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MDPI

Modulable Longwave Pass Filters Based on Kapton Films

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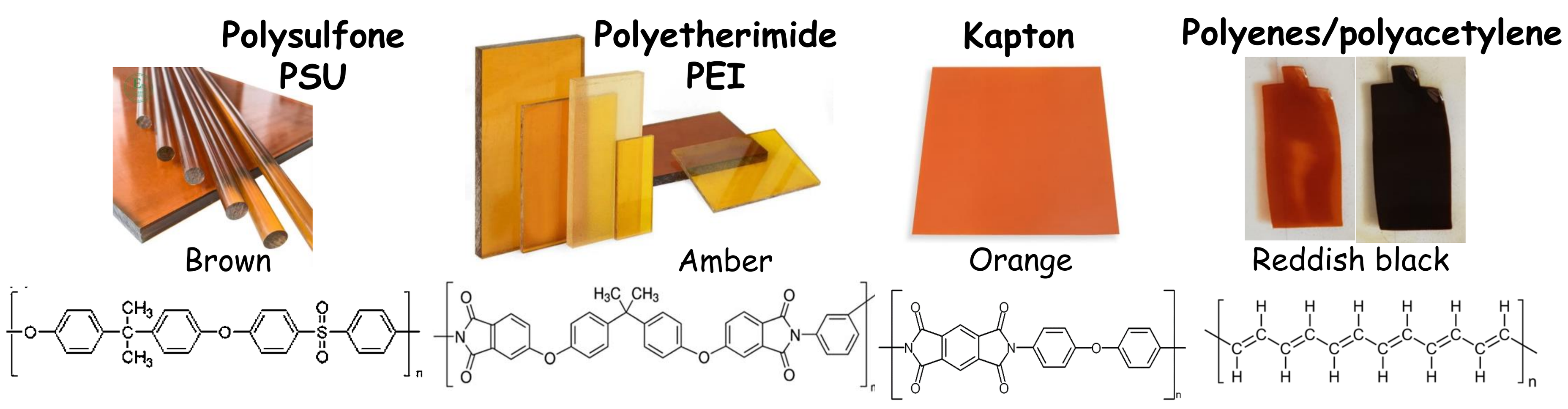
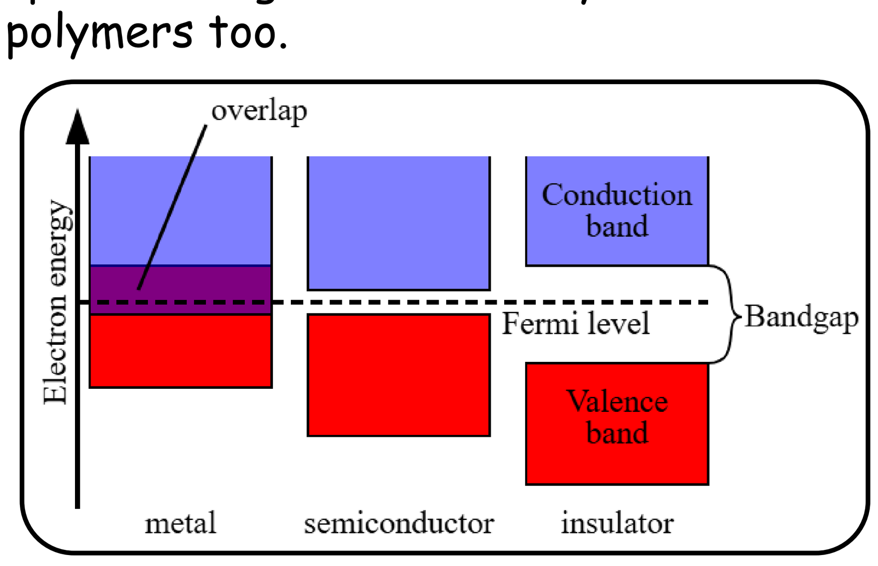
SELF-COLORED POLYMERS

