Department of information technology and media
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Sensor devices
2012-11-01

Written exam in Sensor Devices
Tentamen i Sensorkomponenter

Hjälpmedel: Miniräknare - *Aid*: Calculator

Basic part

1 What is the advantages using batch processing? (3 p)

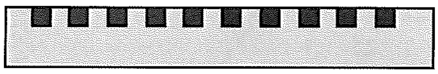
2 What are the two main functions of biosensor packaging? (3 p)

3 Why is silicon dioxide so important in fabrication of silicon detectors? (4 p)

4 You would like to measure ultra violet light with a wavelength of 0.2 um. The detector should also be "solar blind". What type of semiconductor can be used? Bandgap? Example of semiconductor? (4 p)

Calculation part

5 A grating is fabricated by deep etching of grooves in silicon. The silicon wafer is 300 µm thick and the etched groves are 50 µm deep. Two test samples are fabricated; in the first the grooves are filed with Gold (Au), in the other the grooves are filled with Indium (In).



Sketch of grooves viewed from the side.

To investigate the filling quality, X-ray microscopy images are taken of the two gratings using 20 keV monochrome radiation. The result are two "Zebra-like" images showing brighter and darker stripes.

Calculate the relative intensities for the darker and the brighter stripes in the two images. (Images are often normalized to the intensity value "one" when no object is applied.)

(7 p)

Radiation sensors

6.2.3 Interactions of Electromagnetic and Nuclear-Particle Radiation with Semiconductors

Electromagnetic radiation interacts with semiconductors primarily through absorption processes. However, interference, diffraction, reflection, polarization, transmission, and refraction all play a role relative to the electromagnetic radiation's propagation through the various media separating the semiconductor and the radiation source. Absorption is defined as the relative decrease of the irradiance, Φ, per unit path length, $\delta\Phi(x)/\Phi = \alpha\,\delta x$, which has the solution

$$\Phi(x) = \Phi_0 \exp(-\alpha x) \tag{6}$$

where Φ_0 is the incident irradiance, α is the absorption coefficient and x is a path-length variable. The absorbed photon density, $1-\Phi(x)$, reaches 63% of the incident value within one absorption length, $1/\alpha$. The total absorption coefficient is the sum of three mechanisms: the photoelectric effect, Compton scattering, and pair production. We shall consider these mechanisms in the following paragraphs.

The photoelectric effect dominates for low to moderate radiant energies, $h\nu < 50$ keV. Absorption by the photoelectric effect results in a complete transfer of the electromagnetic radiant energy from an incident photon to the interacting atom, which ejects a photoelectron. The minimum photon energy required is approximately equal to the semiconductor bandgap, for example the binding energy of a valence electron involved in an atomic bond. Photons with energy below this threshold may be absorbed by carriers already within the conduction band, which is called free-carrier absorption. However, the probability for this absorption mechanism is low in semiconductors because of small concentration of conduction-band electrons relative to the concentration in the valence band.

Absorption data

Material	Mass absorption coefficient (cm^2/g)		Density (g/cm^3)
	20 keV	50 keV	
Si	4.464	0.4385	2.3290
In	20.44	10.30	7.310
Au	78.83	7.256	19.32
Pb	86.36	8.041	11.35
CdTe	21.44	10.67	6.200
CsI	26.86	12.87	4.510

Table: Material data for calculation of α, the linear attenuation coefficient (cm^{-1})

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$\alpha_{Si} = 10,397 \ cm^{-1}$

$\alpha_{Au} = 1523,0 \ cm^{-1}$

$\alpha_{In} = 149,4 \ cm^{-1}$

$\phi_0 = 1$

$\alpha_{Si} x_{Si} = 10,397 \cdot 0,03 = 0,31190$

$\phi_{Si} = e^{-\alpha x} = e^{-0,31190} = 0,732$

Au:

$\alpha_{Au} \cdot x_{Au} = 1523,0 \cdot 0,005 = 7,615$

Remaining Si $\alpha_{Si} \, x_{rSi} = 10,397 \cdot 0,025 = 0,2599$

$\phi = e^{-\alpha_{Au} \cdot x_{Au}} \cdot e^{-\alpha_{Si} \cdot x_{rSi}} = e^{-(7,615 + 0,2599)} = 0,000380$

In:

$\alpha_{In} \cdot x_{In} = 149,4 \cdot 0,005 = 0,747$

Remaining Si, same as for Au 0,2599

$\phi = e^{-((\alpha x)_{In} + (\alpha x)_{Si})} = e^{-(0,747 + 0,2599)} = 0,365$

First image pattern

Only silicon : 0,732 intensity (white)

Au (gold) : 0,0004 intensity (black)

2:nd image pattern

Only silicon : 0,732 intensity (white)

In (indium) : 0,362 intensity (gray)