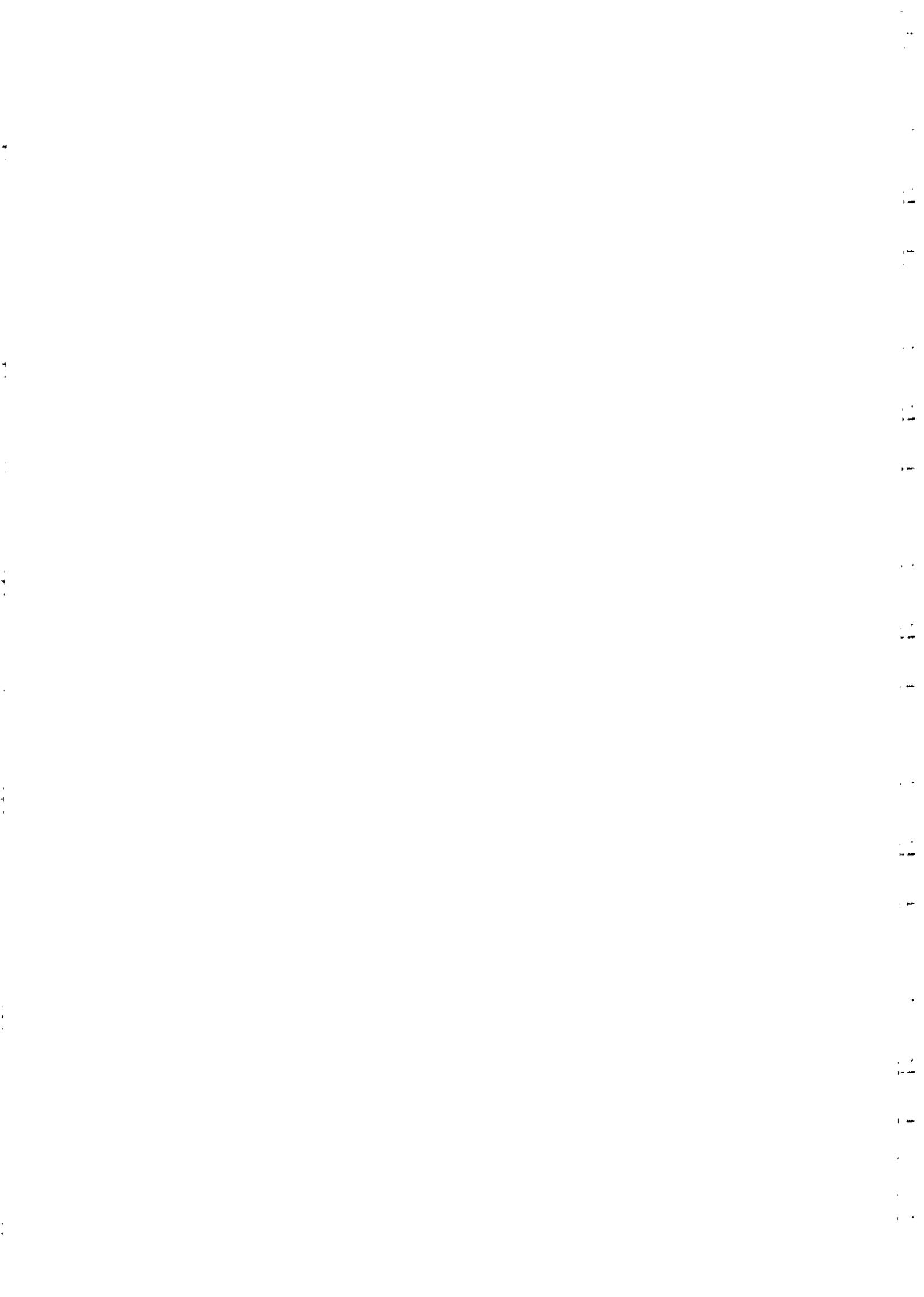


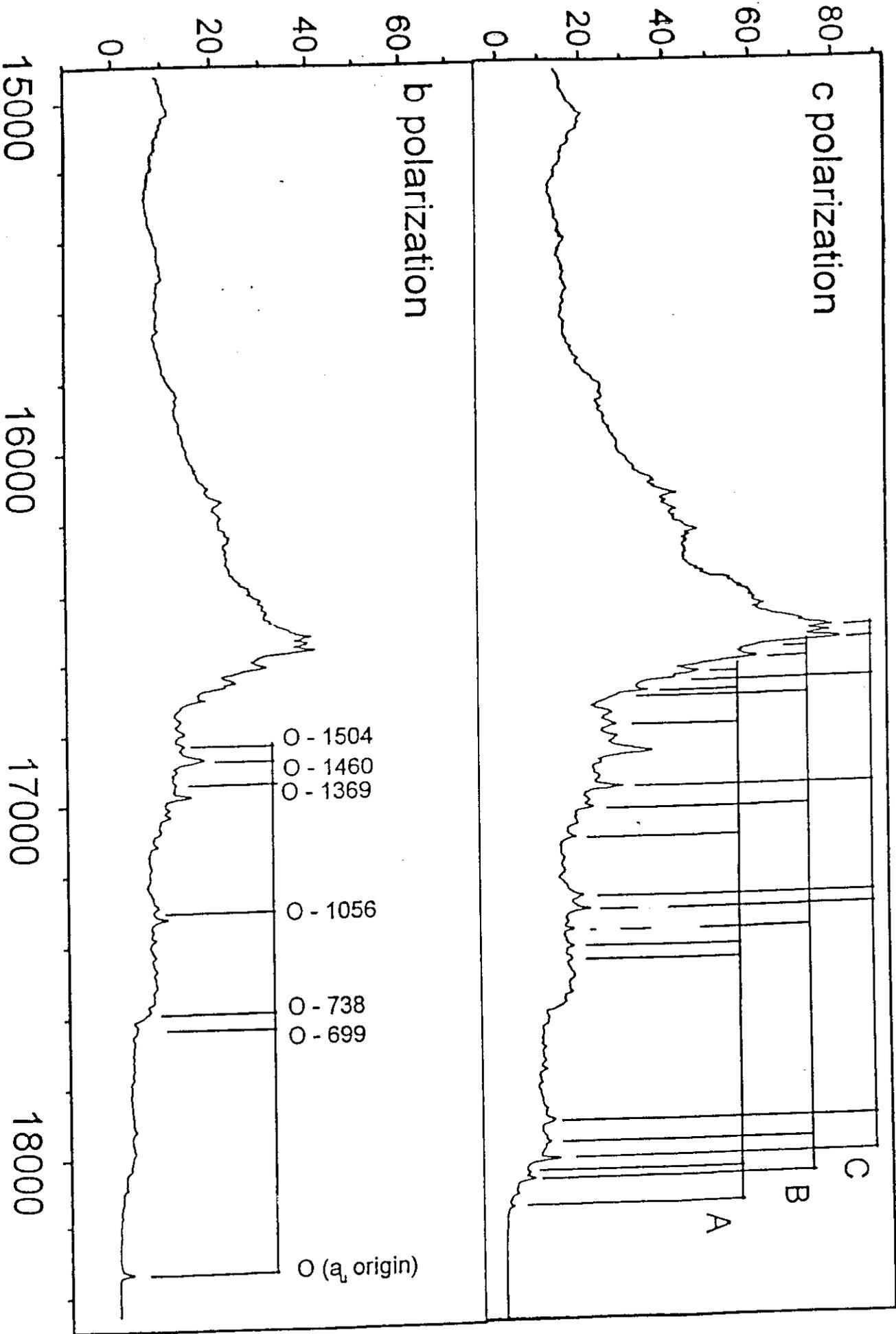
**THIRD WORKSHOP ON
THIN FILMS PHYSICS AND TECHNOLOGY
(8 - 24 MARCH 1999)
including
TOPICAL CONFERENCE ON
MICROSTRUCTURE AND SURFACE MORPHOLOGY
EVOLUTION IN THIN FILMS
(24 - 26 MARCH 1999)**