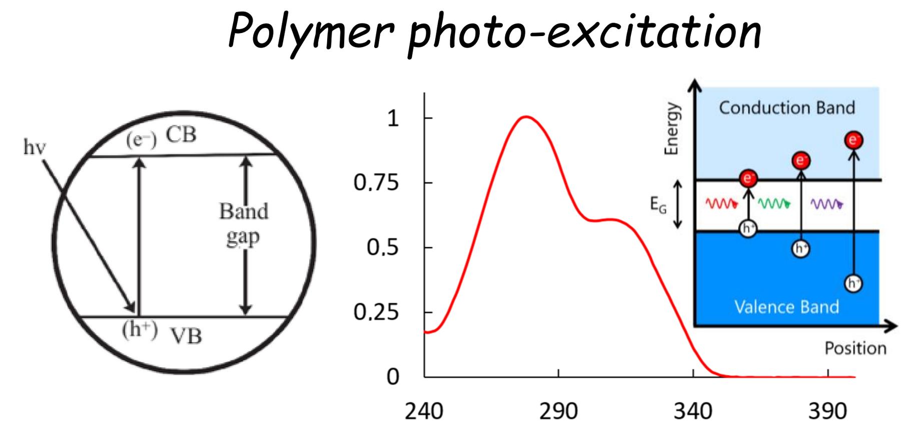
A few polymers are inherently colored (idiochromatism), while most plastics are coloured by some added dye/pigment (allochromatism). Idiochromatic polymers constitute a niche polymer class with great optical potentialities in key technological fields, like color filters, electromagnetic shielding for space architectures, etc.



Band theory is a theoretical model of the solid-state physics describing the states of electrons in crystalline inorganic compounds (e.g., metals, semiconductors). Such theory indicates that electrons in solids can have energy values only within certain specific ranges. This theory has been used for describing optical absorption of solid polymers too.

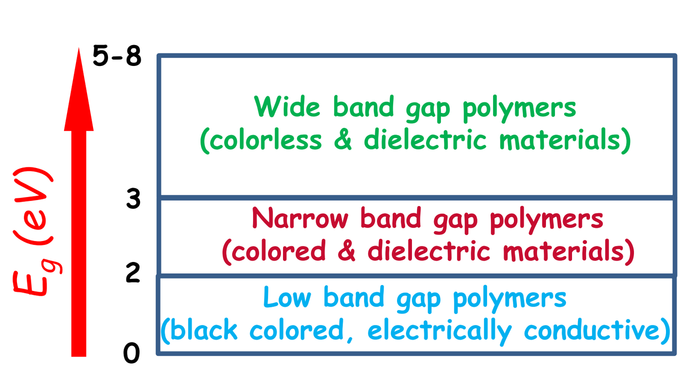


Polymer photo-excitation



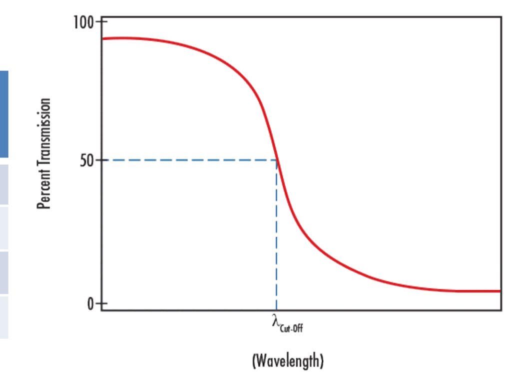
Optical absorption by inter-band electronic transitions is much different from absorption due to molecular chromophores. Indeed, electronic transitions from valence band (VB) levels to conduction band (CB) levels involve many energy values. Differently, identical chromophores absorb light of one single wavelength, thus producing an intensive tight absorption band because of vibronic coupling. Consequently, band theory applied to solid polymers predicts continuous absorption in a broad spectral region. A continuous broad optical absorption is effectively found in the optical characterization of self-colored polymers and such capability to extinct full spectral regions can be exploited for shielding applications.

