Design of Multilayer Stacks for Use as a Selective Emitter in a Thermophotovoltaic System

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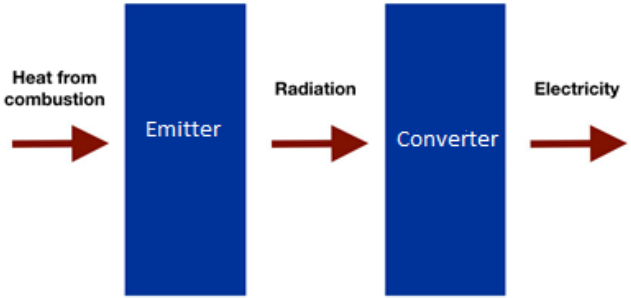

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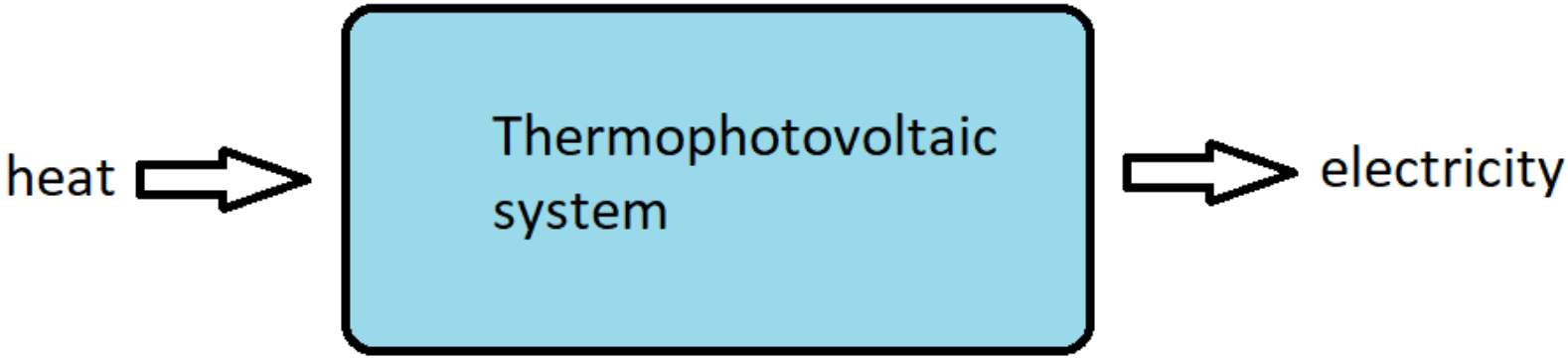
What Is Thermophotovoltaics?

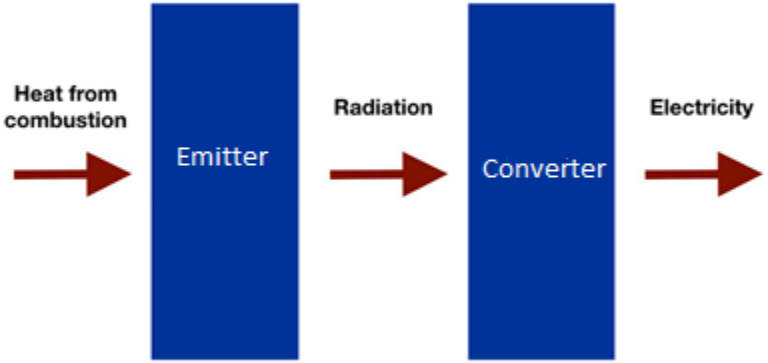


What Does a TPV System Mainly Comprise Of?

Thermophotovoltaic energy conversion

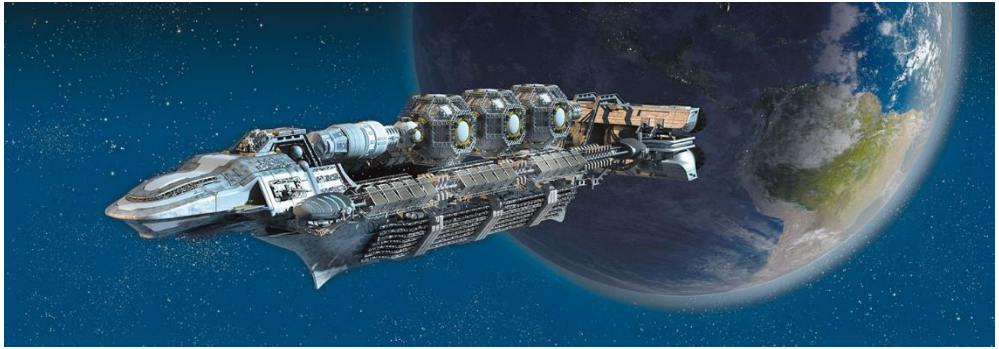
Heat to Electricity

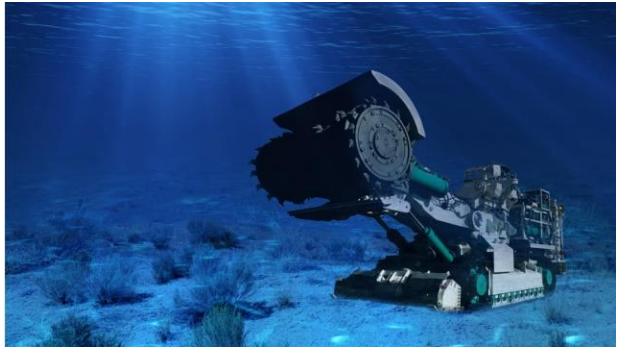
- Solar energy
- Waste heat from fuel combustion
- Radioactive decay



