TEMARIO DEL CURSO DE FUNDAMENTOS DE DISPOSITIVOS ELECTRONICOS

1. Introducción a Física Electrónica

1.1 Propiedades de cristales y crecimiento de semiconductores

1.2 Átomos y electrones

1.3 Bandas de energía y portadores de carga en semiconductores

1.4 Exceso de portadores en semiconductores

2. Uniones

2.1 Fabricación de uniones p-n

2.2 Condiciones de equilibrio

2.3 Polarización de uniones en directa e inversa bajo condiciones de estado estacionario

2.4 Ruptura bajo polarización inversa

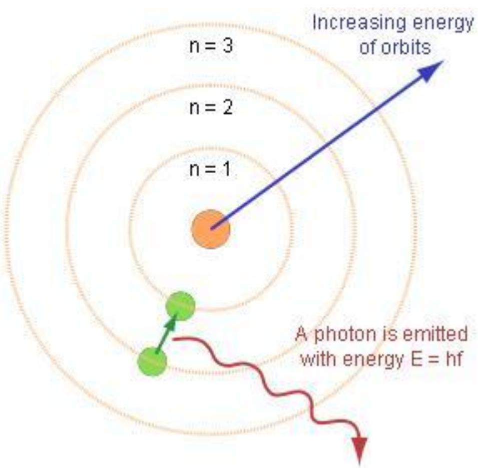
2.5 Condiciones de transitorio y a-c

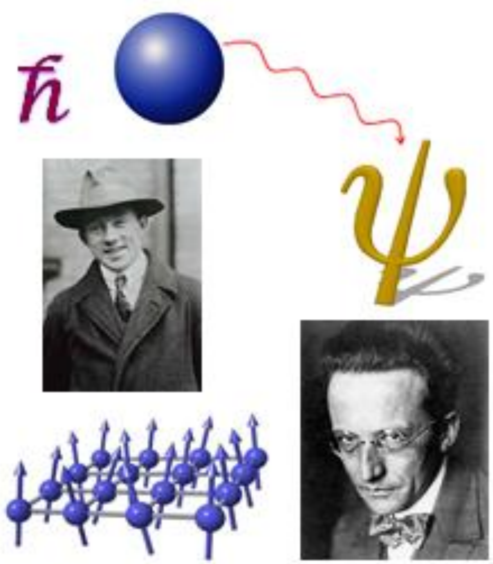
2.6 Desviaciones de la teoría sencilla

2.7 Uniones metal-semiconductor

Atomic structure

The behavior of solid state devices is directly related to atomic theory, quantum mechanics, and electron models.



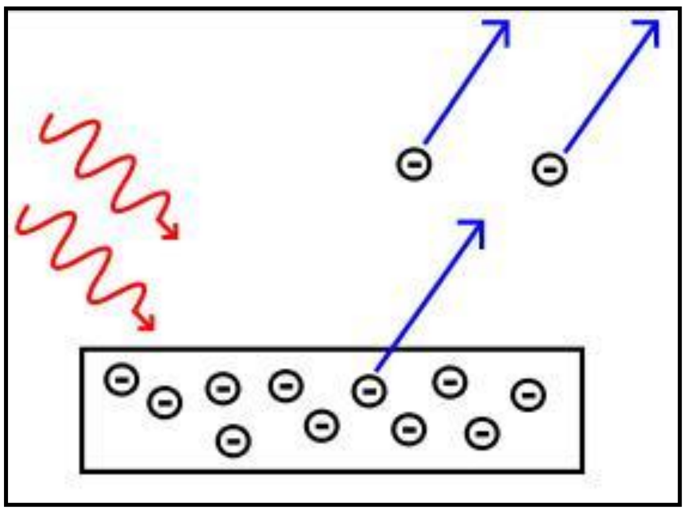


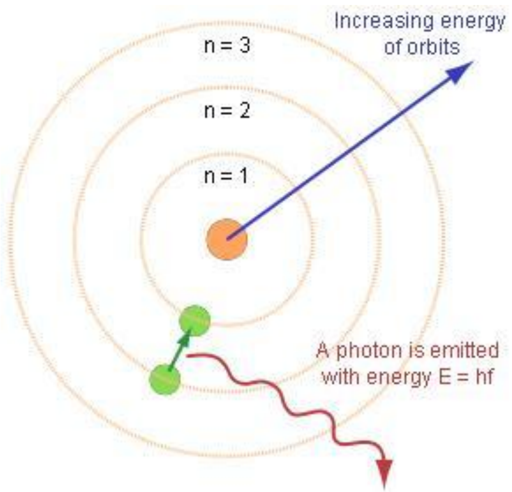
$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

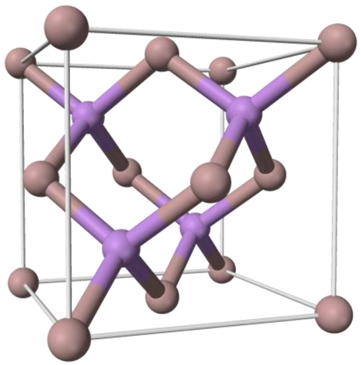
Without these concepts, it would be difficult to understand ***how an electron is transported through a semiconductor***.

Properties of electrons

- The *electronic structure of atoms*.
- The *interaction of atoms and electrons with excitation* (such as the absorption and emission of light).







GaAs

Eg= 1.43
Lattice= Z
a= 5.65

By studying electron energies in an atom, we lay the foundation for understanding ***the influence of the lattice on electrons participating in current flow through a solid***.