KAPTON: A NARROW BAND GAP POLYMER

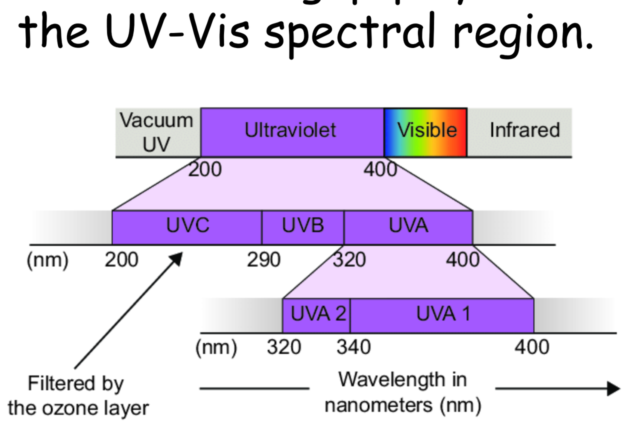


E_g of dielectric polymers

Polymer	E_g (eV)	Cut-on (nm)
PSU	3.89	318
PET	3.15	394
PI	2.83	438
Kapton	2.65	468



Polymers can be categorized based on band gap energy (E_g) in three classes: (i) low band gap polymers, (ii) narrow band gap polymers and (iii) wide band gap polymers. Usually, narrow band gap polymers are photo-excitable optical media with dielectric behaviour (i.e., electrical/thermal insulators). The spectral cut-on wavelength of narrow-band gap polymers is related to the band gap energy and usually it falls in the UV-Vis spectral region.



Kapton is an optical medium (amorphous polymer that does not scatter light) belonging to the narrow band gap polymer class. Kapton is capable to absorb blue/green light and the full ultraviolet spectral region. The last very strong and wide absorption is an important optical characteristics well justified based on band theory.

