus making a CdTe quantum dot, the fluorescence peak shifts towards through the visible range to the ultraviolet.

Chemical properties

CdTe is insoluble in water. [10] CdTe has a high melting point of 1041°C with evaporation starting at 1050°C. [11] CdTe has a vapor pressure of zero at ambient temperatures. CdTe is more stable than its parent compounds cadmium and tellurium and most other Cd compounds, due to its high melting point and insolubility. [12]

Cadmium telluride is commercially available as a powder, or as crystals. It can be made into nanocrystals.

Toxicology Assessment

The compound CdTe has different qualities than the two elements, cadmium and tellurium, taken separately. Toxicity studies show that CdTe is less toxic than elemental cadmium. [13] CdTe has low acute inhalation, oral, and aquatic toxicity, and is negative in the Ames mutagenicity test. Based on notification of these results to the European Chemicals Agency (ECHA), CdTe is no longer classified as harmful if ingested nor harmful in contact with skin, and the toxicity classification to aquatic life has been reduced. [14] Once properly and securely captured and encapsulated, CdTe used in manufacturing processes may be rendered harmless. Current CdTe modules pass the U.S. EPA's Toxicity Characteristic Leaching Procedure (TCLP) test, designed to assess the potential for long-term leaching of products disposed in landfills. [15]

A document hosted by the U.S. National Institutes of Health[16] dated 2003 discloses that:

> Brookhaven National Laboratory (BNL) and the U.S. Department of Energy (DOE) are nominating Cadmium Telluride (CdTe) for inclusion in the National Toxicology Program (NTP). This nomination is strongly supported by the National Renewable Energy Laboratory (NREL) and First Solar Inc. The material has the potential for widespread applications in photovoltaic energy generation that will involve extensive human interfaces. Hence, we consider that a definitive toxicological study of the effects of long-term exposure to CdTe is a necessity.

Researchers from the U.S. Department of Energy's Brookhaven National Laboratory have found that large-scale use of CdTe PV modules does not present any risks to health and the environment, and recycling the modules at the end of their useful life completely resolves any environmental concerns. During their operation, these modules do not produce any pollutants, and, furthermore, by displacing fossil fuels, they offer great environmental benefits. CdTe PV modules that use cadmium as a raw material appear to be more environmentally friendly than all other current uses of Cd.[17] CdTe PV provides a sustainable solution to a potential oversupply of cadmium in the near future.[18] Cadmium is generated as a waste by-product of zinc refining and is generated in substantial amounts regardless of its use in PV, due to the demand for steel products.[19]

Availability

At the present time, the price of the raw materials cadmium and tellurium are a negligible proportion of the cost of CdTe solar cells and other CdTe devices. However, tellurium is a relatively rare element (1–5 parts per billion in the Earth's crust; see Abundances of the elements (data page)). Through improved material efficiency and increased PV recycling systems, the CdTe PV industry has the potential to fully rely on tellurium from recycled end-of-life modules by 2038.[20] See Cadmium telluride photovoltaics for more information.

See also

- Cadmium selenide
- Cadmium telluride photovoltaics
- Cadmium zinc telluride
- First Solar
- Mercury telluride
- Mercury(II) cadmium(II) telluride
- Zinc telluride