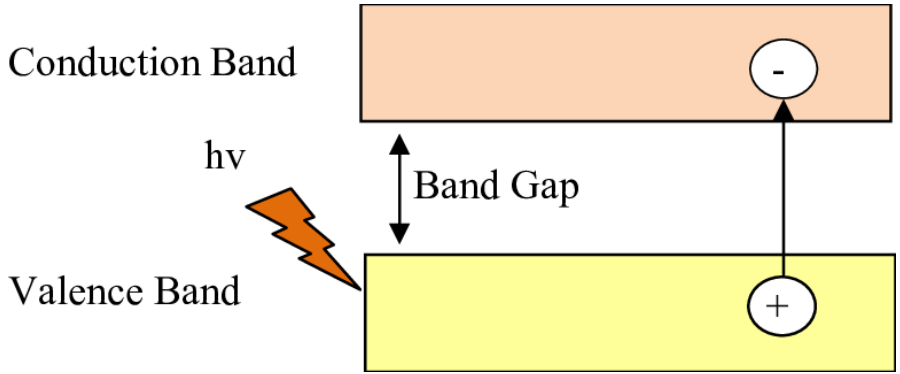
Potential Applications of a TPV System?

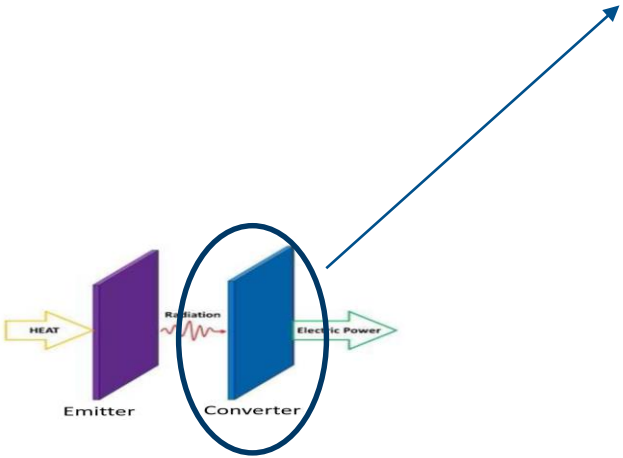
- Waste heat collection
- Space craft
- Electric vehicles
- Deep sea applications





Some Physics: Bandgap of the Converter Cell





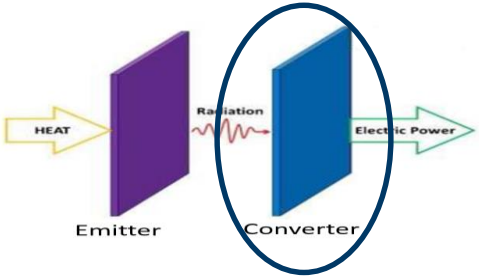
Material	Bandgap Energy	Bandgap Wavelength
Si	1.1 eV	1100 nm
Ge	0.75 eV	1840 nm
GaAs	1.42 eV	870 nm

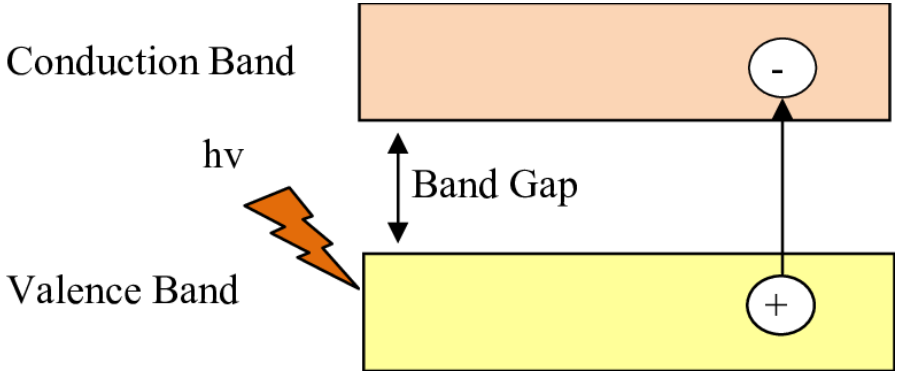
Some Physics: Bandgap of the Converter Cell