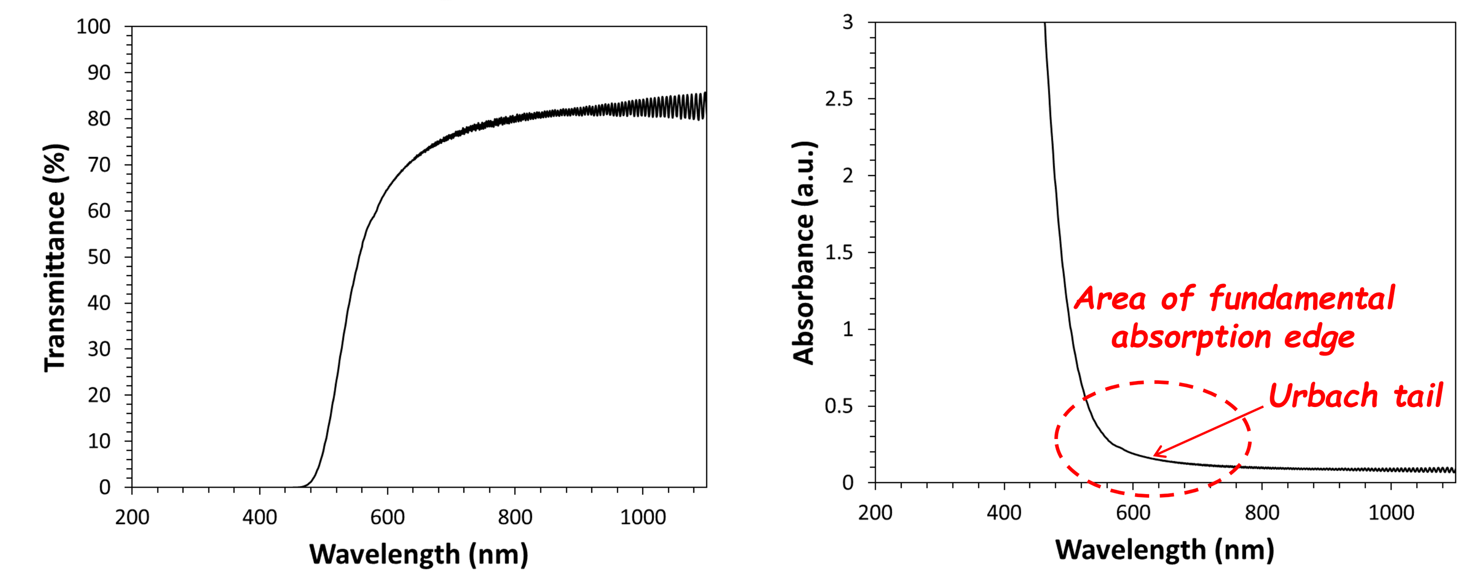
UV ABSORPTION MEASUREMENT TECHNIQUE

VWR, UV-6300PC

Owing to the tight forbidden band, electronic transitions in Kapton can be investigated by UV-Vis spectroscopy. Both cut-on wavelength and T% in UV, Vis and NIR spectral regions can be determined. A great potentiality of this spectroscopy is the optical calculation of E_g (by the Tauc plot method), that can be measured only by this experimental approach because of the polymer dielectric nature.

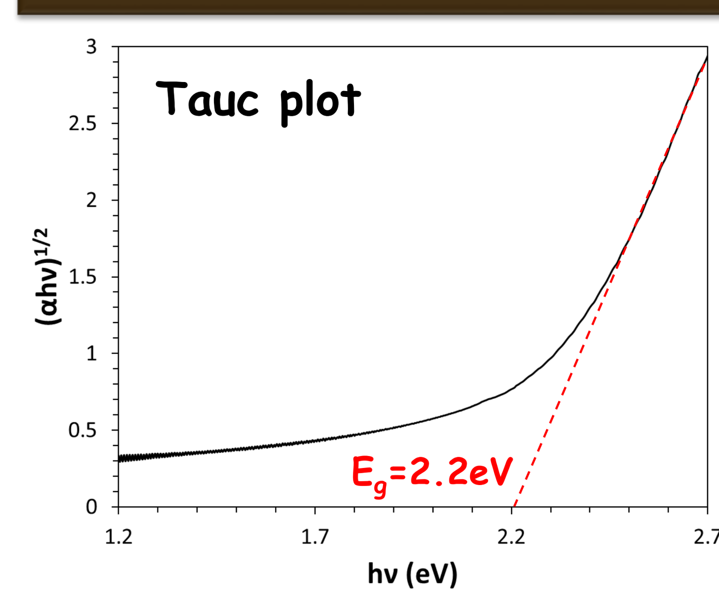
THE UNIQUE KAPTON UV ABSORPTION

Kapton films show a continuous strong optical absorption (saturation) from the UV spectral region (A, B and C) up to a wavelength of ca. 500nm, followed by a considerable Urbach tailing.



UV-Vis-NIR spectra of a Kapton film in transmittance and absorbance modes.