References

1. ^ Peter Capper (1994). *Properties of Narrow Gap Cadmium-Based Compounds* (http://books.google.com/books?id=WAhC3hGYQ7UC&pg=PA39). IET. pp. 39–. ISBN 978-0-85296-880-2. Retrieved 1 June 2012.
2. ^ "Nomination of Cadmium Telluride to the National Toxicology Program" (http://ntp-server.niehs.nih.gov/ntp/htdocs/Chem_Background/ExSumPdf/CdTe_508.pdf). United States Department of Health and Human Services. Retrieved 11 April 2003.
3. ^ ***a b*** "Photovoltaics report" (http://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report.pdf).
4. ^ *Chalcogenide Photovoltaics: Physics, Technologies, and Thin Film Devices* by Scheer and Schock, page 6. Link (subscription required) (http://onlinelibrary.wiley.com/doi/10.1002/9783527633708.ch1/pdf). "Nowadays, CdTe modules are produced on the GWp/year level and currently are the cost leader in the photovoltaic industry."
5. ^ "Cadmium Telluride" (http://www.reading.ac.uk/infrared/library/infraredmaterials).
6. ^ P. Capper (1994). *Properties of Narrow-Gap Cadmium-Based Compounds*. London, UK: INSPEC, IEE. ISBN 0-85296-880-9.
7. ^ "Characterization of M-π-n CdTe pixel detectors coupled to HEXITEC readout chip" (http://dx.doi.org/10.1088/1748-0221/7/01/C01035). IOP Journal of Instrumentation.
8. ^ Palmer, D W (March 2008). "Properties of II-VI Compound Semiconductors" (http://www.semiconductors.co.uk/propiivi5410.htm). Semiconductors-Information.
9. ^ Bube, R. H. (1955). "Temperature dependence of the width of the band gap in several photoconductors". *Physical Review* **98**: 431–3. doi:10.1103/PhysRev.98.431 (http://dx.doi.org/10.1103%2FPhysRev.98.431).
10. ^ Solubility is below 0.1mg/l which equals a classification as insoluble-reference, "ECHA Substance Registration"[1] (http://apps.echa.europa.eu/registered/data/dossiers/DISS-dffb4072-e283-47ae-e044-00144f67d031/DISS-dffb4072-e283-47ae-e044-00144f67d031_DISS-dffb4072-e283-47ae-e044-00144f67d031.html)
11. ^ "Cadmium Telluride" (http://apps.echa.europa.eu/registered/data/dossiers/DISS-dffb4072-e283-47ae-e044-00144f67d031/DISS-dffb4072-e283-47ae-e044-00144f67d031_DISS-dffb4072-e283-47ae-e044-00144f67d031.html).
12. ^ S. Kaczmar (2011). "Evaluating the read-across approach on CdTe toxicity for CdTe photovoltaics" (ftp://ftp.co.imperial.ca.us/icpds/eir/campo-verde-solar/final/evaluating-toxicity.pdf) (pdf).
13. ^ S. Kaczmar (2011). "Evaluating the read-across approach on CdTe toxicity for CdTe photovoltaics" (ftp://ftp.co.imperial.ca.us/icpds/eir/campo-verde-solar/final/evaluating-toxicity.pdf).
14. ^ "Scientific Comment of Fraunhofer to Life Cycle Assessement of CdTe Photovoltaics" (http://www.csp.fraunhofer.de/presse-und-veranstaltungen/details/id/47/). Fraunhofer Center for Silicon Photovoltaics CSP.
15. ^ V. Fthenakis and K. Zweibel (2003). "CdTe PV: Real and Perceived EHS Risks" (http://www.nrel.gov/docs/fy03osti/33561.pdf) (PDF). National Renewable Energy Laboratory.
16. ^ "Nomination of Cadmium Telluride to the National Toxicology Program" (http://ntp-server.niehs.nih.gov/ntp/htdocs/Chem_Background/ExSumPdf/CdTe_508.pdf) (PDF). United States Department of Health and Human Services. 2003-04-11.
17. ^ Fthenakis, V. M. (2004). "Life Cycle Impact Analysis of Cadmium in CdTe PV Production". *Renewable & Sustainable Energy Reviews* **8** (4): 303-334.
18. ^ Dr. Y. Matsuno and Dr. Hiroki Hondo (2012). "Scientific Review on the Environmental and Health Safety (EHS) aspects of CdTe photovoltaic (PV) systems over their entire life cycle" (http://park.itc.u-tokyo.ac.jp/matsuno/files/FS%20Review%20Report%20English.pdf).
19. ^ V. Fthenakis and K. Zweibel (2003). "CdTe PV: Real and Perceived EHS Risks" (http://www.nrel.gov/docs/fy03osti/33561.pdf) (PDF). National Renewable Energy Laboratory.
20. ^ M. Marwede and A. Reller (2012). "Future recycling flows of tellurium from cadmium telluride photovoltaic waste" (http://www.sciencedirect.com/science/article/pii/S0921344912001644). *Resources, Conservation and Recycling* **69**: 35–49. doi:10.1016/j.resconrec.2012.09.003 (http://dx.doi.org/10.1016%2Fj.resconrec.2012.09.003). PMID 19636069 (https://www.ncbi.nlm.nih.gov/pubmed/19636069).

External links

- CdTe page on the web-site of the Institute of Solid State Physics of the Russian Academy of Sciences (html) (http://www.sttic.com.ru/lpcbc/DANDP/cdte_adv.html)
- Optical properties (http://www.reading.ac.uk/infrared/library/infraredmaterials/ir-infraredmaterials-cdte.asp) University of Reading, Infrared Multilayer Laboratory
- CdTe: single crystals, grown by HPVB and HPVZM techniques; windows, substrates, electrooptical modulators. Infrared transmittance spectrum. MSDS. (http://www.sttic.com.ru/lpcbc/DANDP/cdte_adv.html)
- National Pollutant Inventory – Cadmium and compounds (http://www.npi.gov.au/database/substance-info/profiles/17.html)
- MSDS at ISP optics.com (http://www.ispoptics.com/new_webpage/MSDS%20CdTe.doc) (doc)
- MDSD at espimetals.com (http://www.espimetals.com/msds's/cadmiumtelluride.pdf) (pdf)
- Material Safety data Sheet (http://www.ispoptics.com/new_webpage/MSDS%20CdTe.doc) on isp optics web site (MS Word doc)