Detectores de Energía IR Desarrollados en INAOE (Térmicos)

Los **microbolómetros** son sensores que detectan radiación en el rango ~ **8 a 14 μm** a través del calentamiento del material con lo que su resistencia eléctrica cambia. Este cambio en la resistencia con temperatura se relaciona con un parámetro intrínsico de la película denominado **Coeficiente Térmico de Resistencia** (TCR α Ea).

Responsables Técnicos

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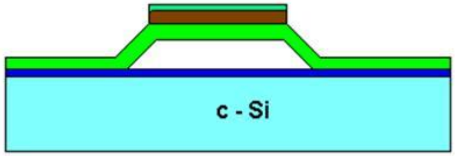
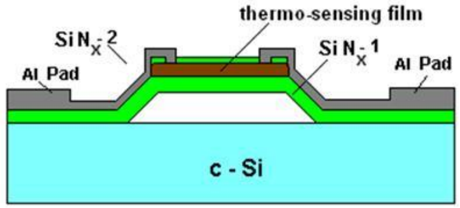
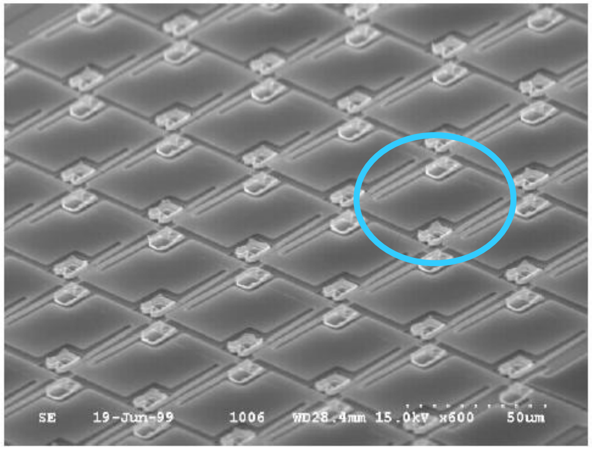
Películas principales para un microbolómetro:

A) Absorbedora de radiación IR.
B) Sensible a la temperatura (con alto TCR).
C) Membrana que provea de aislamiento térmico.

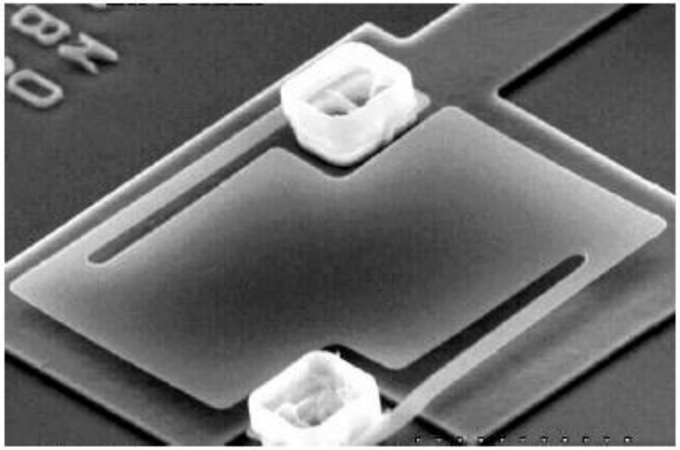
A diferencia de otro tipo de detectores IR, estos dispositivos operan a temperatura ambiente.





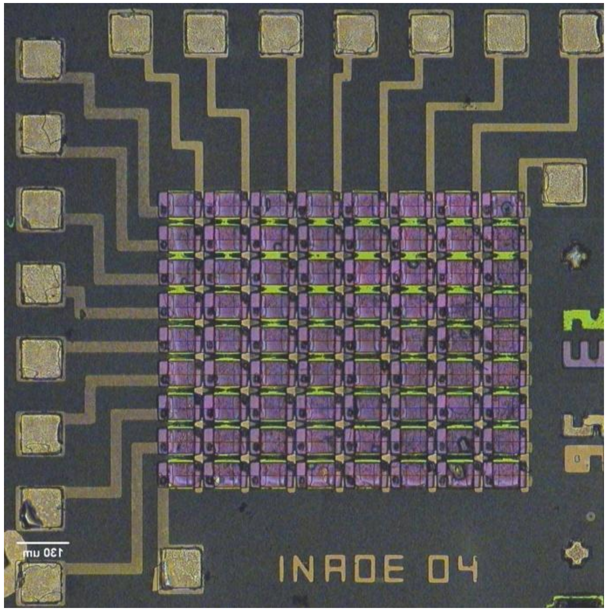


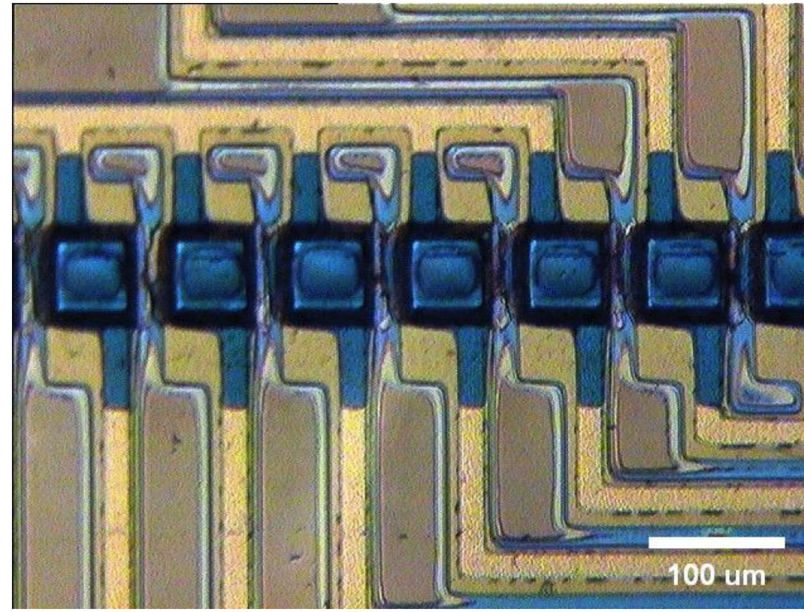
Arreglo 2D (Raytheon).