**"Organic thin films for electronics and photonics"
Part III**

**Carlo TALIANI
Consiglio Nazionale delle Ricerche (C.N.R.)
Istituto di Spettroscopia Molecolare (I.S.M.)
Via Gobetti 101
40129 Bologna
ITALY**



Fluorescence

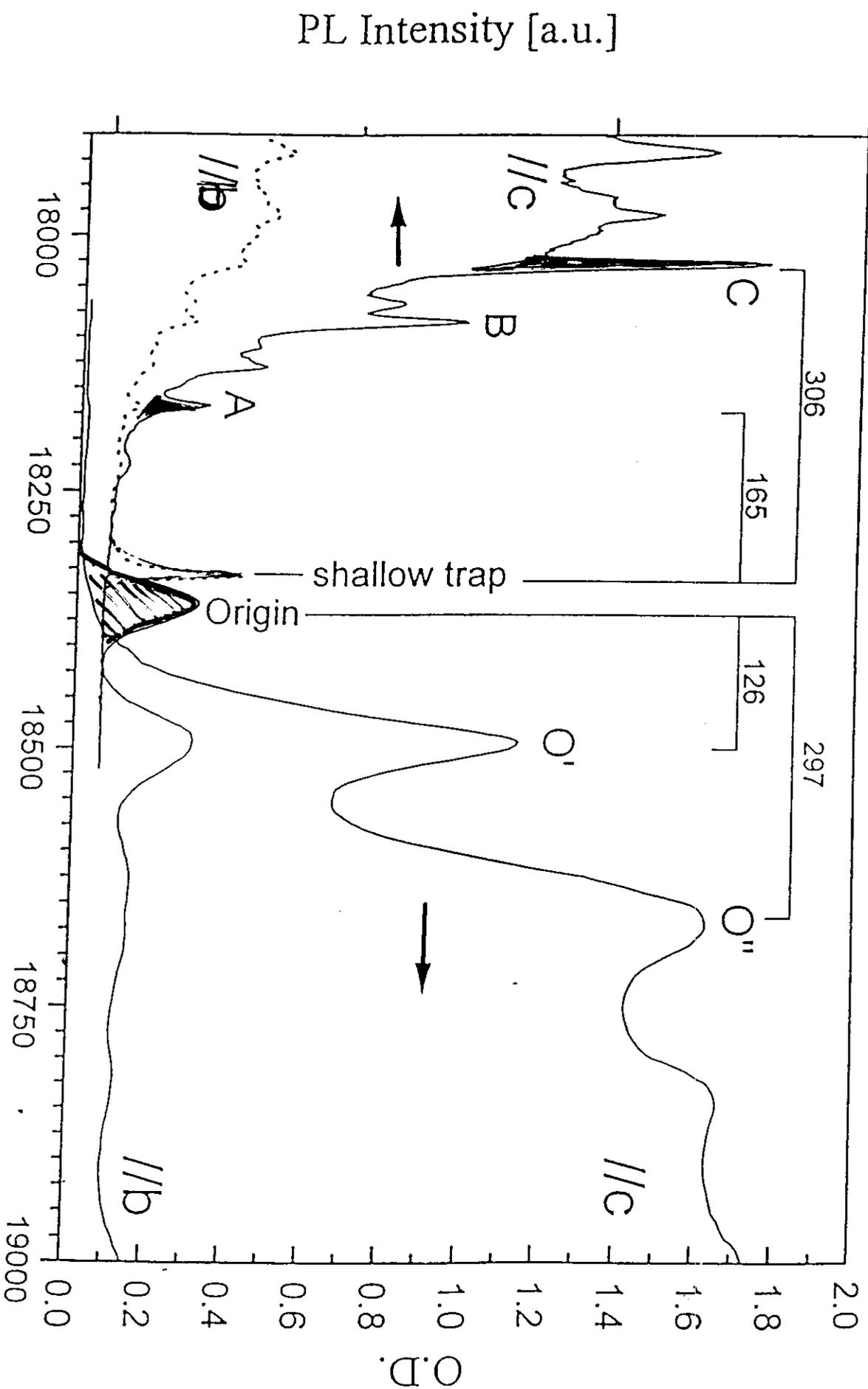


Polarized Single Katalic.