$hv > E_{bg}$ absorbed

$hv < E_{bg}$ wasted

$hv >> E_{bg}$ thermalization heats the cell

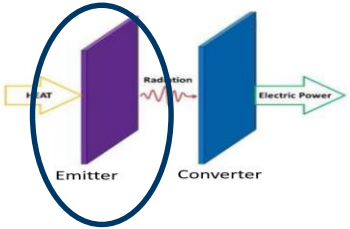


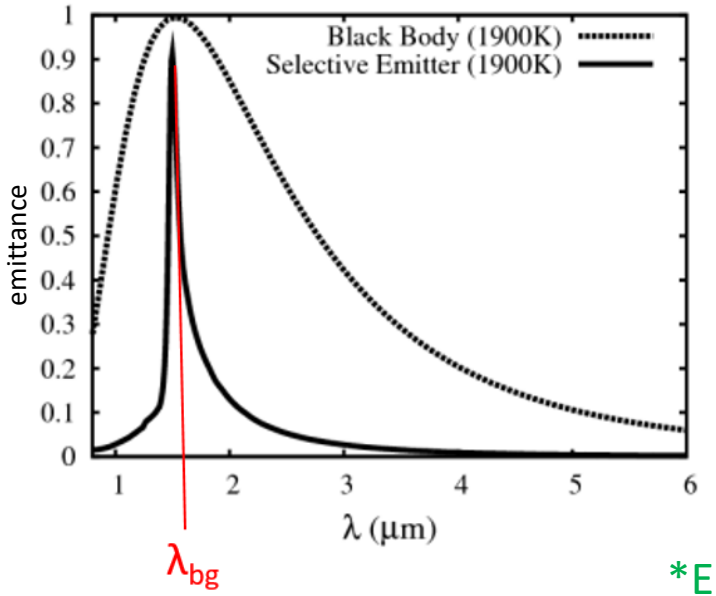


What Is the Role of the Selective Emitter in a TPV System?

convert a broadband into a narrow band

hv > E_{bg} pass
hv < E_{bg} ~~wasted~~ reflected
~~hv >> E_{bg} thermalization heats the cell~~





*E= hc/λ

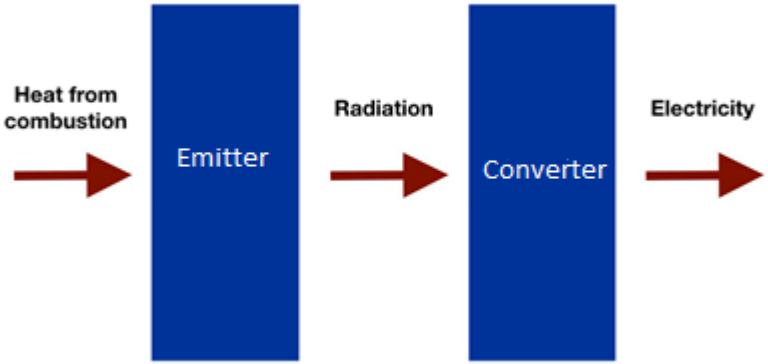
Why Selective Emission?

Broad spectrum of frequencies	Selective emission
Thermalization Increased converter cell heating Complex design configuration	Ideally, would emit light at wavelengths no other than at the bandgap of the converter cell Increased efficiency Simpler design configuration Can be tuned in many ways

So far…TPV System

Thermophotovoltaic energy conversion

Heat to Electricity

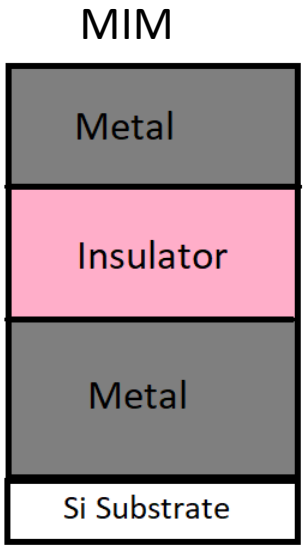


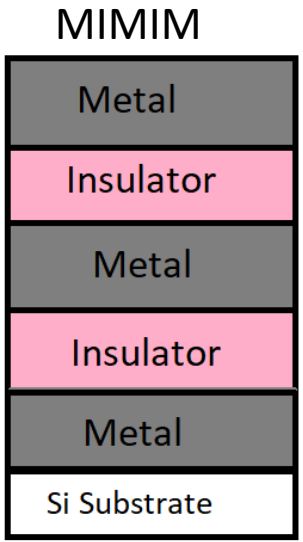
Our Research

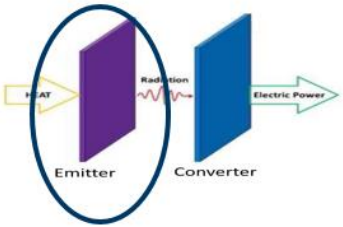
- To study the absorption of various multilayer stacks to be used as selective emitter:

A. Metal Insulator Metal (MIM)

B. Metal Insulator Metal Insulator Metal (MIMIM)



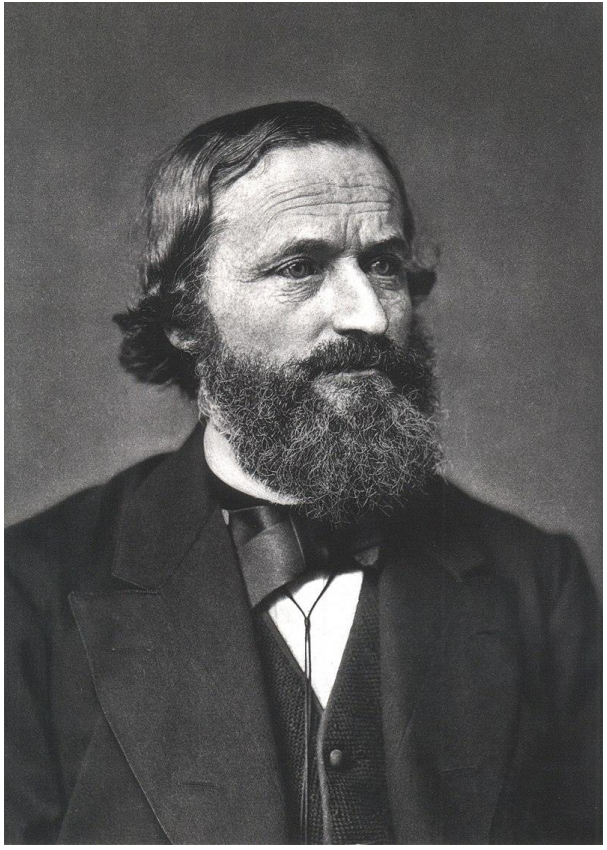




Why Are We Studying “Absorption”?

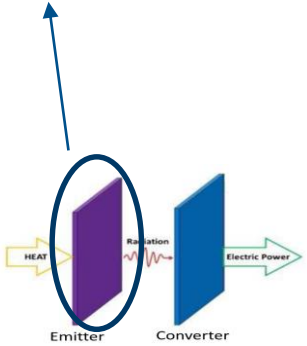
Kirchhoff’s law of thermal radiation:

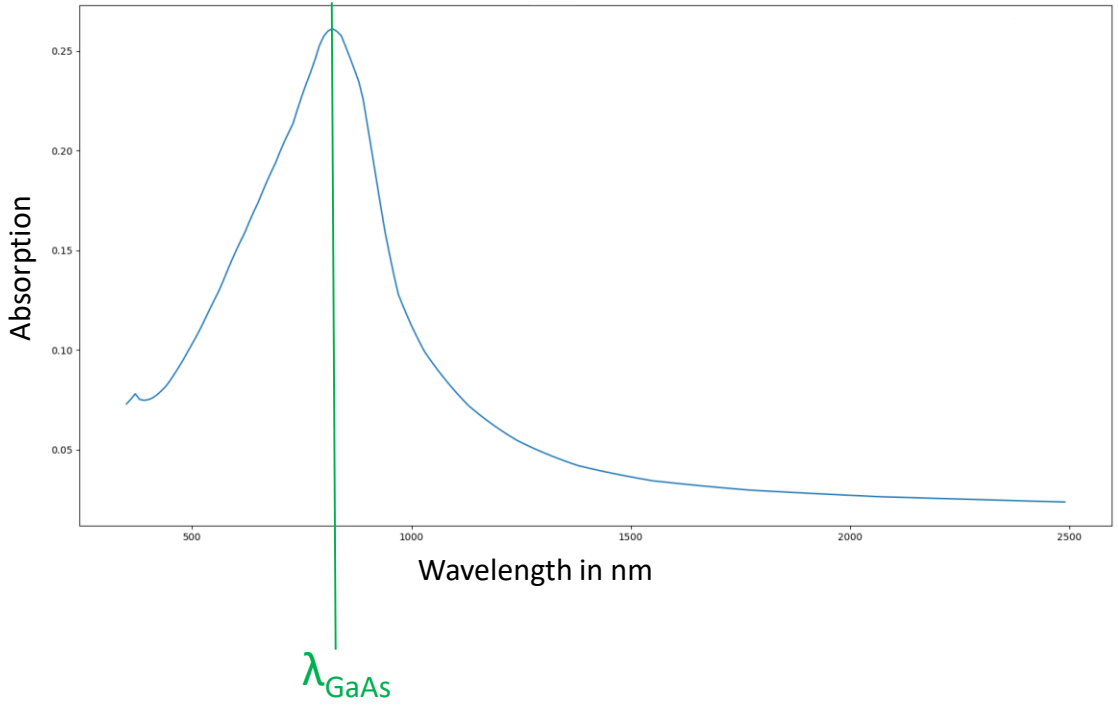
Emission corresponds to Absorption



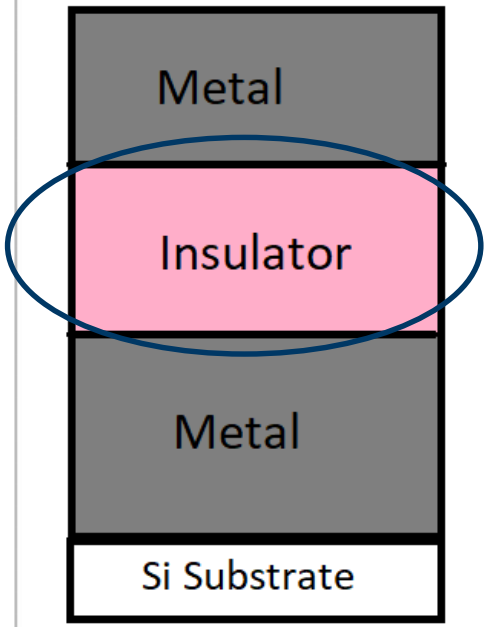
Gustav Kirchhoff

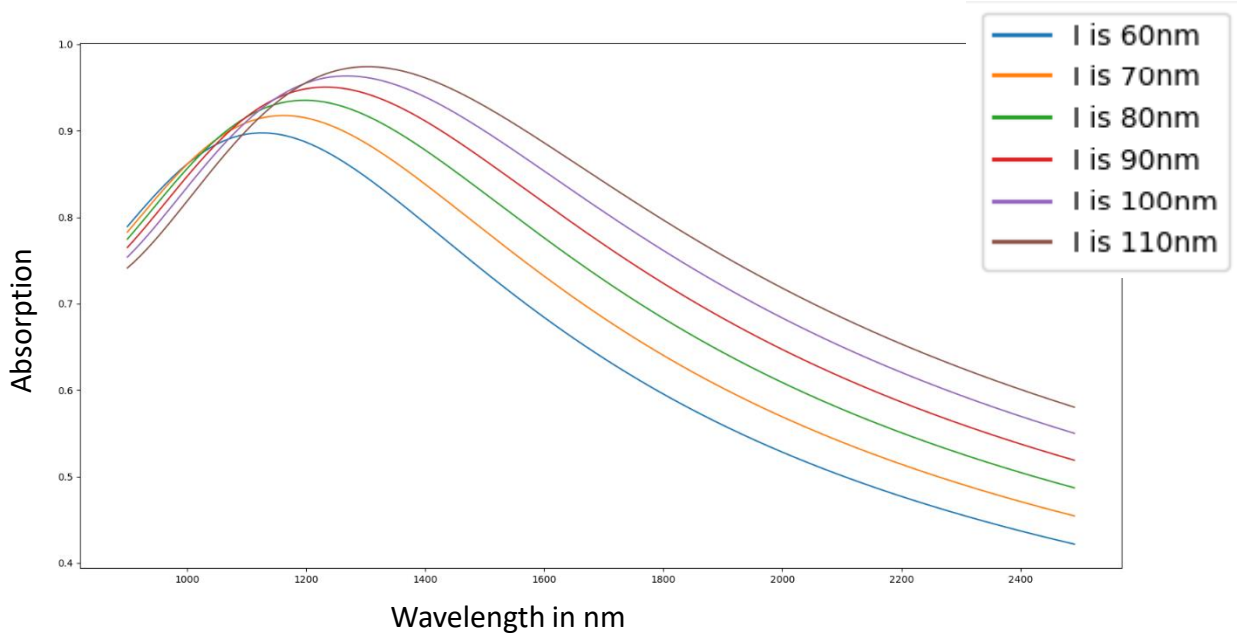
An Example Selective Emitter Design

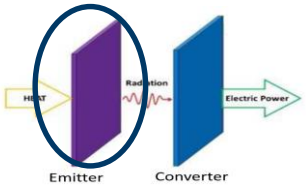




The Spectra Can Be Tuned! (to match the bandgap of the converter cell)