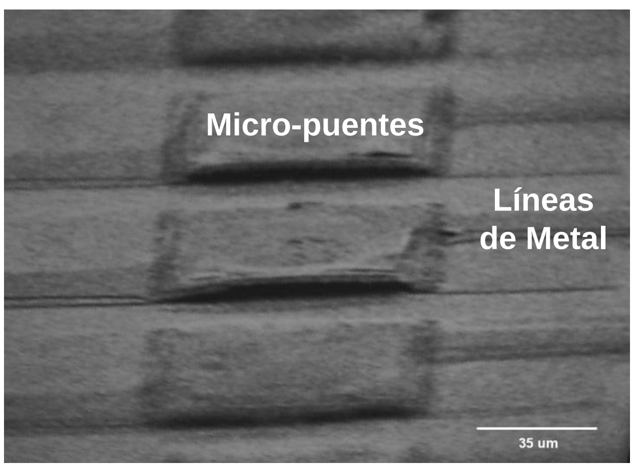


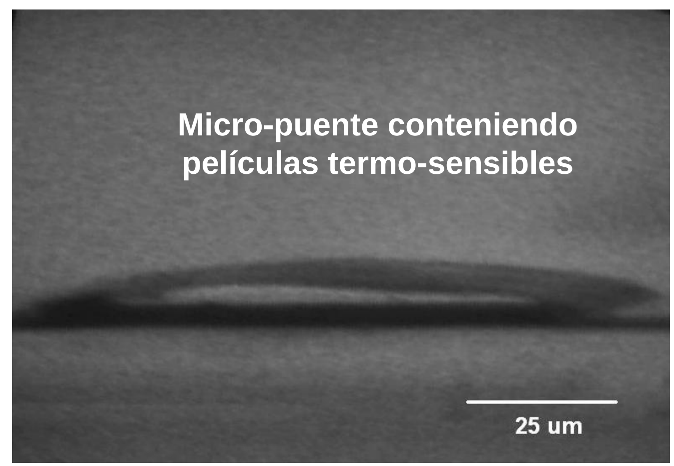
Un solo píxel.

Detectores de Energía IR Desarrollados en INAOE (Térmicos)









Emisores de Energía Óptica Desarrollados en INAOE

Dentro del Laboratorio de Microelectrónica del INAOE, se ha logrado desarrollar **emisores de radiación óptica** utilizando la infraestructura de depósito de películas delgadas en paralelo a al estudio de los parámetros de depósito de estos materiales.

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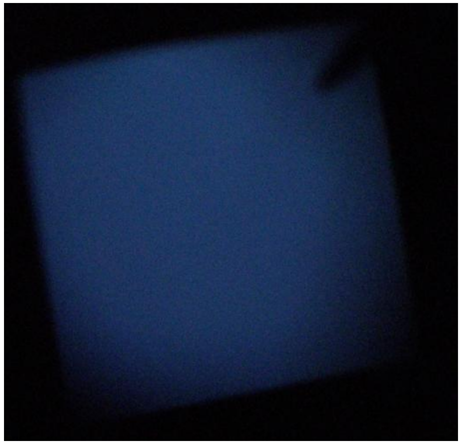
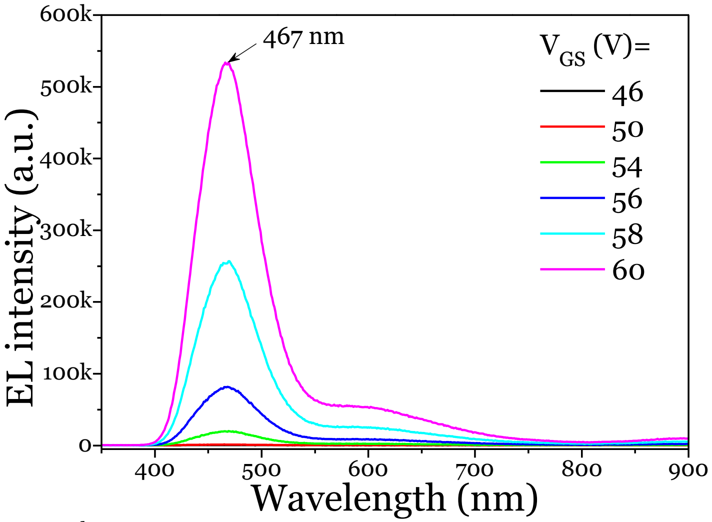
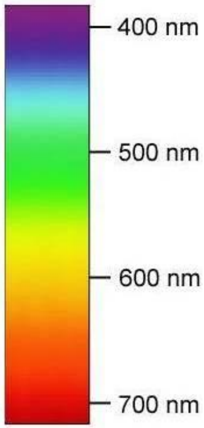
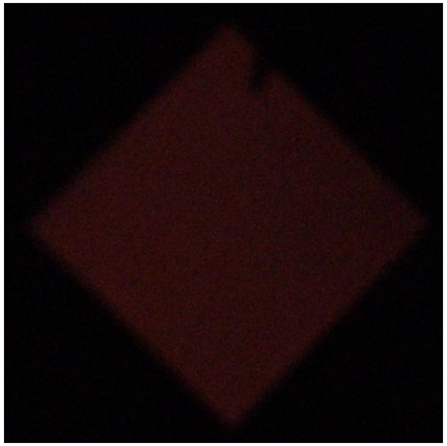
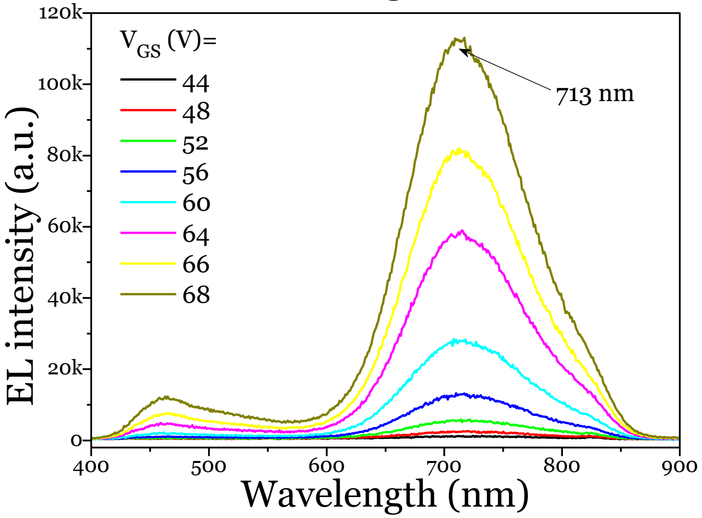