Fluorescence

4.2K

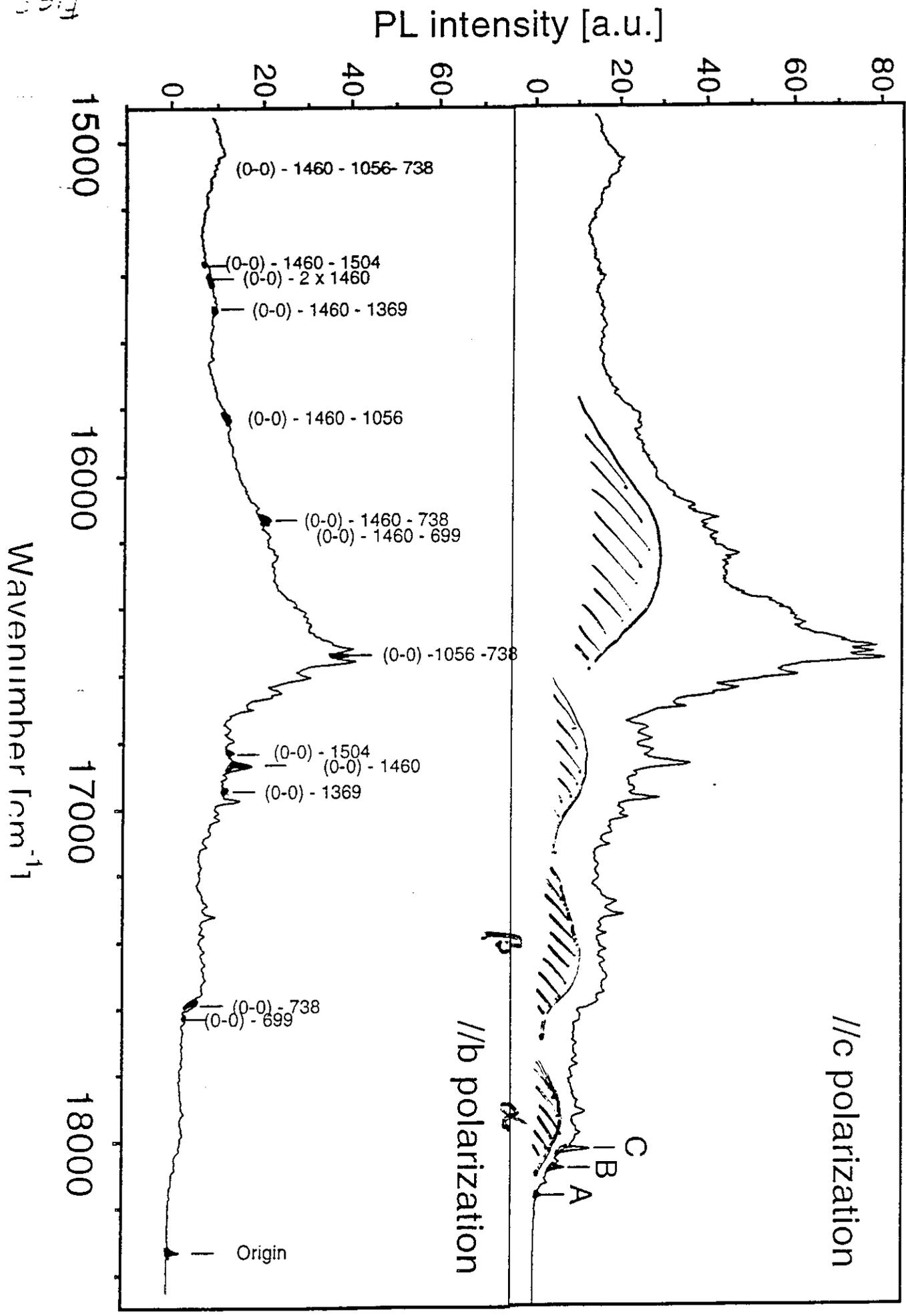
Absorption



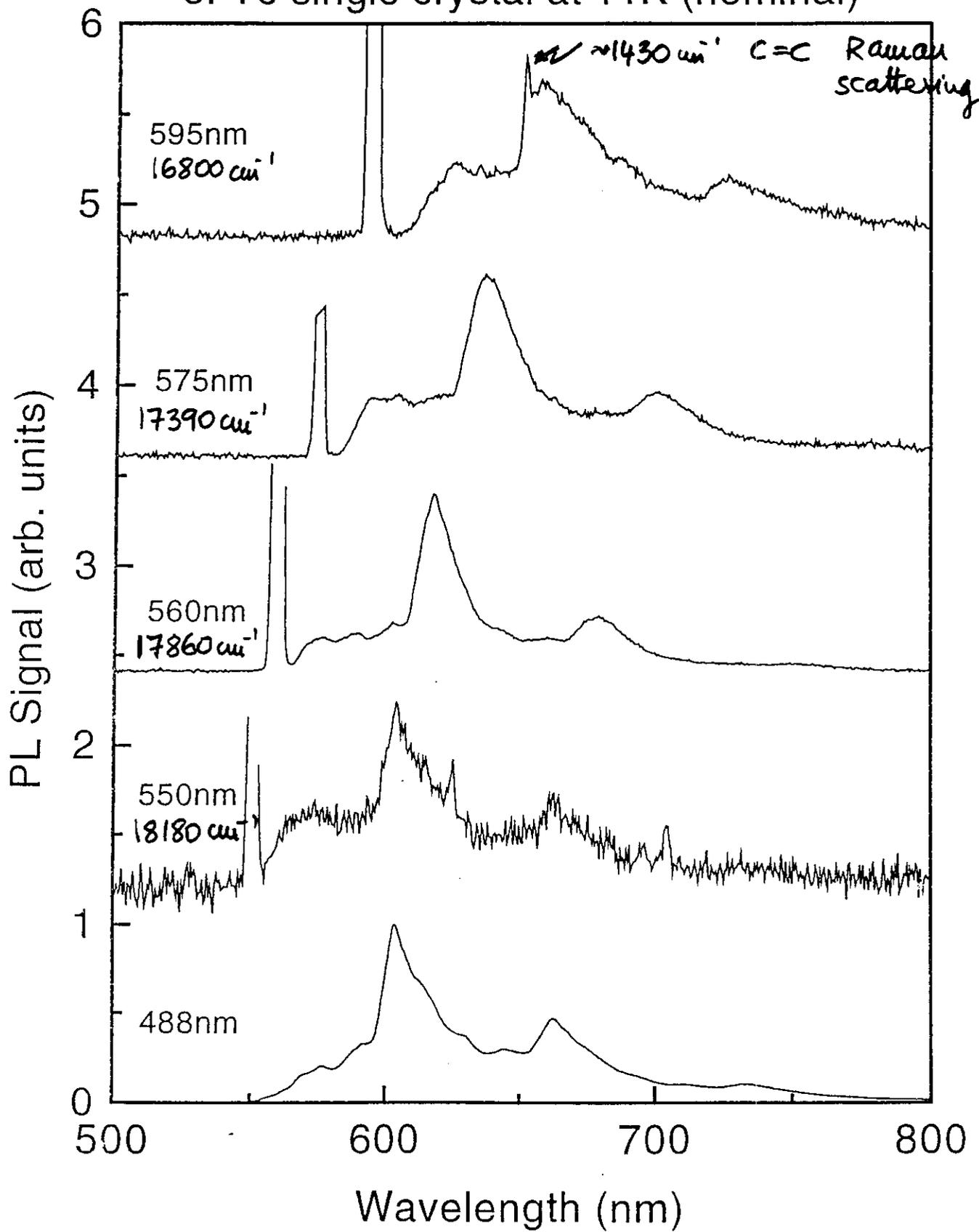
- R.M. Harke et al. *Chem. Phys.* **227**, 49 (1998)
- M. Muccioli et al. *J. C.P.*, **108**, 7327 (1988); *ibid* *J. C.P.* (1988)

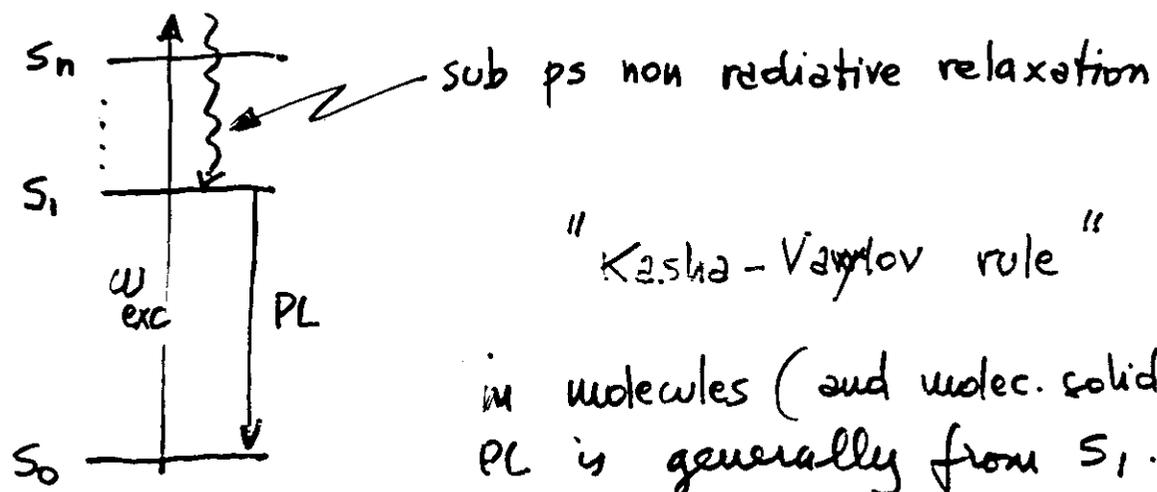
Ti single crystal fluorescence @ 4.2K

Fig. 3



Site-selective fluorescence
of T6 single crystal at 11K (nominal)