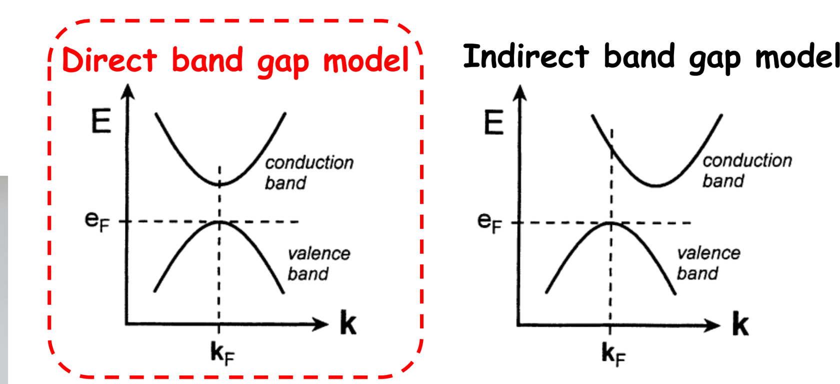
KAPTON BAND GAP ENERGY CALCULATION

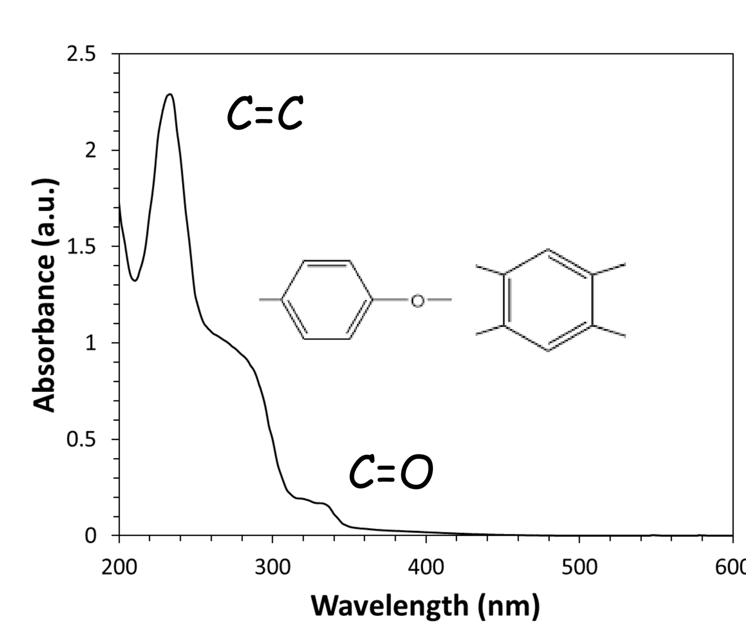


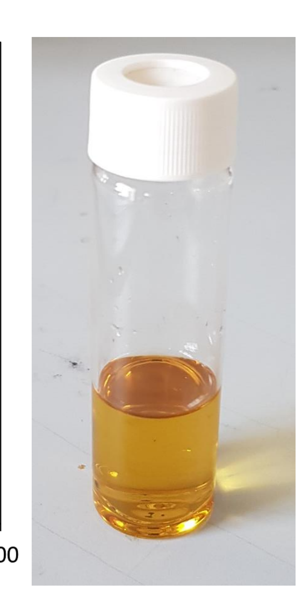
Absorbance data in the range of the fundamental absorption edge as a function of wavelength are used to determine the polymer optical E_g value. These data are plotted in the form of $(\alpha h\nu)^n$ as a function of photon energy (hν). ½ is taken as n value, like in the case of direct band gap semiconductors. E_g is obtained by this plot from the intercept of the linear part of the plot with the hν axis and it corresponds to ca. 2.2 eV.

Plot of $(\alpha h\nu)^{1/2}$ vs. energy (hν) for a Kapton film (model of direct transition).