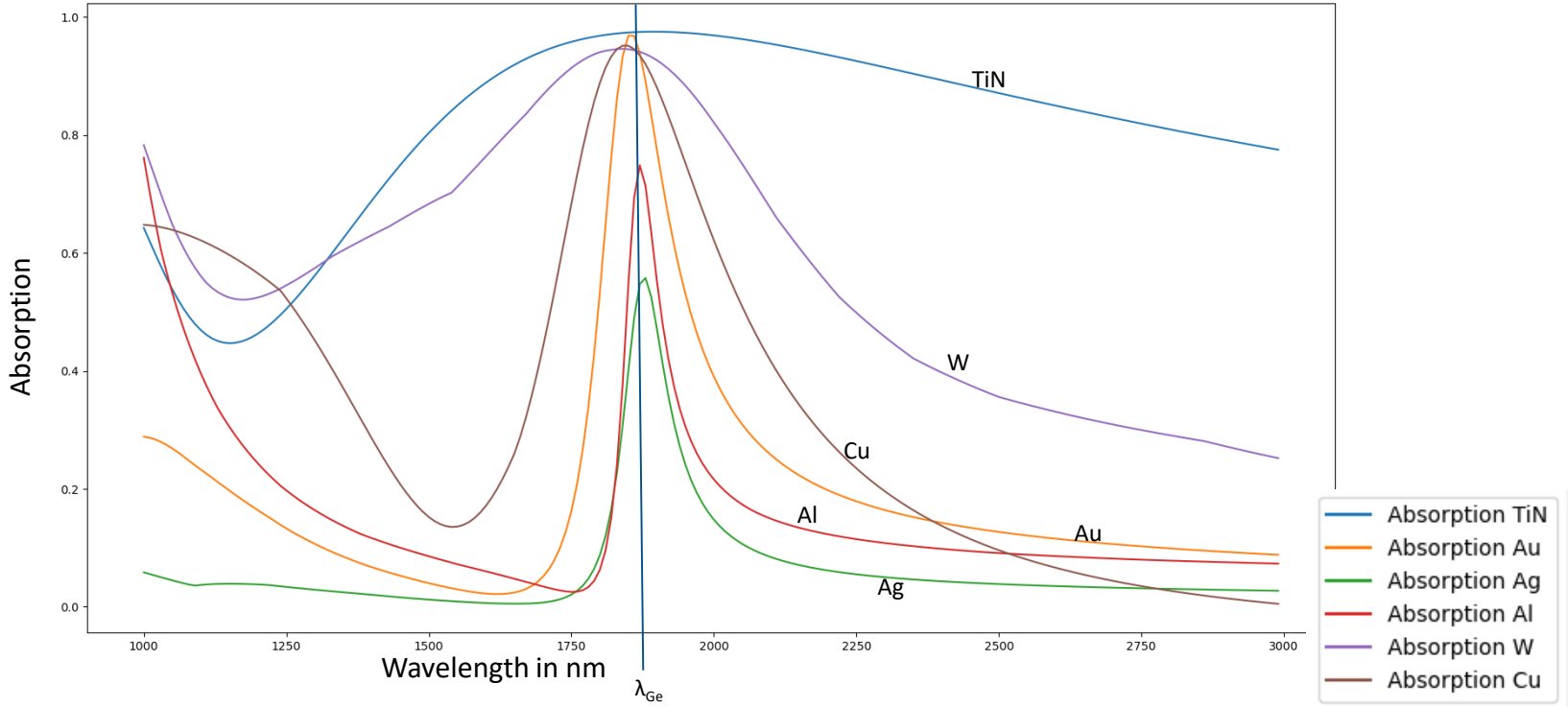




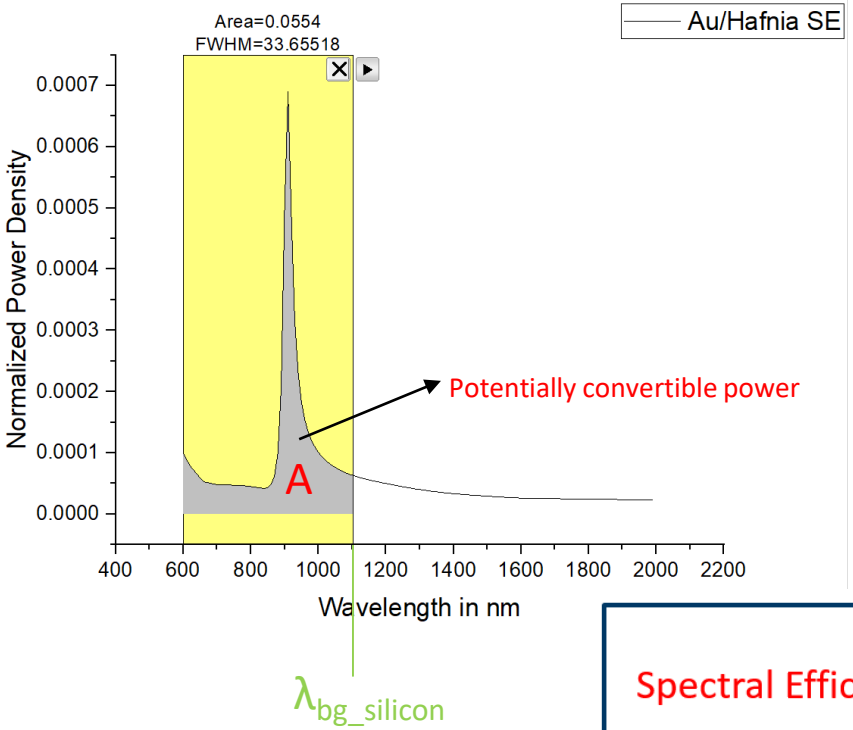


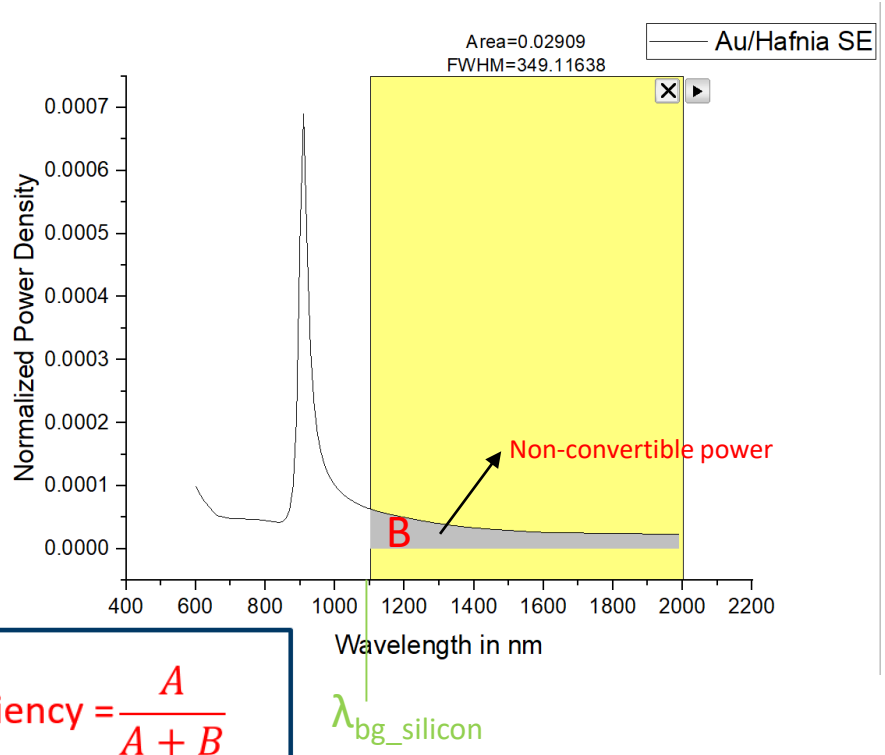
A Comparison of Different Multilayer Stacks As Selective Emitters

