MEMS Fabrication & Design HW#2

Question)

1. What are the properties of Si and GaAs. What are the respective advantages and disadvantages of Si and GaAs?

2. What are their applications?

Answer)

1. Write a report on properties of Si/GaAs and advantages of Si/GaAs

① Si: Silicon is the chemical element that has the symbol Si and atomic number 14. A tetravalent metalloid, silicon is less reactive than its chemical analog carbon. As the eighth most common element in the universe by mass, silicon occasionally occurs as the pure free element in nature, but is more widely distributed in dusts, planetoids and planets as various forms of silicon dioxide (silica) or silicates. On Earth, silicon is the second most abundant element (after oxygen) in the crust making up 25.7% of the crust by mass.

Silicon has three major advantages over GaAs for integrated circuit manufacture. First, silicon is **abundant and cheap to process**. Si is highly abundant in the Earth's crust, in the form of silicate minerals. The economy of scale available to the silicon industry has also reduced the adoption of GaAs.

The second major advantage of Si is **the existence of silicon dioxide—one of the best insulators**. Silicon dioxide can easily be incorporated onto silicon circuits, and such layers are adherent to the underlying Si. GaAs does not form a stable adherent insulating layer.

The third, and perhaps most important, advantage of silicon is that it possesses a **much higher hole mobility**. This high mobility allows the fabrication of higher-speed P-channel field effect transistors, which are required for CMOS logic. Because they lack a fast CMOS structure, GaAs logic circuits have much higher power consumption, which has made them unable to compete with silicon logic circuits.

General	
Name, symbol, number	silicon, Si, 14
Chemical series	metalloids
Group, period, block	14, 3, p
Appearance	As broken ingot: crystalline with dark reflective bluish-tinged faces 

Standard atomic weight	28.0855(3) g·mol^{-1}
Electron configuration	[Ne] $3s^2$ $3p^2$
Electrons per shell	2, 8, 4
Physical properties	
Phase	solid
Density (near r.t.)	2.33 g·cm^{-3}
Liquid density at m.p.	2.57 g·cm^{-3}
Melting point	1687 K (1420 °C, 2577 °F)
Boiling point	3538 K (2355 °C, 5909 °F)
Heat of fusion	50.21 kJ·mol^{-1}
Heat of vaporization	359 kJ·mol^{-1}
Heat capacity	(25 °C) 19.789 J·mol^{-1}·K^{-1}

Vapor pressure

P/Pa	1	10	100	1 k	10 k	100 k
at *T*/K	1908	2102	2339	2636	3021	3537

Atomic properties	
Crystal structure	Diamond cubic
Oxidation states	4, 3 [1], 2 [2], 1 [3] (amphoteric oxide)
Electronegativity	1.90 (Pauling scale)
Ionization energies (more)	1st: 786.5 kJ·mol^{-1}
	2nd: 1577.1 kJ·mol^{-1}
	3rd: 3231.6 kJ·mol^{-1}
Atomic radius	117.6 pm
Atomic radius (calc.)	111 pm
Covalent radius	111 pm
Van der Waals radius	210 pm
Miscellaneous	

Magnetic ordering	Nonmagnetic
Thermal conductivity	(300 K) 149 W·m^{-1}·K^{-1}
Thermal expansion	(25 °C) 2.6 µm·m^{-1}·K^{-1}
Speed of sound (thin rod)	(20 °C) 8433 m/s
Young's modulus	150 GPa
Bulk modulus	100 GPa
Mohs hardness	7
CAS registry number	7440-21-3
Band gap energy at 300 K	1.12 eV
Selected isotopes	

Main article: Isotopes of silicon

iso	NA	half-life	DM	DE (MeV)	DP
^{28}Si	92.23%	^{28}Si is stable with 14 neutrons			
^{29}Si	4.67%	^{29}Si is stable with 15 neutrons			
^{30}Si	3.1%	^{30}Si is stable with 16 neutrons			
^{32}Si	syn	170 y	β^-	13.020	^{32}P

② GaAs: Gallium arsenide (GaAs) is a compound of two elements, gallium and arsenic. It is an important semiconductor and is used to make devices such as microwave frequency integrated circuits (ie, MMICs), infrared light-emitting diodes, laser diodes and solar cells. GaAs has some electronic properties which are superior to those of silicon. It has a **higher saturated electron velocity** and **higher electron mobility**, allowing transistors made from it to function at frequencies in excess of 250 GHz.

Also, GaAs devices generate **less noise** than silicon devices when operated at high frequencies. They can also be operated at **higher power levels** than the equivalent silicon device because they have higher breakdown voltages.

Another advantage of GaAs is that it has a **direct band gap**, which means that it can be used to emit light efficiently. Silicon has an indirect band gap and so is very poor at emitting light.

Due to its **high switching speed**, GaAs would seem to be ideal for computer applications, and for some time in the 1980s many thought that the microelectronics market would switch from silicon to GaAs. The first attempted changes were implemented by the supercomputer vendors Cray Computer Corporation, Convex, and Alliant in an attempt to stay ahead of the ever-improving CMOS microprocessor. Cray eventually built one GaAs-based machine in the early 1990s, the Cray-3, but the effort was not adequately capitalized, and the company filed for bankruptcy in 1995.

Gallium arsenide	
IUPAC name	Gallium arsenide
Identifiers	
CAS number	[1303-00-0]
SMILES	Ga#As
Properties	
Molecular formula	GaAs
Molar mass	144.645 g/mol
Appearance	Gray cubic crystals
Melting point	1238°C (1511 K)
Boiling point	°C (? K)
Solubility in water	< 0.1 g/100 ml (20°C)
Structure	
Crystal structure	Zinc Blende
Molecular shape	Linear
Hazards	
MSDS	External MSDS
Main hazards	Carcinogenic

2. Applications

① Si: Pure silicon is used to produce ultra-pure silicon wafers used in the semiconductor industry, in electronics and in photovoltaic applications. Ultra-pure silicon can be doped with other elements to adjust its electrical response by controlling the number and charge (positive or negative) of current carriers. Such control is necessary for transistors, solar cells, integrated circuits, microprocessors, semiconductor detectors and other semiconductor devices which are used in electronics and other high-tech applications. In Photonics, silicon can be used as a continuous wave Raman laser medium to produce coherent light, though it is ineffective as a light source. Hydrogenated amorphous silicon is used in the production of low-cost, large-area electronics in applications such as LCDs, and of large-area, low-cost thin-film solar cells.

② GaAs: There are some advantages like high resistivity, high electron mobility, high saturated drift velocity, wide direct band gap, operability over a wide temperature range, etc. These properties recommend GaAs circuitry in mobile phones, satellite communications, microwave point-to-point links, and some radar systems. It is used in the manufacture of Gunn diodes for generation of microwaves.

Another important application of GaAs is for high efficiency solar cells. GaAs solar cells took over from silicon as the cell type most commonly used for Photovoltaic arrays for satellite applications. Later, dual- and triple-junction solar cells based on GaAs with germanium and indium gallium phosphide layers were developed as the basis of a triple junction solar cell which held a record efficiency of over 32% and can operate also with light as concentrated as 2,000 suns. This kind of solar cell powers the rovers Spirit and Opportunity, which are exploring Mars' surface. Also many solar cars utilize GaAs in solar arrays.

Complex designs of AlxGa1-xAs-GaAs devices can be sensitive to infrared radiation (QWIP). GaAs diodes can be used for the detection of x-rays.