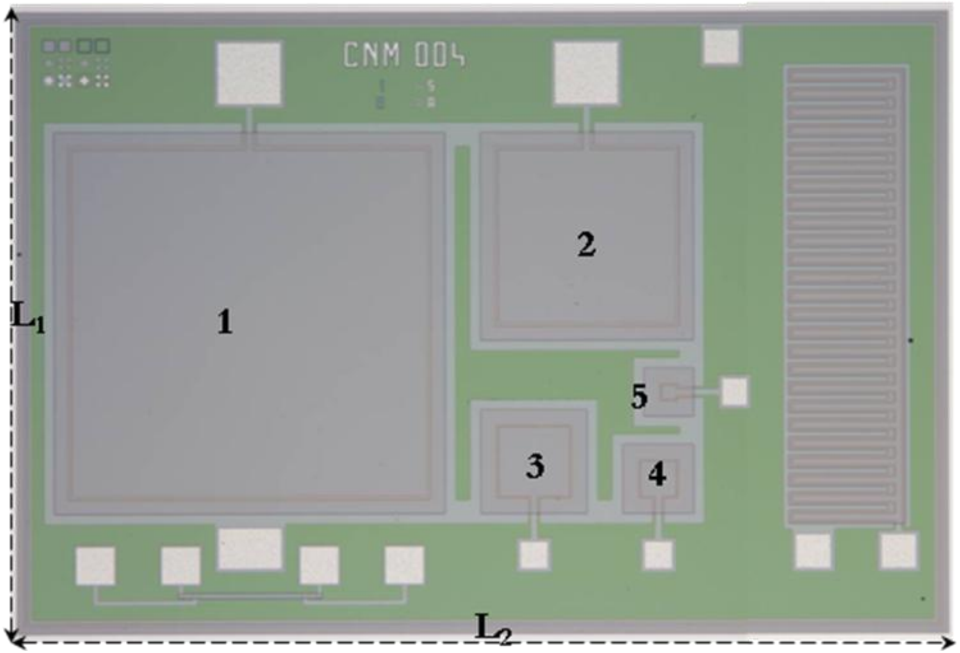


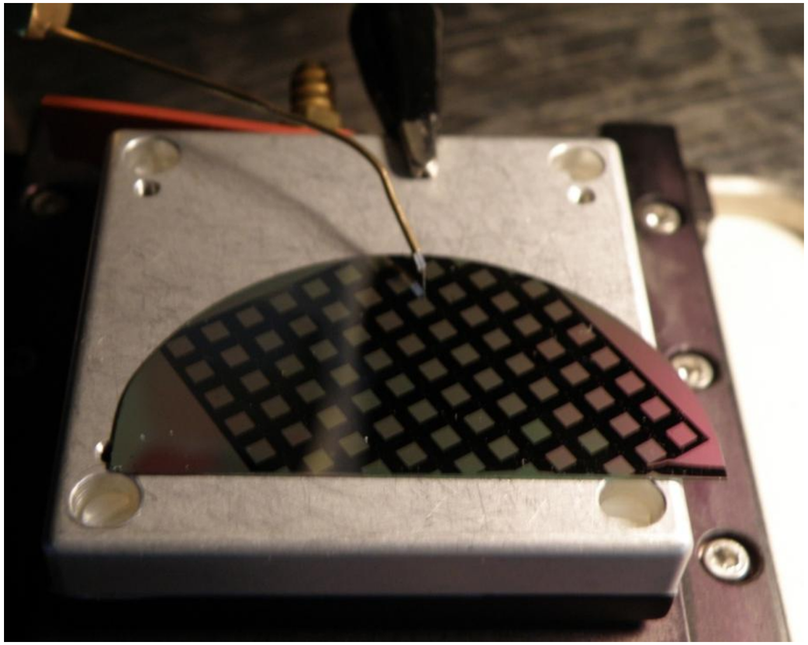
"Blue and red electroluminescence of silicon-rich oxide light emitting capacitors",
Alfredo Morales-Sanchez, Mariano Aceves-Mijares, et al., to be presented at SPIE Photonics Europe. (2010).

