Tutorial Glossary

Absorptance

The absorptance or absorption quantum efficiency is a measure of performance of the detector. Absorptance is defined as: absorbed optical power by the detector, divided by the total optical power impinging on the detector. Usually monochromatic (one wavelength) radiation is assumed. In the literature it is common practice to present curves where the absorptance is plotted as a function of wavelength. This also provides information on the detector response versus wavelength (see also responsivity below).

Background Limited Infrared Photodetector (BLIP)

The current from an infrared detector may be subdivided into two parts: photocurrent and dark current. The photocurrent is the useful response of the detector, whereas the dark current is an undesired part.

Photocurrent results from absorption of infrared photons in the detector. These photons create charge carriers which can be collected as a photocurrent.

Dark current is by definition present even if the detector is not illuminated. The origin of dark current is usually thermal excitation of charge carriers, a process that competes with photo excitation. Due to the thermal origin dark current depends on the detector temperature. The most efficient way of getting rid of dark current is to cool down the detector to a temperature where the photocurrent becomes the dominant one. However, since cooling is expensive, during the detector design phase, every action should be taken to minimize dark current and maximize photocurrent.

When photocurrent dominates over dark current the detector is said to be background limited or BLIP (Background Limited Infrared Photodetector). The highest detector temperature at which this happens is called the BLIP temperature. Background here means the high temperature (not cooled) surroundings or scene (including imaged objects) within the detector field of view. The background scene emits infrared photons sensed by the detector giving rise to a photo current.

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- The detector operating characteristics do not depend on detector temperature
- The electronics used for amplifying and shaping the detector signal is easier to design, due to the absence of (useless) dark current using up considerable part of the dynamic range.

CMOS

CMOS is an acronym for complementary Metal Oxide Semiconductor, and is an integrated circuit (IC) technology basedon both p-channel and n-channel MOSFETs. MOSFET stands for Metal Oxide Semiconductor Field Effect Transistor. MOSFETs are used as switches in digital circuits and as the building blocks of e.g. amplifiers in analogue or mixed ICs (analogue and digital circuits combined). Digital CMOS has the capacity of low power dissipation. CMOS is extensively used for VLSI (Very Large Scale Integration) circuits.

Flip-chip bonding

Flip-chip bonding is a method of hybridizing two chips together, in a "face to face" or "surface to surface" fashion. Advantages are for example a very high (electrical) interconnect density resulting in compact design, and the interconnects may achieve low capacitance and inductance, of importance for high speed operation.

Flip-chip bonding is in common use when fabricating infrared detector arrays. Here the detector chip is often made of another material than silicon, e.g. gallium arsenide or mercury cadmium telluride. Since it is difficult to implement all necessary signal conditioning and multiplexing functions on chips based on non-silicon materials, all those functions are included on a separate readout chip, based on silicon CMOS or CCD (charge coupled device) technology.

Flip-chip bonding of detector arrays involves the processing of metal bumps onto contact holes, one per pixel, of both the detector chip and the ROIC. Using special equipment, the two chips are first aligned to each other. Then the chips are put in contact, while applying heat and/or mechanical force. During this process the two chips become electrically connected to each other via the metal bumps. Usually indium is used as bump material due to its excellent low temperature properties.

Grating

A grating is an optical device consisting of a periodic pattern of grooves, channels or cavities machined into a substrate. Diffraction gratings are used to diffract electromagnetic radiation.During diffraction the propagation angle of the radiation (compared with the incident radiation) will change. The diffraction angle changes with wavelength. If the periodic pattern is in one direction only the grating is a linear grating, if the periodicity is in two (usually orthogonal) directions, it is a two-dimensional grating.

Longitudinal optical (LO) phonons

Phonons are quanta of lattice vibrations. Longitudinal means that the atomic displacements have the same direction as the direction of propagation of the wave. Optical means that the frequency (or, equivalently, the energy) is of the same order of magnitude as the electromagnetic waves propagating in the lattice. Therefore, electromagnetic waves often couple to phonon modes. A typical characteristic of optical phonons is that the frequency (energy) is nearly independent on wavelength. Another type of phonon is the acoustic phonon which has lower frequency and propagates with the velocity of sound.