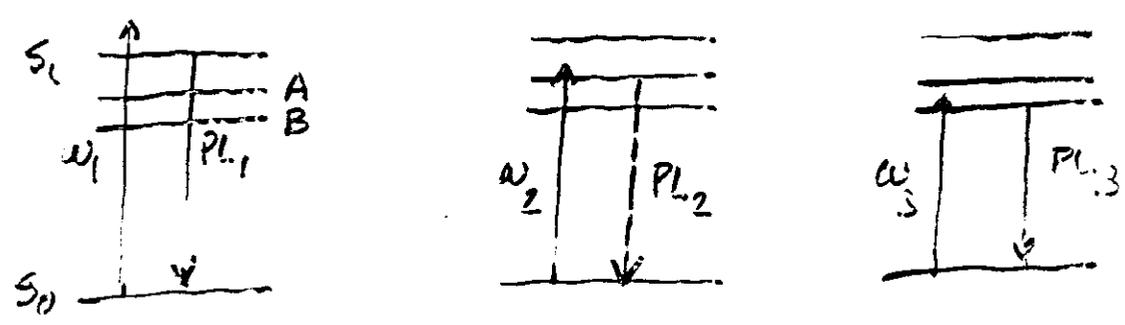




Site selective photoluminescence

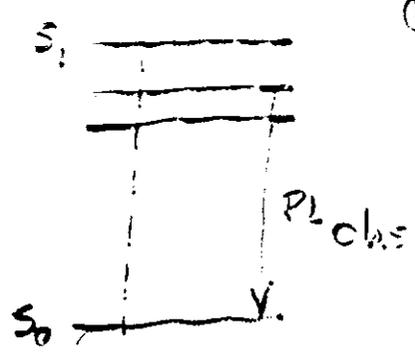
Changing ω_{exc} \rightarrow Measuring PL spectrum

if $K_{NR} S_1 \rightarrow A$ and $S_1 \rightarrow B \approx 0$



Photoluminescence Excitation

Scanning ω_{exc} \rightarrow Measuring PL at fixed frequency



Fluorescence excitation spectrum of αT_6 single crystal.