Emisores de Energía Óptica Desarrollados en INAOE

En conjunto con el desarrollo de los procesos de fabricación de materiales, el empleo de técnicas de diseño de LAYOUTS o distribución de los patrones geométricos que formarán la estructura final del dispositivo se ha venido perfeccionando continuamente.

LAYOUT (4 Mascarillas) para obtención de dispositivos y estructuras de prueba.



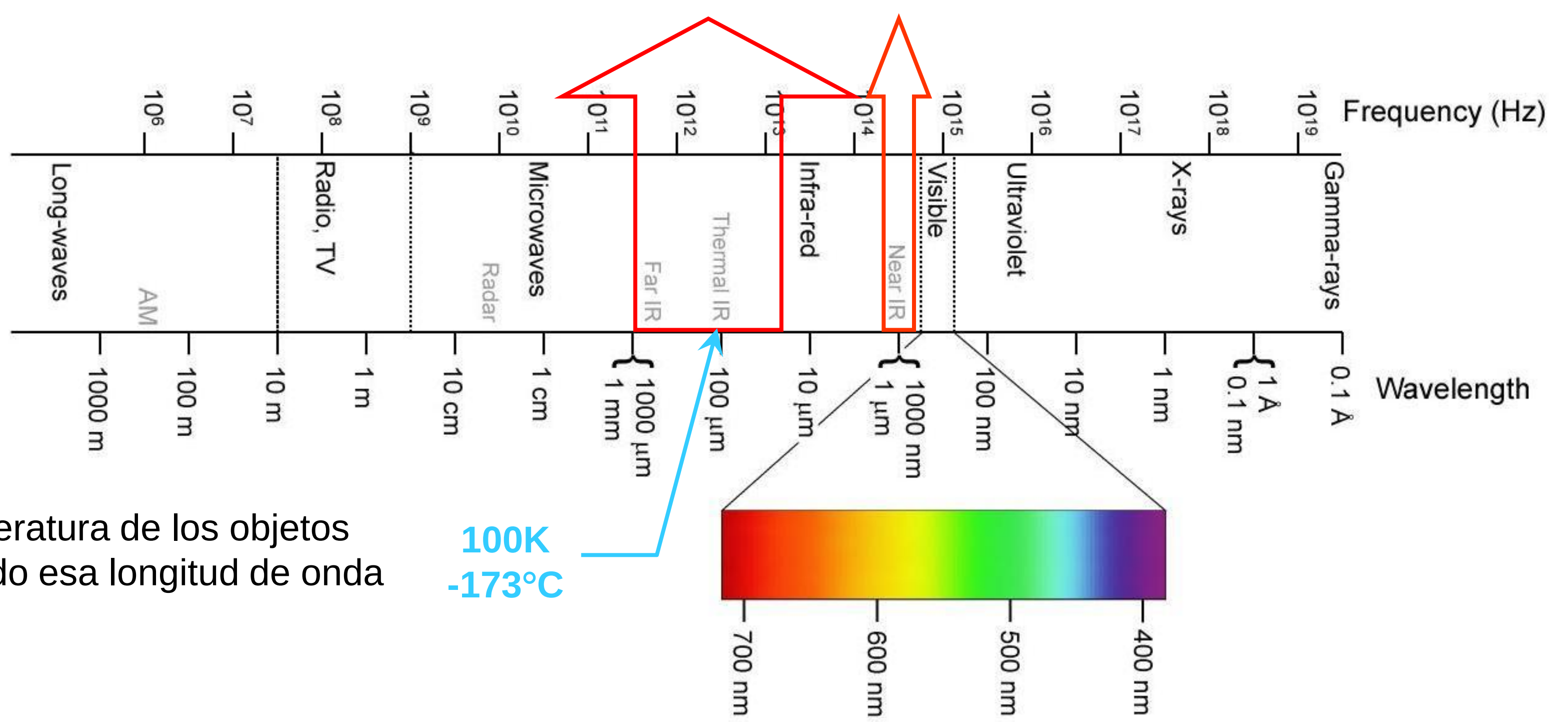


"The mechanism of electrical annihilation of conductive paths and charge trapping in silicon-rich oxides",
A Morales-Sánchez, J Barreto, et al.,Nanotechnology 20, 045201 (2009).
"DC and AC electroluminescence in silicon-nanoparticles embedded in silicon-rich oxide films",
A Morales-Sánchez, J Barreto, et al., Nanotechnology. (2009).

Ventanas de Detección IR dentro del EEM

Dentro del espectro EM, el rango de frecuencias perteneciente a la radiación IR cubre las longitudes de onda de entre **0.7µm – 300µm** lo cual provee de una ventana amplia para el diseño de detectores/emisores electrónicos basados en materiales sensibles a este rango de radiación electromagnética.

