UV – VIS spectrometer

Aim of the Experiment:

Task 1: Find the energy band gap of given materials (samples) by measuring the absorption spectrum using UV-VISIBLE spectrometer and identify the type of material.

Task 2: Find the thickness of the thin films for a given set of samples (aluminium)

Principle:

The measurement of the band gap of materials is important in the semiconductor, nanomaterial and solar industries. In this experiment we demonstrate how the band gap of a material can be determined from its UV – VIS absorption spectrum.
The term "band gap" refers to the energy difference between the top of the valence band to the bottom of the conduction band (See Figure 1); electrons are able to jump from one band to another. In order for an electron to jump from a valence band to a conduction band, it requires a specific minimum amount of energy for the transition, the band gap energy.
Measuring the band gap is important in the semiconductor and nanomaterial industries. The band gap energy of insulators is large (> 4eV), but lower for semiconductors (< 3eV).
A diagram illustrating the band gap is shown in Figure 1.

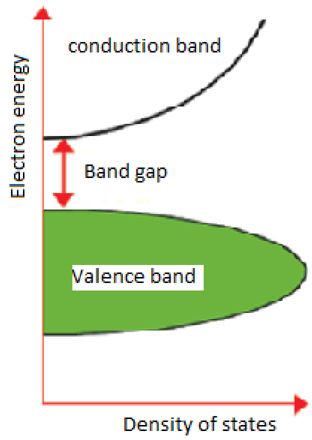


Fig 1. Explanation of Band gap

Fig: 2 UV-VIS Photo spectrometer

UV-Visible spectrometer measures the intensity of light passing through the sample (I) and compares it to the calibrated intensity (I_0). The ratio I/I_0 is called the transmittance for a particular wavelength.

The absorbance A is defined as, $A = - Log\ (I/I_0)$.

The sources of UV-Visible light are tungsten and deuterium lamps. If the current in the circuit is gradually increased from zero, the tungsten lamp filament at first can be felt to be emitting warmth, then glows dull red and then gradually brightness until it emits an intense white light (visible light). Later, source of light will be switched to Deuterium lamp, which emits UV (ultra violet) light. The diffraction setup incorporated in the spectrometer selectively separates different wavelengths from 200–1100 nm with desired step size.

Formula:

Task 1:

Calculate energy band gap of a given material using **method 1** as well as **method 2** as given below

Method 1:

Band gap energy, $E = \frac{hc}{\lambda}$

where $h = 6.626\text{x}10^{-34}$ JS, $c = 3\text{x}10^{8}\ ms^{-1}$

$\therefore E = \frac{1.24\text{x}10^{-6}}{\lambda}$ eV, λ in meter

Method 2:

Energy band gap of a given material can be precisely calculated using Tauc method as given below.

$$\propto = \frac{A(h\nu - E_g)^n}{h\nu}$$

Rearrange the above equation, $(\propto h\nu)^{1/n} = A^{1/n}h\nu - A^{1/n}E_g$

Where $\propto = \frac{\ln(1/T)}{x}$

α = absorption coefficient

T = Transmittance

x = Thickness of the sample

E_g = band gap of the material

n= 2, 1/2, 2/3 and 1/3 for direct allowed, indirect allowed, direct forbidden, and indirect forbidden transitions respectively.

Plotting graph of $(\alpha\, h\nu)^{1/n}$ Vs $h\nu$, we will get slope as $A^{1/n}$ and y intercept as $A^{1/n}E_g$. Dividing y intercept by A^n, we can estimate the band gap. For the present case n=? (find yourself!)

Task 2

Thickness calculations

Absorbance A = - Log (I/I_0)

$I=I_0\ e^{-t/\delta}$

Where,

I_0= intensity of the glass plate

I= intensity of the coated glass sample

t= thickness of the sample

δ= skin depth of the material

$$\delta = \sqrt{\frac{\rho\lambda}{\pi c\mu}}$$

Where,

ρ= resistivity (for Aluminium $2.8 \times 10^{-8}\ \Omega$ m)

λ= wavelength

c= velocity of light

μ= absolute magnetic permeability. (1.256×10^{-6} H/m)

Calculate thickness for 3 wavelengths for a given sample/slide and take the average of them.

Experiment procedure:

First turn on the switch provided back side of the device and leave it for 15 minutes for warm up

Step 1: Enter into wavelength scan

Press on Main menu and select “wavelength scan” and press “Enter”.

Step 2: Parameters setup

Press right arrow to set parameters, set "Scan From" , "Scan to" , "Scan step" and "Scan speed ", press enter to confirm.

Step 3 : Scan Sample

To take reference, choose "T%", "Abs" or "E" and press "E**nter"** to confirm. Reference can be air, glass plate, empty cuvette, or cuvette with distilled water. It depends upon your sample.