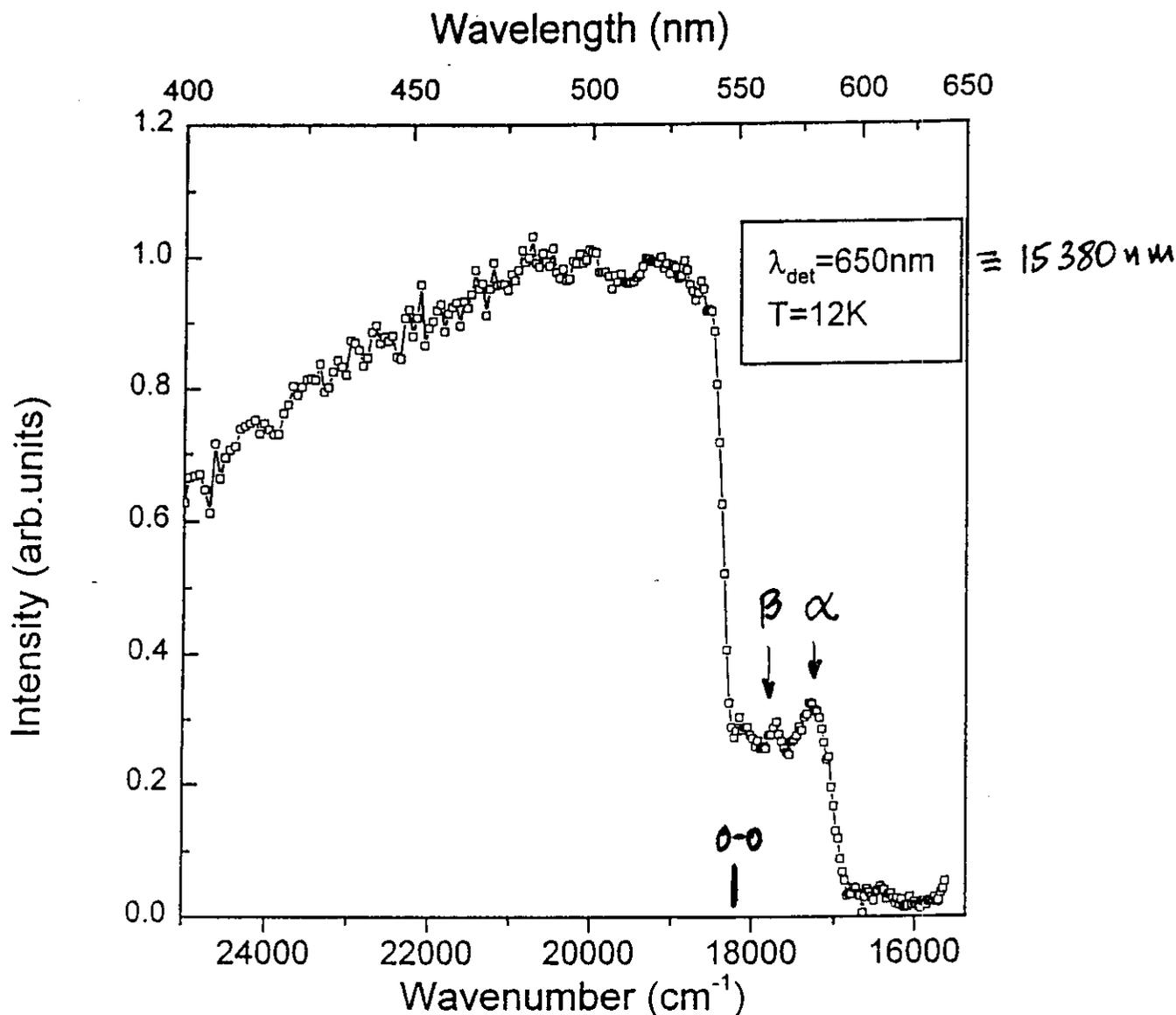
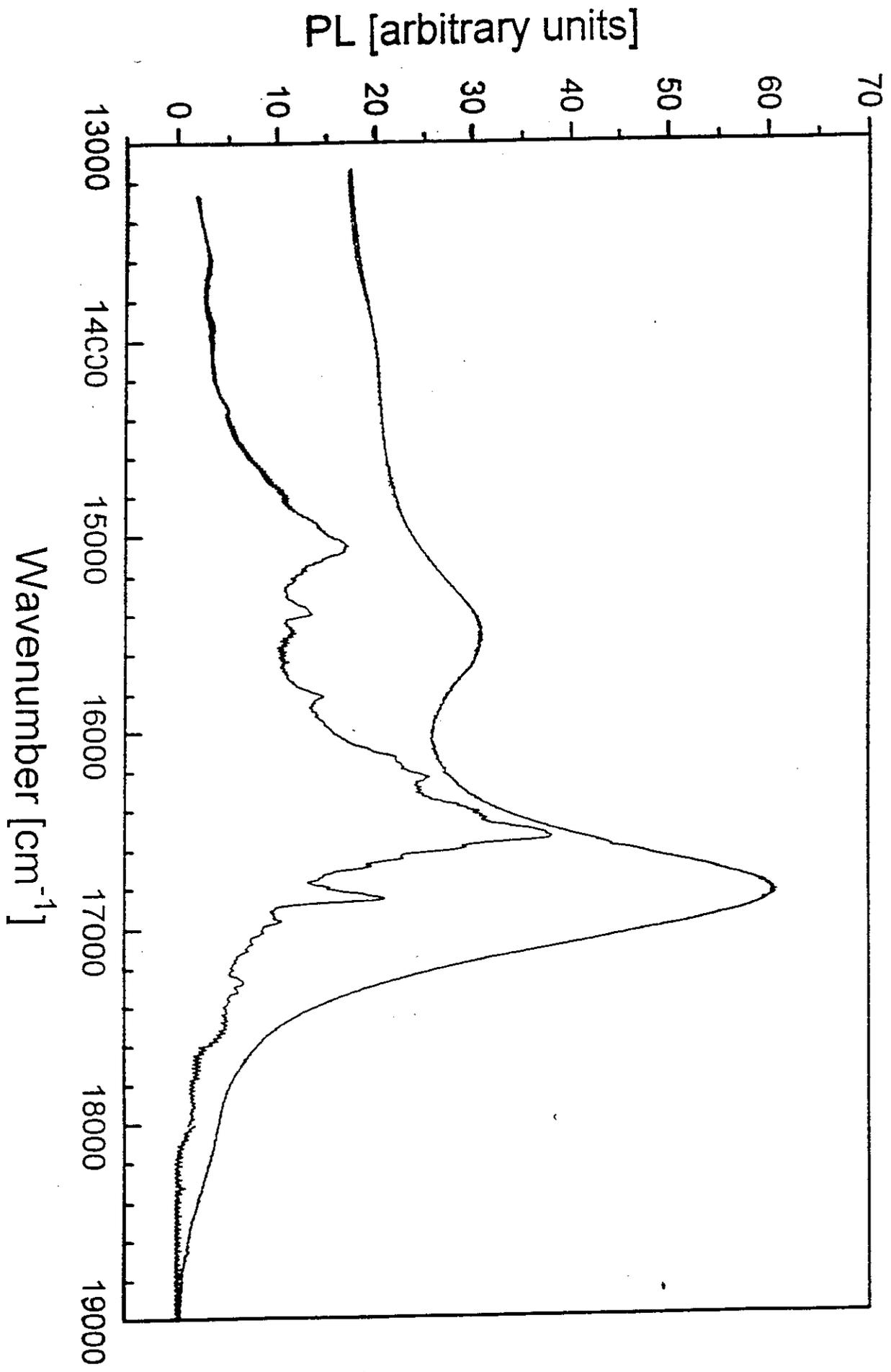