15µm – 1000 µm :FIR **NIR: 0.75µm – 1.4 µm**

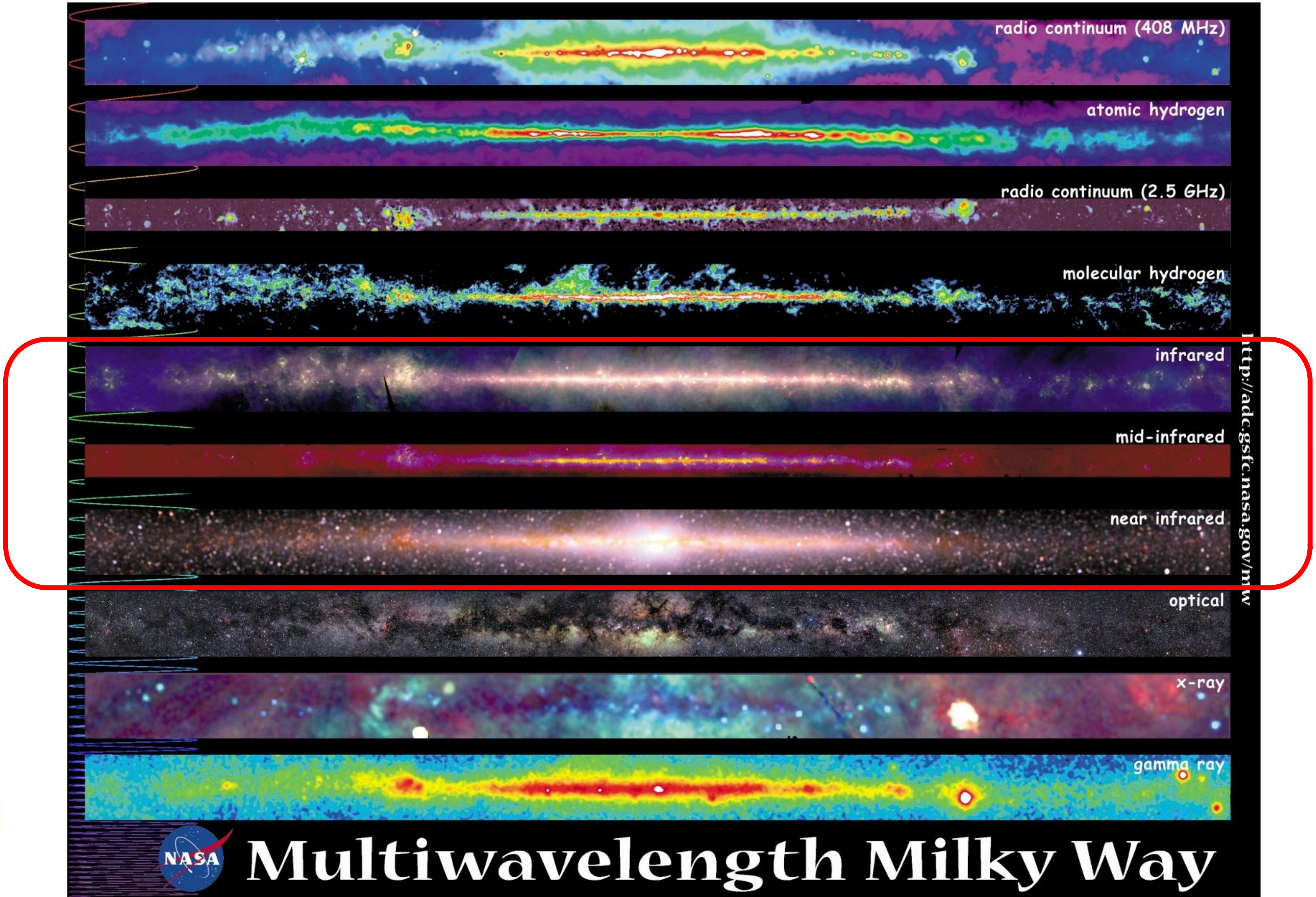


Temperatura de los objetos emitiendo esa longitud de onda

Integrated Circuit (IC) Fabrication Technology Applied to the Development of IR Sensors in Mexico

Ventanas de Detección IR dentro del EEM

En Astronomía, la observación de objetos celestes en la porción IR del espectro requiere del uso de componentes ópticas como espejos, lentes y detectores digitales de estado sólido que en conjunto forman un arreglo óptico que debe de ser protegido de fuentes de radiación térmica, y los detectores enfriados en helio líquido.



The Photoelectric Effect

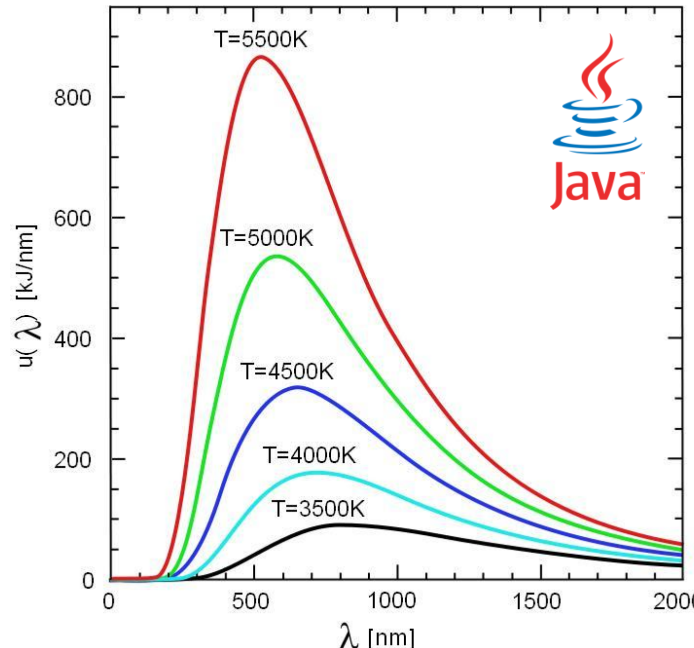
- **Planck hypothesis**

  Planck observed that ***radiation from a heated sample*** (known as black-body radiation) ***is emitted in discrete units of energy*** called ***quanta***.

