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PROPERTIES OF THE MOST IMPORTANT SEMICONDUCTORS

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ABSTRACT: The article examines the properties of semiconductors, the history of the creation of semiconductors and the semiconductors widely used in the field of technology are covered in detail.

KEYWORDS: silicon (Si), germanium (Ge), gallium phosphide (GAP), gallium arsenide (GAAS), indium phosphide (INP), indium arsenide (INAS), indium antimonide (INSB).

INTRODUCTION

In human history, the 20th and 21st centuries have been called the age of electronics - microelectronics and nano-electronics. 2021 marks the 74th anniversary of the discovery of the first transistor by Shockley, D. Barden and W. Brettein (December 23, 1947), that is, the era of solid-state electronics began. This is a very small period for history.

Although the science of electronics, which was been formed and developed very quickly during this period, opened not only the way to space for mankind, but also unimaginable high-speed computing machines, completely new information systems, the most accurate and reliable diagnostic devices, not only enables the creation of compact, high-capacity electronic devices, but also radically improves the economy, military power, people's living standards, and employment conditions of the countries that pay attention to this field made it possible to solve environmental problems and continues to do so.

MAIN PART

Silicon (Si) - The most widely used substance in the production of semiconductor devices and systems is silicon. It ranks 14th in the periodic system of elements. Atomic weight is 28, its largest valency is 4, melting temperature (at normal pressure) is 1414 ^{0}C, density of solid silicon is 2.23$g/$□□3, dielectric permittivity e=11.7 is diamagnetic.

At room temperature, silicon is chemically stable, insoluble in water, resistant to many acids. Nevertheless, it dissolves well in a mixture of nitric and hydrofluoric acids:

$$3Si+4HNO_3+18HF=3H_2SiF_6+4NO+8H_2O$$

Alkaline abrasives are used to clean the surface of silicon. For polishing, abrasives based on the above mixture are used.

Silica in alkaline solutions:

$$Si+2KOH+H_2O=K_2SiO_3+2H_2$$

According to the reaction, it dissolves well.

Silicon remains stable when heated in air up to 900 ^oC. However, it oxidizes at higher temperatures. Silicon directly reacts with hydrogen at a temperature of about 2000 ^oC, Si_nH_{2n+2} silanes are formed. Nitrogen reacts with silicon at 1100^0C-1300^0Cda to form nitrites. Silicon reacts easily with halogens: with fluorine at room temperature at 200^0C-500^0C with chlorine, with iodine at 700^0C-750^0C.

Liquefied silicon will have high activity. The best material for growing silicon nanocrystals is synthetic quartz-SiO_2.

Electrical properties. It is known that the electrical conductivity of semiconductors is described by the expression$\sigma = (n\mu_n + \rho u_p)$. In the n-type semiconductor, the conductivity $\sigma = e\, n\mu_n$ should be equal to (at the temperature at which the input is fully ionized) the density of electrons is n, and the density of the donor input should be equal to N, that is, N_d. This equality is maintained up to a certain number of inputs. Nevertheless, this equality does not hold when the input density is high enough ($n<N$).

This phenomenon is called "polytropy of alloying elements". The reason for this is that a sufficiently large amount of charge introduced into the semiconductor can be in different states. For example, atoms of the input semiconductor or defects in its structure form connections, are located between nodes, etc. it can. In one of these cases, the input may be electrically active in the crystal, in others, it may be in a neutral state. The stability of the alloying elements at which the phenomenon of polytropy starts to occur is called the threshold stability.