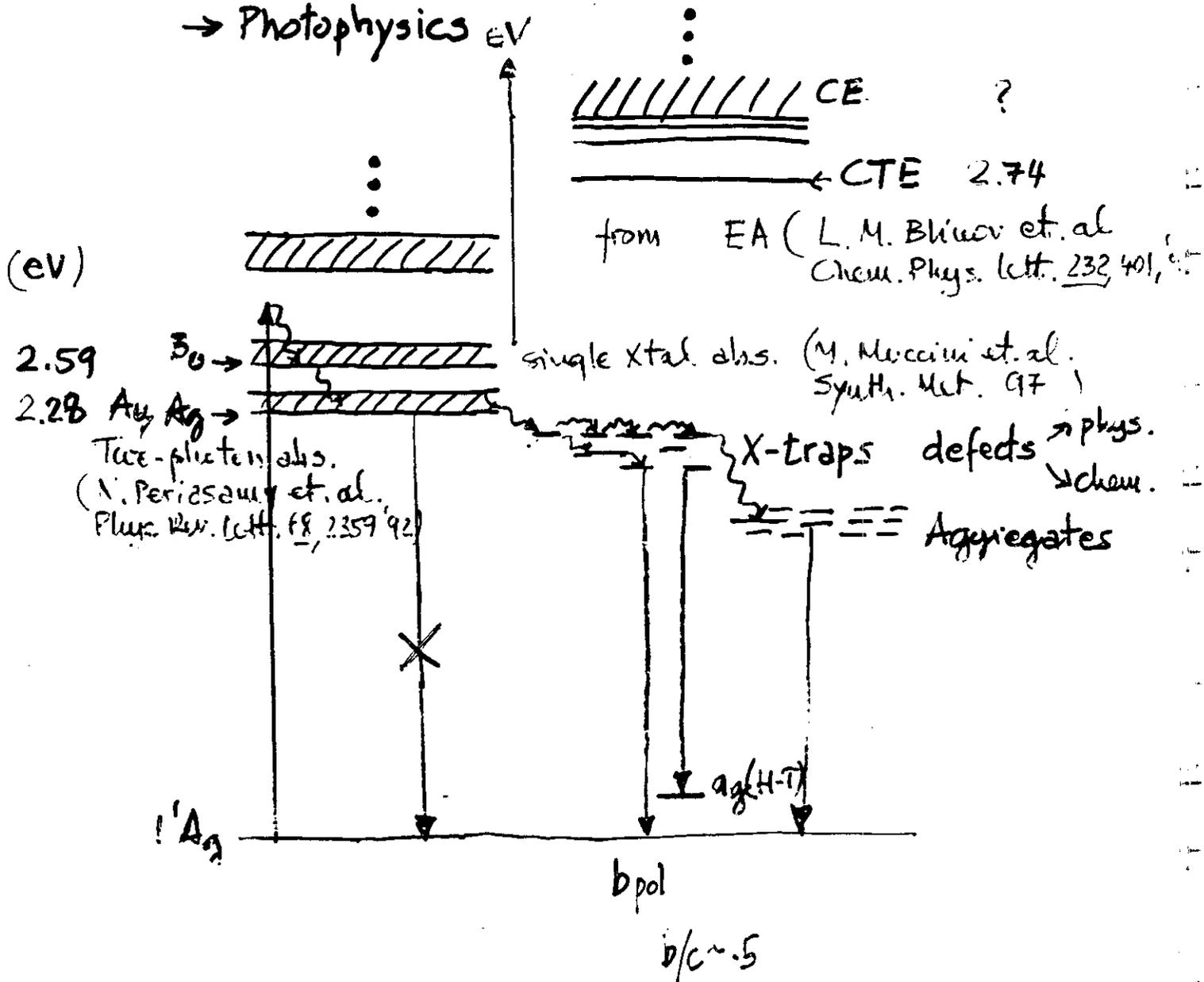
Fig.5 R.N.Marks et al. Disorder influenced...