Put the sample in the light path. Press $\frac{START}{STOP}$ to scan the sample Base line, Press "ESC" to cancel.

Task 2: Thickness Measurement

1. Take air as reference.
2. Scan plain glass plate sample and take the reading as I_0.
3. Scan the coated sample and take the reading as I for your further calculation.

Result:

1. **Band gap of various samples:**
2. **Thickness of different aluminium films:**

Error Analysis: (example)

$$E = \frac{hc}{\lambda} \qquad \Longrightarrow \frac{\Delta E}{E} = \frac{\Delta\lambda}{\lambda^2}$$

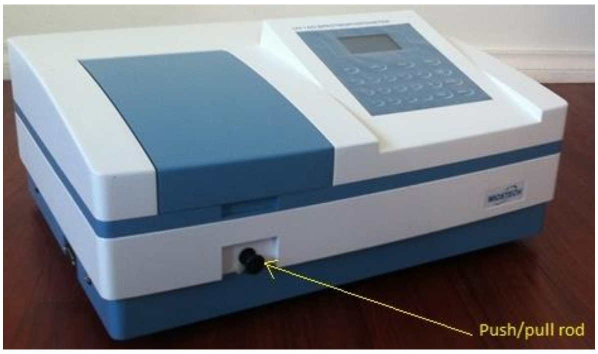
Where $\Delta\lambda$ = 10 nm (Scan step of instrument),

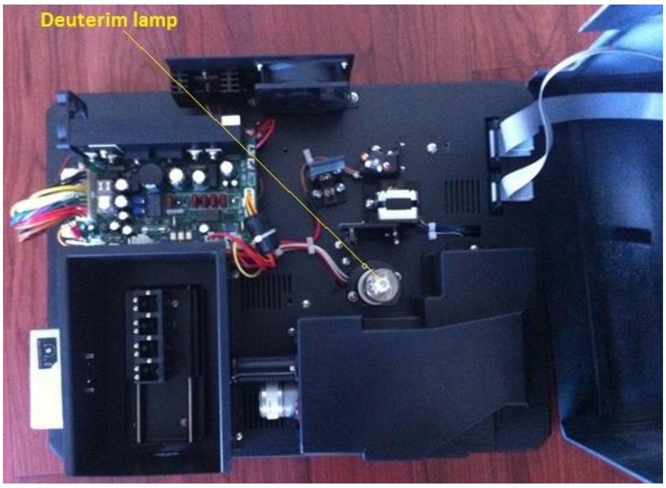
$$\lambda = \left(\frac{190+1100}{2}\right) = 645 \text{ nm.} \qquad \Longrightarrow \frac{\Delta E}{E} = ?$$

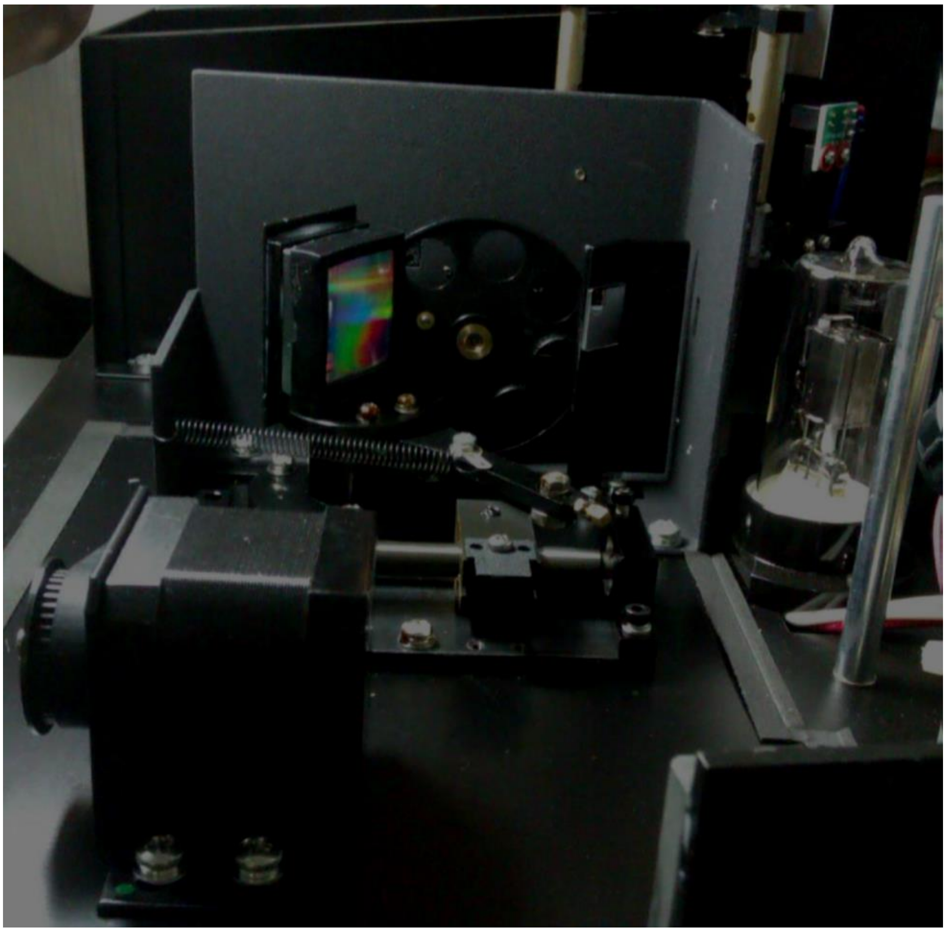
References:

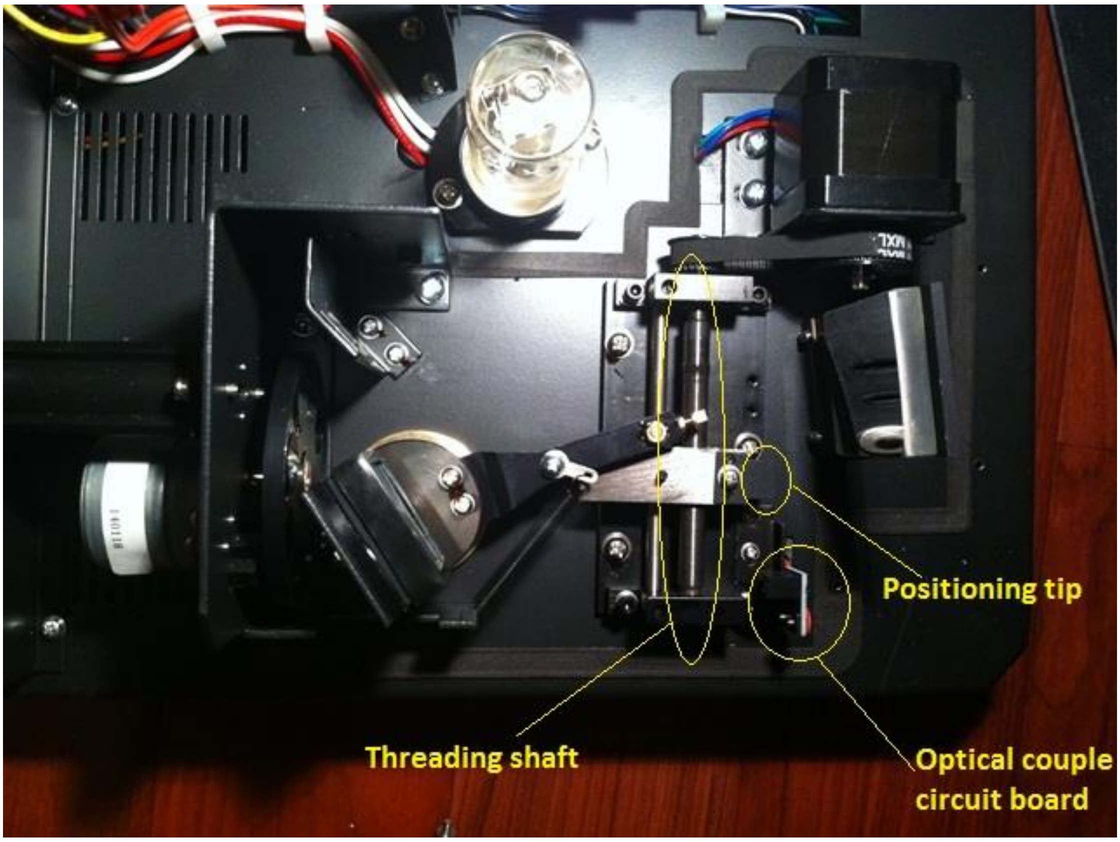
1. **http://www.indiastudychannel.com/resources/146681-Principle-working-and-applications-of-UV-spectroscopy.aspx**
2. Spectroscopic Analysis of Lead Borate Systems, Akash Daniel Georgi, K.P. Ramesh, K. J. Mallikarjunaiah, AIP Conference Proceedings 1942, 070021 (2018); doi: 10.1063/1.5028819 **DAE-2017 poster**
3. **http://www.bio.huji.ac.il/upload/Optical_Spectrophotometers_Tutorial.pdf**
4. **http://mtweb.mtsu.edu/nchong/Spectroscopy-CHEM6230.pdf**
5. Mamiyev and Balayeva, Preparation and optical studies of PbS nanoparticles optical materials, **46**, 522 (2015)

Pictures of the parts of the spectrometer








Positioning tip
Threading shaft
Optical couple
circuit board