Experimental study of band offsets at the GeSn/SiGeSn interface by Internal Photon Emission

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In heterojunction semiconductor devices the band structure of the interfacing materials plays a pivotal role in the resulting device's performance and characteristics. Therefore, measuring and understanding the band offsets of emerging materials is crucial since the type of band alignment (Type I, Type II, Type III) and the magnitude of energy offsets determine the magnitude of the potential barriers, and thus, the possible carrier confinement in any resulting device. [1]

The band offsets between GeSn and SiGeSn in a quantum well photoconductor device were measured using internal photon emission (IPE). This technique was used as it is precise with values reported with sub millielectronvolt resolution and is not limited by surface depth penetration like many electron spectroscopy techniques.[1],[2] IPE is characterized by the product of a device's responsivity and energy of incident exciting photons. This product is known as quantum yield (Y) and is proportional to photon energy exceeding the energy threshold required for photocurrent generation from an emitter material to a collector material.[2] In the measurement of the GeSn/SiGeSn device it was determined that the band alignment was Type-1 with a VBO of 0.06 eV and a conduction band offset (CBO) of 0.02 eV.

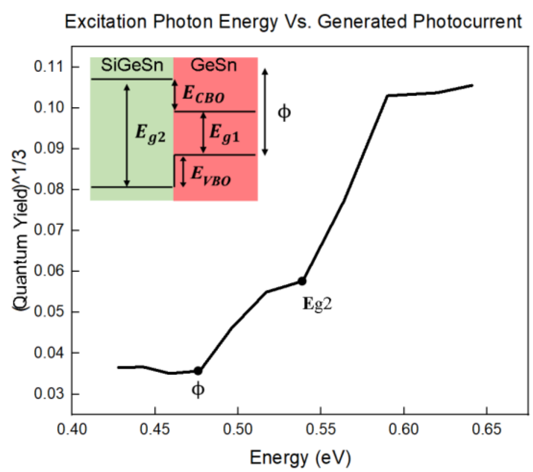

Figure 1 – Quantum yield from the measured photocurrent vs. the incident energy of excitation photons.

[1] Afanas′ev, Valery V. Internal Photoemission Spectroscopy: Fundamentals and Recent Advances. Elsevier, 2014.
[2] Y. F. Lao and A. G. U. Perera, "Physics of Internal Photoemission and Its Infrared Applications in the Low-Energy Limit," *Adv. Optoelectron.*, vol. 2016, pp. 1–18, Jan. 2016, doi: 10.1155/2016/1832097.

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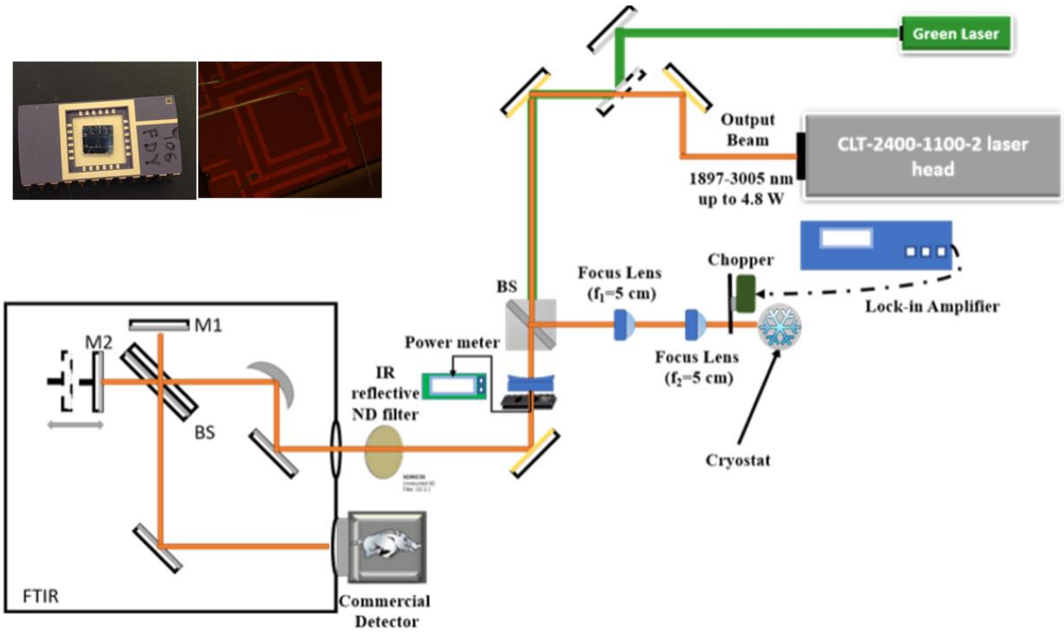

Figure 2 – IPE measurement setup and sample. The measurements used a tunable 1.9 – 3 um laser which was aligned with a visible green laser on a common path. The beam passed through a CaF2 50:50 beam splitter. The split beam struck the sample in a cryostat and a power meter at a equal distance so the measurement could be conducted and the incident beam power could be measured simultaneously. An FTIR and commercial detector were used to determine the wavelength of the laser during each collection. The sample was a square device single quantum well photoconductor.

Design

	Si (%)	Sn (%)	Thickness (nm)
Barrier 2	3	8	15
Well 1	0	15	20
Barrier 1	3	8	100
GeSn buffer	0	8~11	>800
Ge Buffer	0	0	900
Substrate	100	0	735,000

SIMS

	Si (%)	Sn (%)	Thickness (nm)
Barrier 2	2.4	8.4	71.5
Well 1	0	11.8	39.1
Barrier 1	2.2	8.4	73.8
GeSn buffer	0	6~9	850
Ge Buffer	0	0	560
Substrate	100	0	735,000

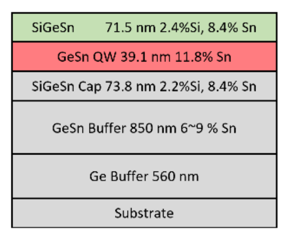

Figure 3 – GeSn/SiGeSn quantum well sample design and composition information. The thick buffer layers are intended to reduce potential defects in the top active layers.