- A black body is an object that absorbs all light that falls on it. *No electromagnetic radiation passes through it and none is reflected*. Because no light is reflected or transmitted, the object appears black when it is cold.
- If the black body is hot, these properties make it an *ideal source of thermal radiation.*
- *Planck's law* describes the spectral radiance of electromagnetic radiation at all wavelengths from a black body at temperature T:

$$I(\upsilon,T)=\frac{2h\upsilon^3}{c^2}\frac{1}{e^{\frac{h\upsilon}{kT}}-1}$$

hv= 2.82*kT*



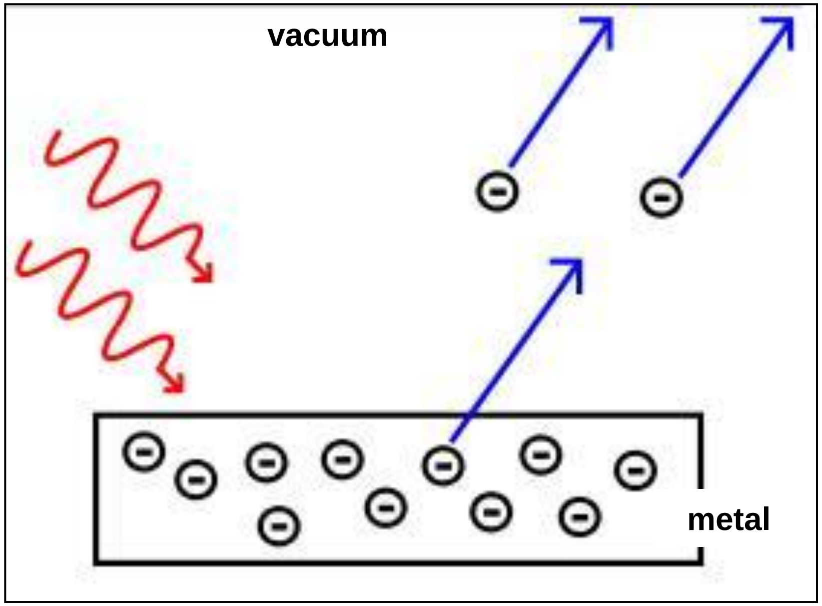
Wien's displacement law

The energy units were described by *hv* where *v* is the frequency of the radiation, and *h* is a quantity now called Planck's constant (*h* = 6.63X10-34 J-s = 4.14 eV-s).

The Photoelectric Effect

- **Einstein interpretation**

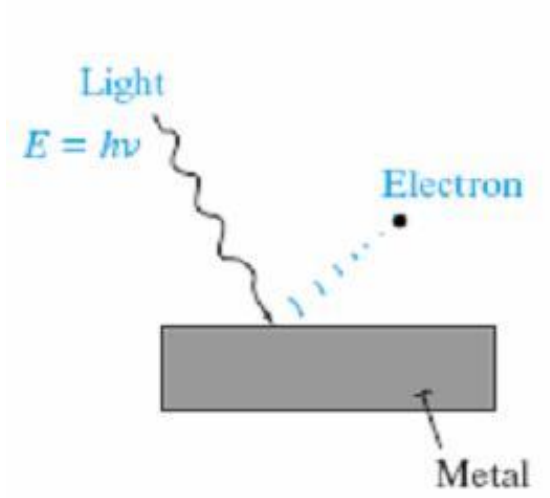
  Einstein ***interpreted an experiment that clearly demonstrated the discrete nature (quantization) of light***. This experiment involved absorption of optical energy by the electrons in a metal and the relationship between the amount of energy absorbed and the frequency of the light.



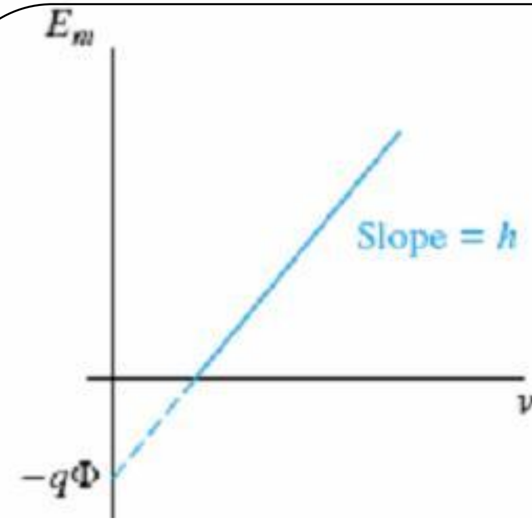
Absorbed Energy
vs.
Light Frequency

the energy of the emitted electrons increased with the frequency and NOT with the intensity of light

Let us suppose that monochromatic light is incident on the surface of a metal plate in a vacuum. The electrons in the metal absorb energy from the light, and some of the electrons receive enough energy to be ejected from the metal surface into the vacuum. This phenomenon is called the ***photoelectric effect***.



(a) Electrons are ejected from the surface of a metal when exposed to light of frequency *v* in a vacuum



(b) Plot of the maximum kinetic energy of ejected electrons vs. frequency of the incoming light

The resulting plot of E_m vs ν is linear, with a slope equal to Planck's constant.