At higher concentrations, the semiconductor becomes a strong alloying agent. Electron (E) single crystals of silicon (K) are alloyed with phosphorus (F), hollow type is alloyed with boron (B). Therefore, they are designated as KEF or KDB. Silicon is obtained by reducing trichlorosilane with hydrogen:

$$SiHCl_3+H_2 \rightarrow Si+3HCl.$$

GERMANIUM (GE) - It ranks 32nd in the periodic system of elements, atomic weight is 72.5, greatest valence is 4, melting point is 936 ^oC, density is 5.3 g/sm^3, dielectric strength is 16, it is diamagnetic. Germanium is chemically stable at room temperature. It is almost insoluble in water. Nitrogen with a density of 2-3 mol/liter is readily soluble in an acid solution, but when the acid density increases, a film of GeO_2 oxide forms on the surface, and the solubility decreases greatly. At

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room temperature, germanium is actively dissolved by horn vodka (HF), hydrogen H_2O_2 oxide and oxidizing agents.

If it is heated above 700° in air, germanium is oxidized, and at this temperature, it is also oxidized by carbon monoxide. GeO oxide is a black powder that can be easily driven above 700°. Above 1000°, germanium reacts with hydrogen to form GeO_2H_{2n+2} compounds. Nevertheless, it does not interact with nitrogen. Liquid germanium does not react with either carbon (C) or silicon oxide ((SiO_2)) at temperatures up to 1500° C. Due to this property, germanium can be stored in graphite and quartz vessels. The electrical properties of germanium are similar to those of silicon in many respects because they are group IV elements. Germanium IV oxide is usually obtained by hydrolyzing purified tetrachloride in water.

$$\text{Gelu}+2H_2\text{O}\rightarrow GeO_2+4\text{HCL}$$

By reducing GeO_2IV oxide with pure hydrogen, elemental germanium is obtained:

$$GeO_2+2H_2 \rightarrow \text{Ge}+2H_2\text{O}$$

GALLIUM PHOSPHIDE (GaP) - Gallium phosphide has a high chemical stability: it does not react with oxygen in the air up to 700°C-800°C: it is stable against many oxygen and alkaline solutions. The rate of dissolution of gallium phosphide in nitric acid (at room temperature) is 0.16mg/sm^2 hours, in a boiling (1:3) mixture of nitric and hydrochloric acids, it is 7.8mg/sm^2 hours. When hydrogen peroxide is added to the acid mixture, the solubility of GaP increases dramatically. When gallium phosphide dissolves in acids, the highly toxic phosphine PH_3 is released. Other $A^{III}B^{IV}$ compounds also react with acids in the same way.

GaAs and InAs-asrin AsH_3 ; release toxic substances consisting of InP-phosphine PH_3 and INSb-stibine SbH_3. Liquid GaP reacts actively with all container substances, because its melting temperature is -1500°C. Top-pure graphite for synthesizing polycrystalline GaP. Quartz serves as a container for monocrystalline GaP growth. In semiconductor $A^{III}B^{IV}$ compounds (GaAs, GaP...), elements of group II are acceptors; elements of group IV are donors.

If atoms of IV group elements are located instead of gallium atoms, they act as donors, if phosphorus is located instead of axenium, they act as acceptors. Unalloyed GaP has electronic type conductivity, where n>1*10^{17} sm^{-3} and μ<120sm^2/vs. In GaP crystals doped with Te and S, the main charge carriers-electrons-stability (1,25:40) $10^{17}sm^{-3}$, mobility (110-60) sm^2/vs. Cavity type GaP has a mobility of 20sm^2/vs. The resistivity of basic GaP is more than 10^6 Om cm.

GALLIUM ARSENIDE (GaAs) - Gallium arsenide does not react with water, actively reacts with acids and produces toxic AsH_3 arsine. The solubility of gallium arsenide is much greater in a mixture of acids. Its solubility in a hydrochloric acid solution is $2 * 10^{-5}mg/sm^2$ hours, in an aqueous mixture of hydrochloric and nitric acids (1:1:1) - 60 *mg/sm² hours*, in an aqueous solution

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of nitric and hydrofluoric acids - 1200. When heated to 300^{o}C, GaAs does not oxidize, from 300^{o}C it decomposes and releases arsenic.

