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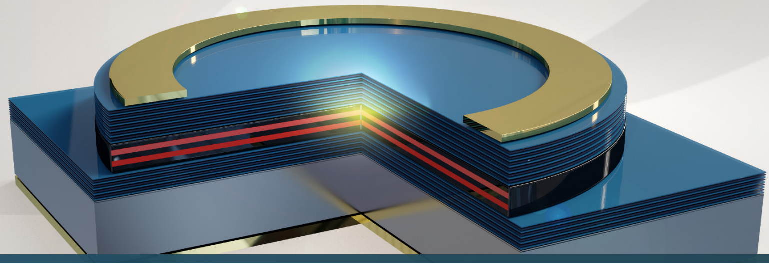

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Factsheet 2: Properties of Germanium

Germanium is a crucial material in the field of photonics due to its unique optical and electrical properties. These properties make germanium highly suitable for a range of photonic applications, from telecommunications to sensing. But what is behind germanium and what makes it such an enrichment for the photonics industry? We discuss this topic in this factsheet edition.

Chemical properties

Oxidation States: The oxidation state of an atom is a measure of the degree of oxidation or reduction of that atom. It represents the hypothetical charge that an atom would have if all bonds to atoms of different elements were fully ionic. Understanding the oxidation states of germanium is crucial for its applications in chemistry and materials science, particularly in the design and synthesis of new compounds and materials. Germanium typically exhibits two main oxidation states: +2 and +4. The +4 oxidation state is the most stable and common in germanium compounds. In its +4 oxidation state, germanium forms covalent compounds resembling those of silicon and tin.

Bonding Characteristics: Germanium, as a metalloid, exhibits bonding characteristics that share similarities with both metals and non-metals. In its elemental form, germanium has a metallic crystal structure (diamond cubic), which is characteristic of covalent bonding but with some delocalization of electrons, giving it metalloid properties. It typically forms tetrahedral structures due to its electron configuration, resembling the bonding characteristics of silicon. Its bonding characteristics allow it to act as a semiconductor, essential for various electronic and optical applications.

Optical Properties

High Refractive Index: Germanium has a high refractive index (~4 in the infrared spectrum), which is significantly higher than many other materials. This high refractive index allows for effective light confinement and guiding in optical waveguides and fibres. The ability to confine light efficiently is critical for developing high-performance photonic devices.

Absorption Coefficients: Germanium has strong absorption in the near-infrared (IR) region, particularly around the 1550 nm wavelength, which is the standard for optical communication. The high absorption coefficient in this range makes germanium an excellent material for photodetectors and other sensing applications. Also, the broad transmission range makes it useful for IR optics and detectors in applications such as thermal imaging and spectroscopy.

Optical Bandgap: Germanium has an indirect bandgap of approximately 0.66 eV (electron Volt). While indirect bandgaps are generally less efficient for light emission compared to direct bandgaps, germanium's bandgap is suitable for photodetection in the near-IR range. The smaller bandgap allows germanium to detect longer wavelengths.

Electrical Properties

High Electron and Hole Mobility: Germanium exhibits high electron mobility (~3900 $cm^2/V{\cdot}s$) and hole mobility (~1900 $cm^2/V{\cdot}s$). High carrier mobility is beneficial for high-speed electronic and photonic devices, enabling faster response times and higher performance in applications such as modulators and photodetectors.

n-type and p-type Doping: Germanium can be easily doped to form both n-type and p-type semiconductors. This versatility allows for the creation of various photonic devices, including diodes, transistors, and integrated photonic circuits.

Good Thermal Conductivity: Germanium has a thermal conductivity of about 60 W/m·K at room temperature, which is beneficial for dissipating heat in high-power photonic devices. This property helps maintain device performance and reliability over extended periods of operation

Advantages of Germanium in Photonics

Germanium's unique combination of high refractive index, strong near-infrared absorption, and excellent carrier mobility positions it as an invaluable material in photonics. As technological advancements continue to push the boundaries of photonic applications, germanium's intrinsic properties and advantages will play a crucial role in driving innovation and enhancing the performance and efficiency of photonic devices:

- Germanium can be integrated with silicon technology, leveraging existing semiconductor fabrication processes. This compatibility enables the development of hybrid photonics platforms, combining the strengths of both materials for enhanced performance and cost efficiency.
- Germanium is considered a more environmentally friendly solution compared to some other semiconductor materials. Its production and use have less environmental impact, supporting sustainable development in photonics technology.
- Germanium-based photonic devices exhibit better uniformity and lower defect density, leading to more reliable and high-performance components. Improved material quality translates to enhanced device performance and longevity.

Did you know?

- Germanium was discovered by Clemens Winkler in 1886.
- It is named after Germany, the discoverer's home country.
- Germanium was predicted by Dmitri Mendeleev in 1871 based on gaps he identified in the periodic table. He named the hypothetical element "eka-silicon" because he believed it would resemble silicon but be heavier.

Germanium's unique combination of optical and electrical properties makes it a valuable material for photonics. Its high refractive index, strong near-IR absorption, and high carrier mobility enable the development of efficient and high-performance photonic devices. The compatibility with silicon technology and its environmentally friendly nature further enhance germanium's appeal for a wide range of photonic applications. As research and technology continue to advance, germanium will play an increasingly important role in the future of photonics.

Physical properties of Germanium:

Symbol: Ge
Atomic Number: 32 Atomic Weight: 72,63
Element Category: Metalloid
Appearance: Shiny, hard, grayish-white Cristal
Structure: Diamond cubic

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