Figure: A comparison of the absorption of different multilayers around the bandgap wavelength of Ge (1840nm)



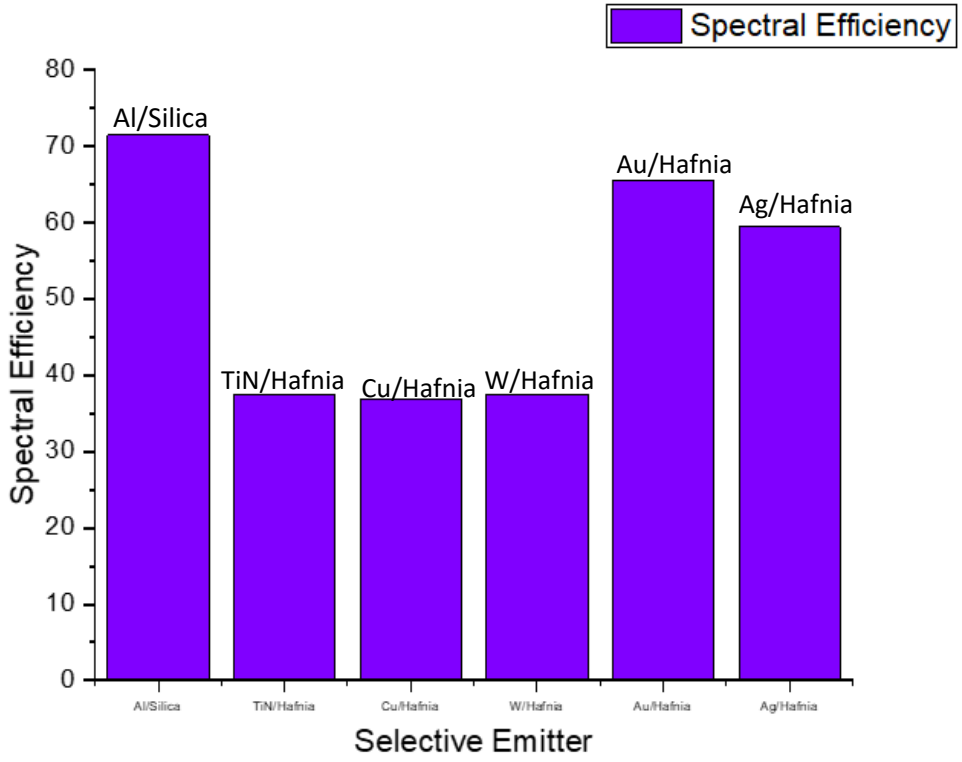
Spectral Efficiency



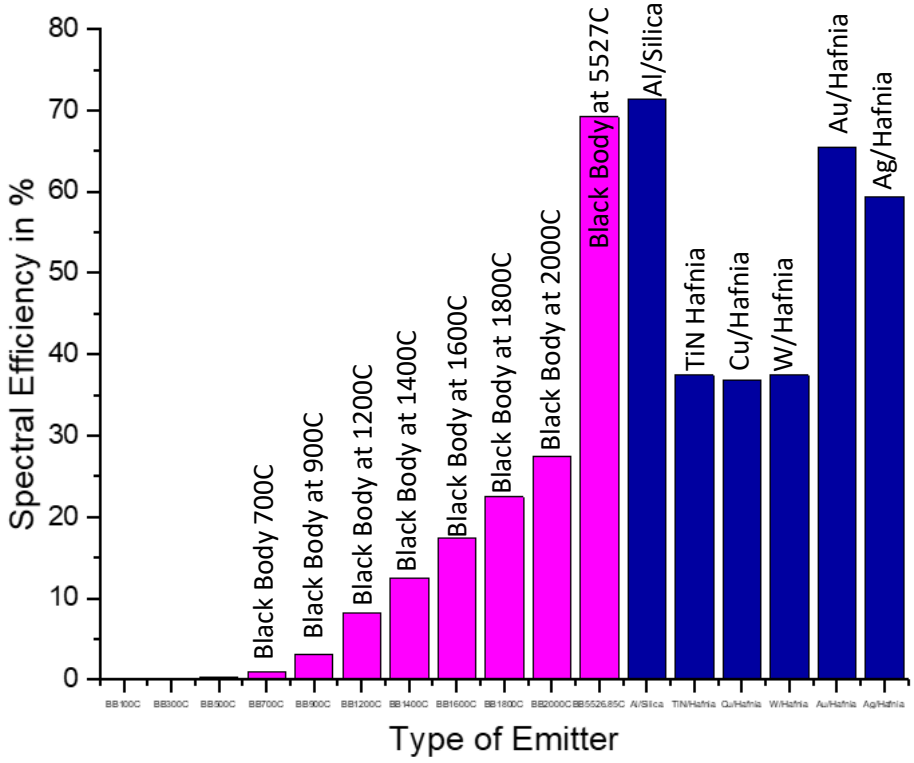


$$\text{Spectral Efficiency} = \frac{A}{A + B}$$

A Comparison of Spectral Efficiencies of Various Selective Emitters



A comparison of Spectral Efficiencies of Various Emitters

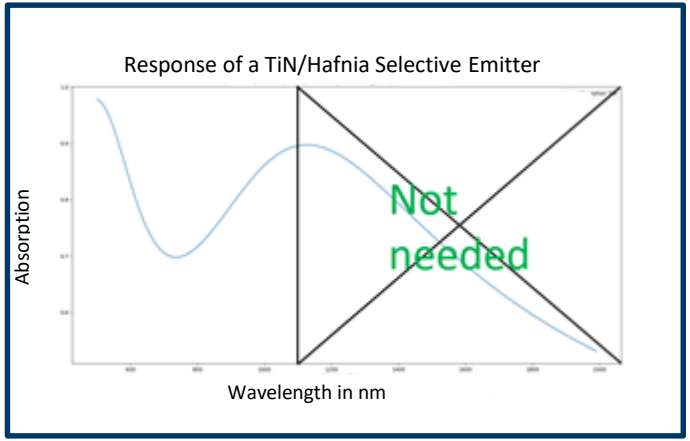


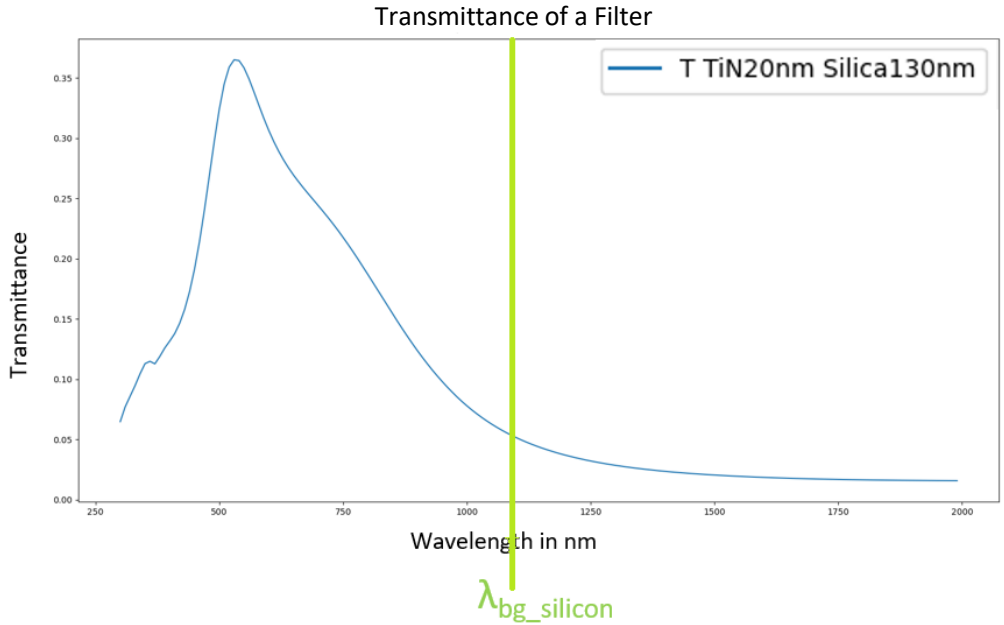
We Made the Design Better!

We are interested in CMOS materials

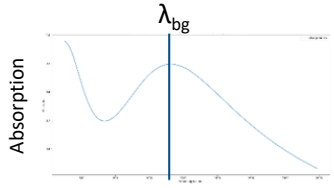
TiN Selective Emitter has a very broad peak

Use a filter!





A Proposed Design of a Complete TPV System



Filter reflects many $\lambda_{above\text{-}bandgap}$ photons back to the emitter

Filter Lets $\lambda_{below\text{-}bandgap}$ photons pass

Heat Source

heat

TiN/Hafnia multilayers as **Selective Emitter**

Low energy photons

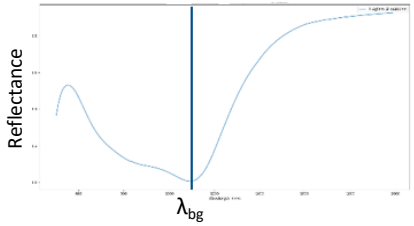
Ag/Silica multilayers as **a Filter**

Photovoltaic cell

photons

High energy photons

Selective emitter converts heat to photons



Summary and Outlook

Simulations as useful tools for studying light propagation in multilayers

Multilayers as Selective Emitters

Fabrication

- CMOS compatible materials
- Considering melting points of materials

Experimental validation

Emittance adapter

Thank you for your attention!

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