In III-V materials such as GaAs, InP, AlAs etc, the coupling between LO phonons and electrons is very strong. The mechanism is named the Fröhlich interaction, where the lattice displacements resulting from phonons create strong electric fields which in turn interact with the electrons and cause transitions between electron states. The electric field in turn depends on that the material is polar,i.e. cations (e.g. Ga in GaAs) and anions (e.g. As inGaAs) have different electronegativity (as defined for example by Pauling). A propagating optical phonon displace cations and anions relative to each other, which results in an electric field. This type of coupling is consequently absent in monatomic semiconductors such as silicon.

MOVPE

MOVPE stands for metal organic vapour phase epitaxy. MOVPE is a kind of gas phase epitaxy where highly reactive metal organic precursors are used as sources for the epitaxial material. At Acreo TMG (tri-methyl-gallium) and TMA (tri-methyl-aluminum) are used as the metal-organic gallium and aluminum sources, respectively. The gases arsine and silane are used as the arsenic and silicon (n-type dopant) source, respectively. The substrate wafer is placed onto a susceptor consisting of a block of graphite, typically heated to about 700 degrees C. The wafer can be rotated in order to average out growth rate non-uniformities. The growth takes place in a stream of hydrogen gas ata total pressure of 100 mbar. The source materials are introduced into the hydrogen gasby bubblers or direct injection in the gas.

Optical coupler

An optical coupler is a structure used for enhancing the absorption and detection of radiation in a detector. It may be based on a grating, in which case it is named grating coupler. Another common type of coupler is the prism coupler.

Quantum efficiency

Quantum efficiency (QE) is a measure of performance of the detector. It is defined as the number of charge carriers (or electron-hole pairs) generated per photon striking the detector. QE is in common use especially for photovoltaic devices.For photoconductive devices QE suffers from some ambiguity and needs to be clearly defined.

Quantum well

Quantum wells (QW) are the real world implementation of the particle in the box problem. The latter is a theoretical textbook problem covered by introductory texts on quantum mechanics. Quantum wells act as potential wells for charge carriers, and are usually experimentally realized by epitaxial growth of a sequence of ultra-thin layers consisting of semiconducting materials of varying composition. Since layer thicknesses are chosen to be comparable to the carrier de Broglie wavelengths in the material, energy quantization takes place. The quantum well material system most often used for making quantum wells is the aluminum gallium arsenide (AlGaAs) / gallium arsenide (GaAs) system. As a result of the larger bandgap of AlGaAs compared with GaAs (and the proper band offsets - the band energy difference between two materials), the carrier energy will be lower in GaAs than in AlGaAs, and carriers tend to collect in the GaAs layers. Typical thicknesses of the layers are in the range 1-10 nm.

Due to the requirement of extreme thickness and composition control only gas phase epitaxy can be used for growth. The two most common methods for growth of QW structures are metal organic vapor phase epitaxy (MOVPE) and molecular beam epitaxy (MBE). Acreo uses low pressure MOVPE for fabricating QWIP structures.

Readout integrated circuit (ROIC)

The electronic chip used to multiplex or read out the signals from the detector elements are usually simply called readout integrated circuit (ROIC) or (analogue) multiplexer. Usually this chip is based on silicon CMOS or CCD (charge coupled device) technology.

Surface micromachining

Surface macromachining is a processing technique used to fabricate freestanding microstructures such as thin membranes which are fastened to a substrate through a few points only. The process steps are (in brief):

1) a sacrificial layer is deposited on the (silicon) substrate,

2) windows are openened in the sacrificial layer,

3) the thin film used as membrane material is deposited and etched, and

4) selective etching of the sacrificial layer leaves a freestanding membrane.

III-V materials

Materials consisting of equal number of atoms from group III (boron, aluminum, gallium, indium, thallium) and group V (nitrogen, phosphorus, arsenic, antimony, bismuth) of the periodic table. The crystal structure is usually of the cubic zincblende or the hexagonal wurtzite type. Gallium arsenide is of the zincblende type