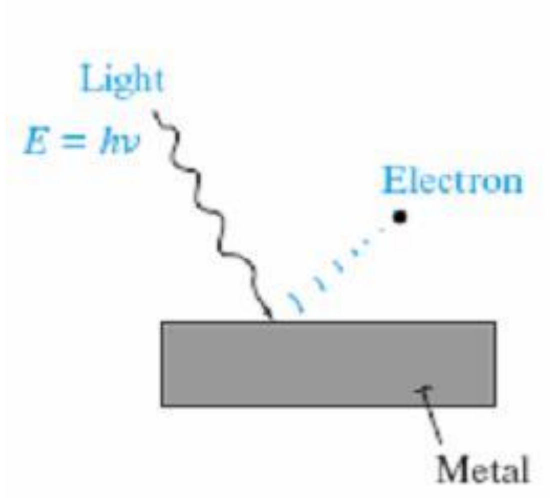
$$E_m = h\nu - q\Phi$$

The electrons receive an energy hv from the light and lose an amount of energy $q\Phi$ *in escaping from the surface of the metal.*

q (Coulombs)= magnitude of the electronic charge.
Φ (volts)= characteristic of the particular metal used.

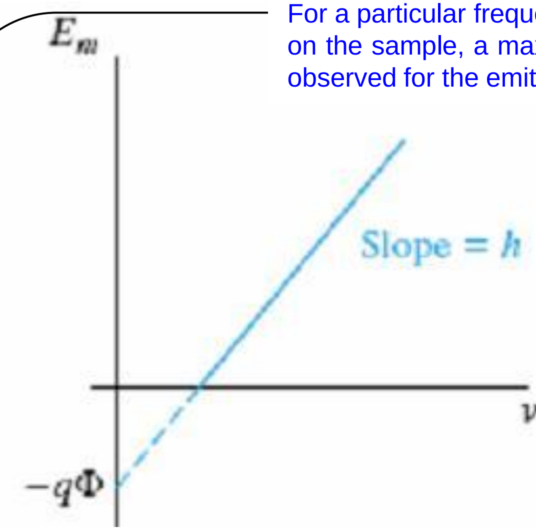
$q\Phi$ = minimum energy required for an electron to escape from the metal into the vacuum (*work function*)

One simple way of finding the maximum energy of the ejected electrons is to place another plate above the one shown in fig. (a) and then create an electric field between the two plates. The potential necessary to retard all electron flow between the plates gives the energy $\boldsymbol{E_m}$.



(a) Electrons are ejected from the surface of a metal when exposed to light of frequency *v* in a vacuum

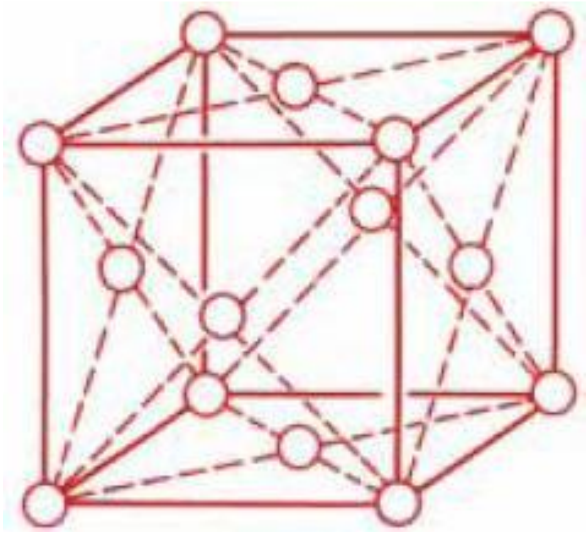
For a particular frequency of light incident on the sample, a maximum energy $\boldsymbol{E_m}$ is observed for the emitted electrons.

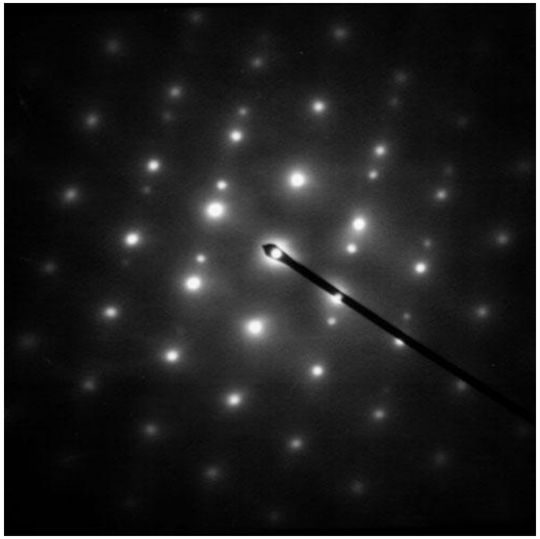


(b) Plot of the maximum kinetic energy of ejected electrons vs. frequency of the incoming light

Some experiments emphasize the wave nature of light, while other experiments reveal the discrete nature of photons. This *wave–particle duality* is fundamental to quantum processes and does not imply an ambiguity in the theory.

Austenite: face-centered cubic iron alloyed with other element.





Determination of Crystal Structures by X-Ray Diffraction

A thin crystalline specimen is subjected to a parallel beam of high-energy electrons. Because the wavelength of high-energy electrons is a fraction of a nanometer, and the spacings between atoms in a solid is only slightly larger, the atoms act as a diffraction grating to the electrons, which are diffracted. That is, some fraction of them will be scattered to particular angles, determined by the crystal structure of the sample, while others continue to pass through the sample without deflection.