$$(\alpha h\nu)^n = A(h\nu - E_g)$$



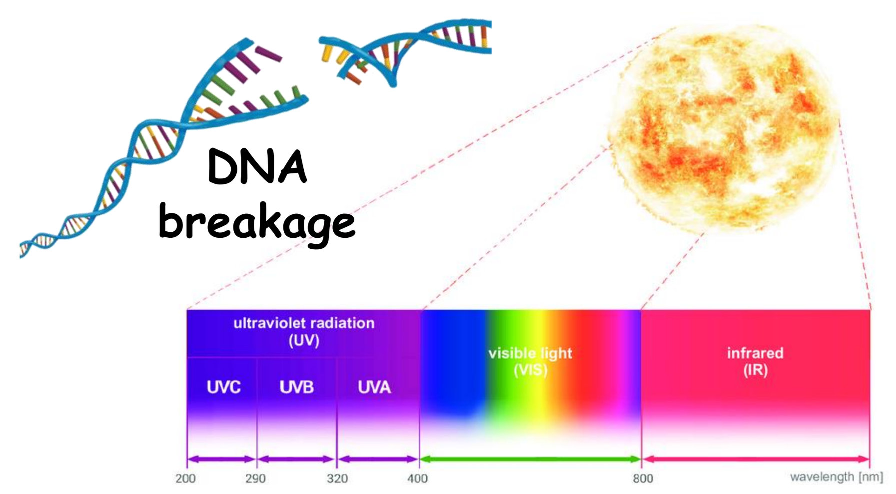


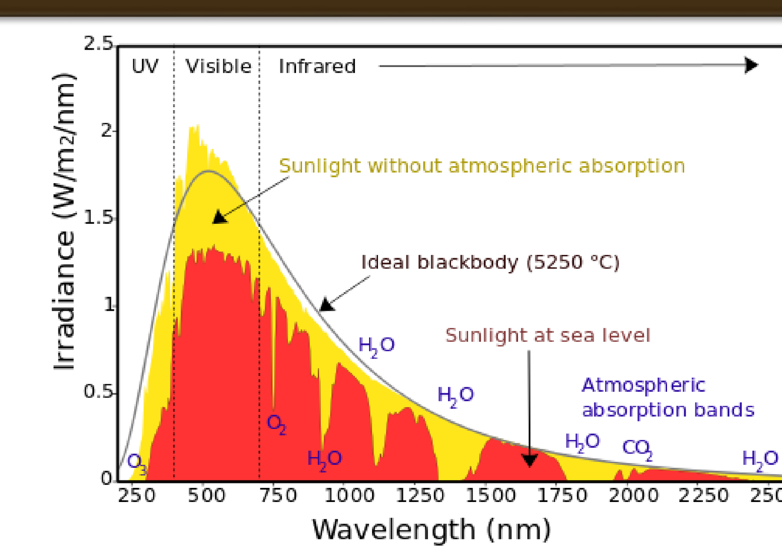


UV-Vis spectrum of Kapton very dilute solution in H_2SO_4

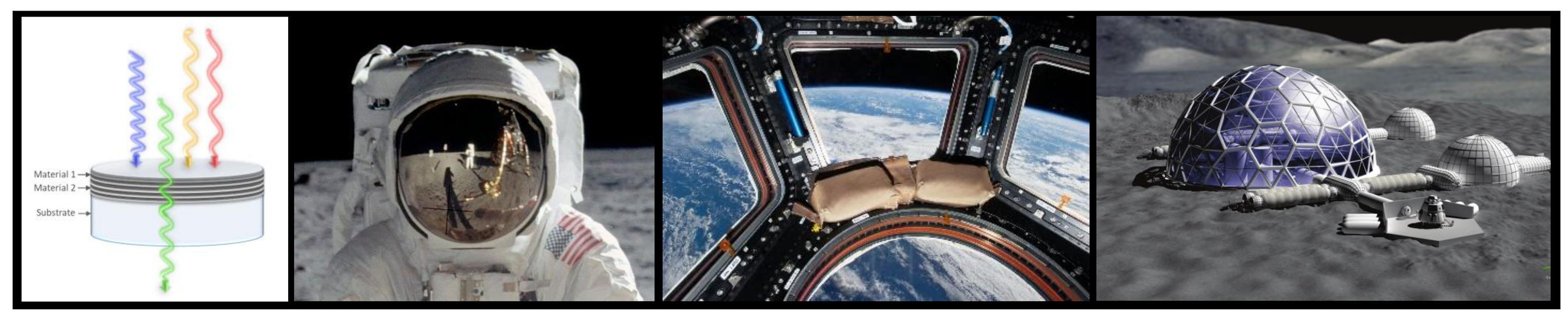
Kapton dissolves in H_2SO_4 and these solutions show absorption bands in the optical spectrum with intensities depending on Kapton concentration. Optical spectra of such solutions are used to establish the molecular chromophore types.

KAPTON UV-SHIELDING WINDOWS





UV is a strongly actinic radiation with ionizing power capable to produce significant biological effects, including DNA structure alteration. Hot celestial bodies (stars) mainly emit ultraviolet light (Wien's law). Sun emits UV radiation at all wavelengths. Very hot stars emit more UV than sun. Sunlight in the Earth's outer atmosphere is made of ca. 50% IR, 40% visible, and 10% UV light. Therefore, the first concern of a space station is to ensure high shielding from the UV radiation and Kapton film can be one component (i.e., the UV absorber) of a multi-layered optical filter (e.g., in combination with X-ray absorbing materials like lead glass or metal-polymer nanocomposites).



Multilayer optical filter & windows/domes for UV protection in space architectures.