Liquid GaAs is very active. Synthetic quartz (SiO_2) is most often used in GaAs technology. Density of GaAs is 5.2 g/sm^3, melting temperature is 1238^{0}C. Unalloyed GaAs single crystals have n-type conductivity, where n< $6.10^6 sm^{-3}$ and mobility μ> $4200sm^3$/vc (300K) n-GaAs single crystal is doped with Zn. In most cases, when GaAs (semi-insulating) single crystals are alloyed with chromium Cr, their specific resistance is from $1 * 10^5$ to $1 * 10^7$ ohm cm. GaAs crystals are grown in [111] and [100] directions.

INDIA PHOSPHIDE (INP) - InP is insoluble in water. Its best solvent is hydrochloric acid, and as the acid concentration increases, the dissolution rate of InP increases, but it also releases PH_3 toxic phosphine. Stability $4.8 g/sm^3$, melting temperature 1058^{o}C. When heated up to 300^{0}C, InP does not oxidize, at higher temperatures it decomposes and releases phosphorus. Liquid InP interacts poorly with quartz, so synthetic quartz is used in InP growth devices.

In unalloyed InP crystals, the density of charge carriers does not exceed $5 * 10^{16}\ sm^{-3}$, and the mobility does not exceed $3000\ sm^2$/vc. n - InP single crystals are alloyed with Te and Sn. They have n = (5:500) $10^{16}\ sm^{-3}$;μ_n= (2500:1000) sm^2/vc. P = (5:8) * $10^{17}\ sm^{-3}$. in p-LnP doped with zinc. Semi-insulating LnP single crystals are alloyed with iron (Fe). Them $p > 1 * 107$□□*□□.

INDIUM ARSENIDE (InAs) - InAs is insoluble in water, the rate of corrosion in hydrochloric acid at +750C is $300 mg/(cm^2 hours)$. If nitric acid is added, this rate increases. When InAs dissolves in acids, toxic AsH_3 arsine is released. Above 450^{o}C, InAs oxidizes in air. In vacuum, near and above 7000C, InAs decomposes, releasing arsenic. Stability $5.67 g/sm^3$, melting temperature 942^{0}C. In undoped indium arsenide single crystals, the stability (3:5) $10^{16} sm^{-3}$ and mobility (3:4) $10^4 sm^2$ of the main charge carriers /vs (at 77 K). InAs single crystals doped with Te and Sn have p-type conductivity, n = (1. 10^{16} : 8 * 10^{19}) sm^{-3} (at 77K). InAs crystals are grown in the [111] direction.

INDIUM ANTIMONIDE (InSb) - InSb is insoluble in water, it is easily digested by acids: the rate of digestion in nitric acid is $360 mg/(cm^2 min)$, in a HNO_3; HF; H_2O =1:1:1 mixture - 480 $mg/(cm^2 min)$, etc. When InSb dissolves in SbH_3 acids, toxic stibin is released. Density of InSb is 5.78 gr/sm^3, melting temperature is 525^{0}C. Oxidation of InSb in air starts above 525^{0}C.

Unalloyed or alloyed with Ge, Zn or Mn InSb single crystals have p-type conductivity: $p = (1 * 10^{12}$: $1 * 10^{18}) m^{-3}$, $p \approx 500 m.\ sm$ $\mu = (3:5) 10^3 sm^2$/vs (77K). Tellurium- doped InSb <Te> single crystals have n-type conductivity: $n = (8 * 10^{13}$: $5 * 10^{18}) m^{-3}$, p ≈ $500 m\ sm$, $\mu = (7:8)\ 10^5 sm^2$/vs (77K). Indium antimonide InSb single crystals are grown in (211) crystallographic direction.

CONCLUSION

In conclusion, it can be noted that the concentration of electrons in semiconductors is low (much less compared to metals) and it depends on external factors. Under the influence of an external electric field, free electrons move and create electronic conductivity (N-conductivity). Under the influence of an external electric field, the holes move in the direction of the field. The displacement of these holes is equivalent to a current of positive charges equal in magnitude to the charge of electrons. This process is called hole conduction (R-conduction). Thus, the conductivity of semiconductors consists of the sum of electronic conductivity and hole conductivity.

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