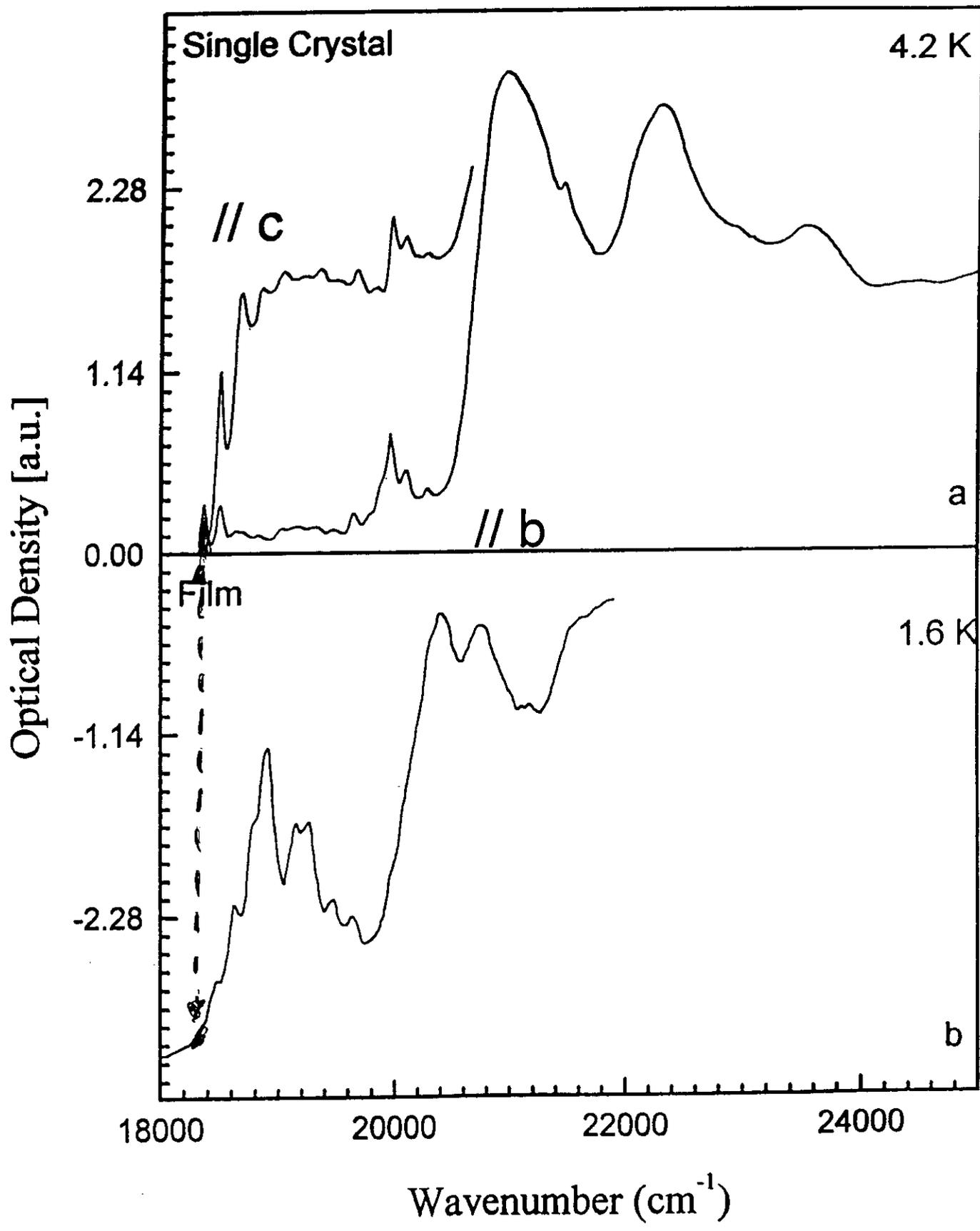
Chem. Phys. 227, 47 (1998)

Photoluminescence spectra of two αT_6 single crystals



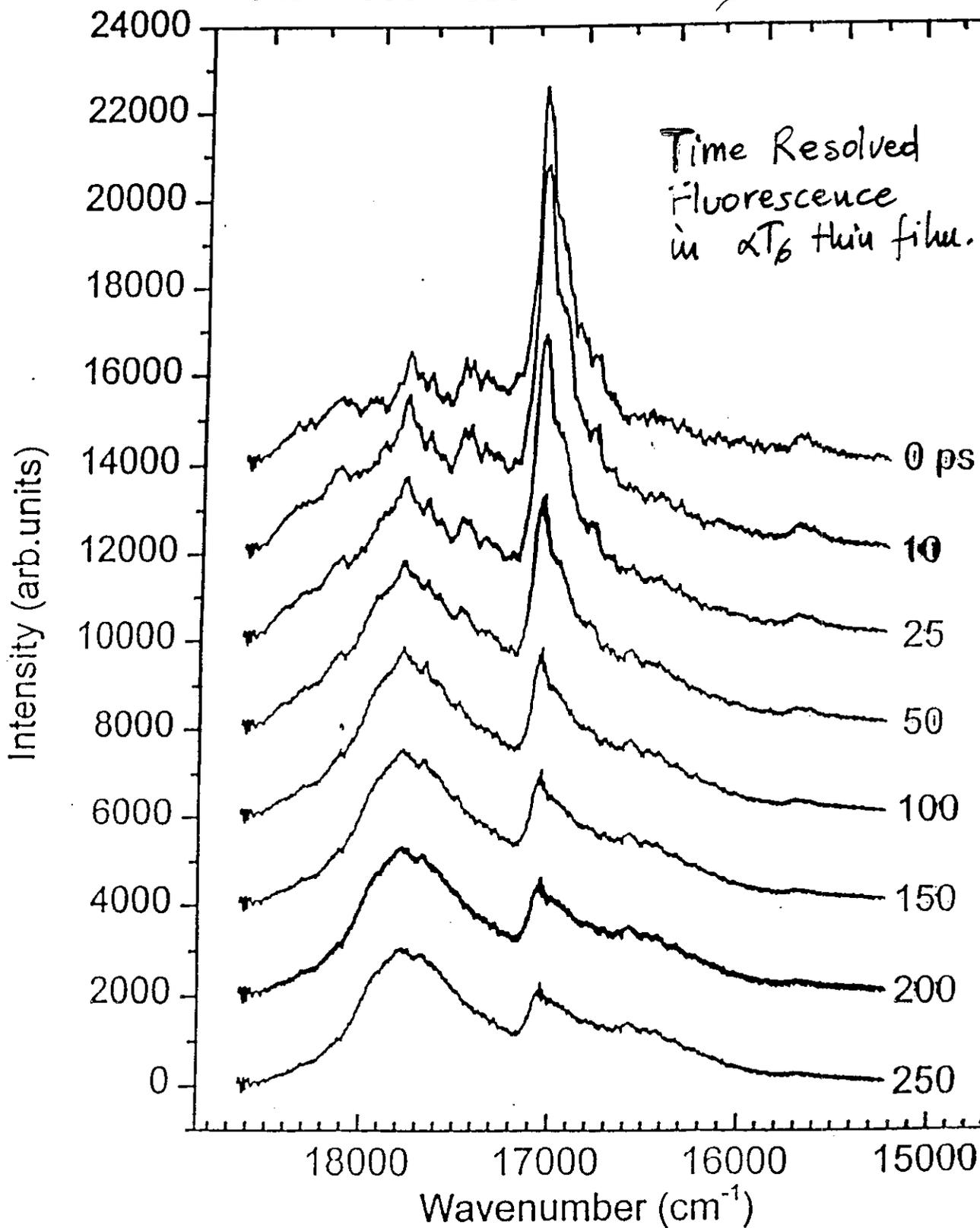
- T_6 lowest el. excited states and
- Photophysics eV



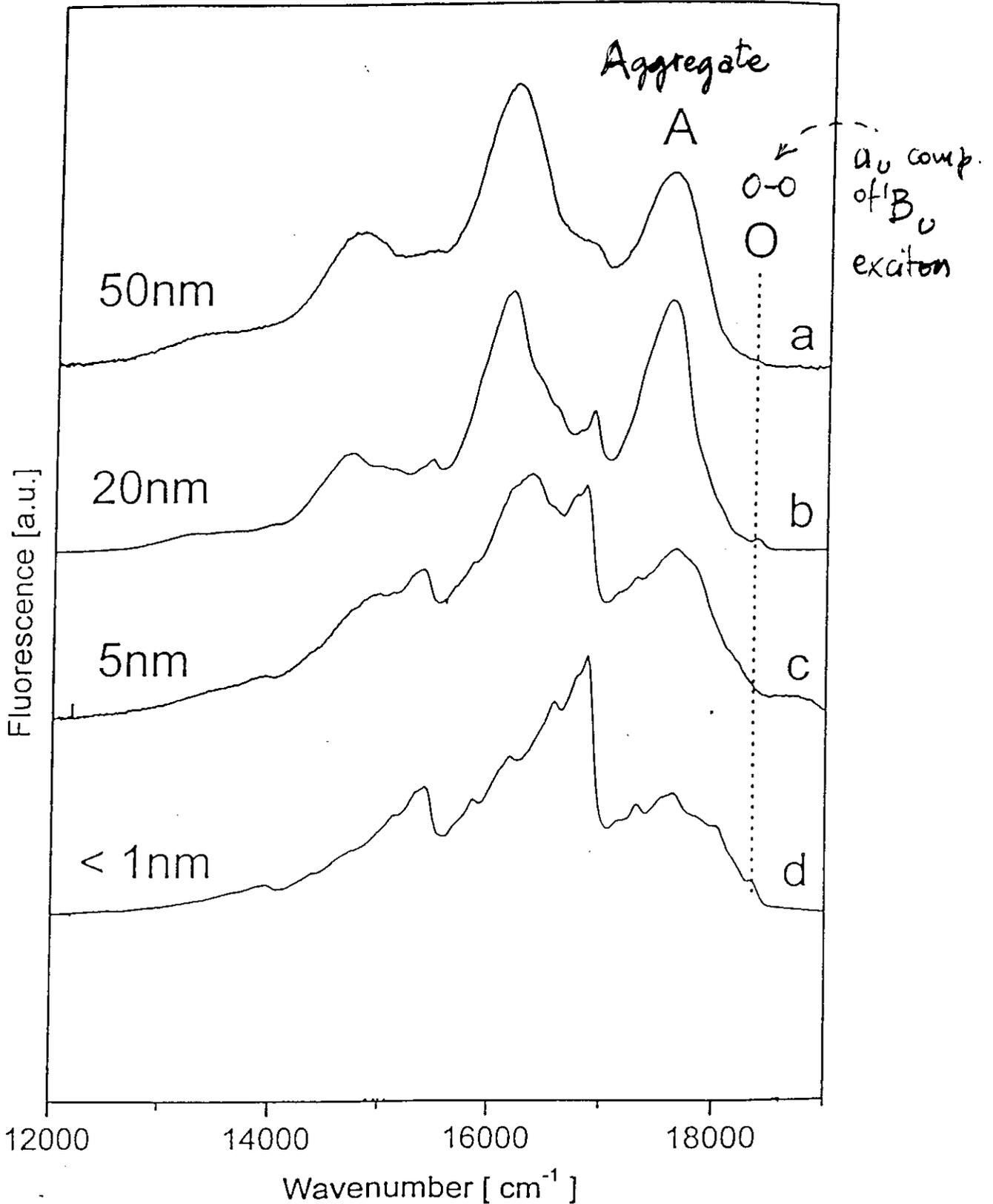
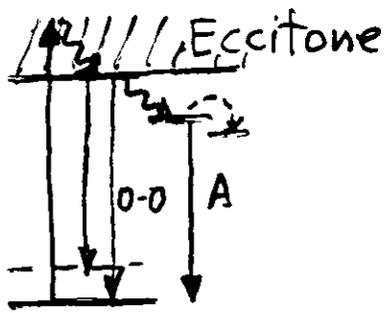


Wavelength (nm)

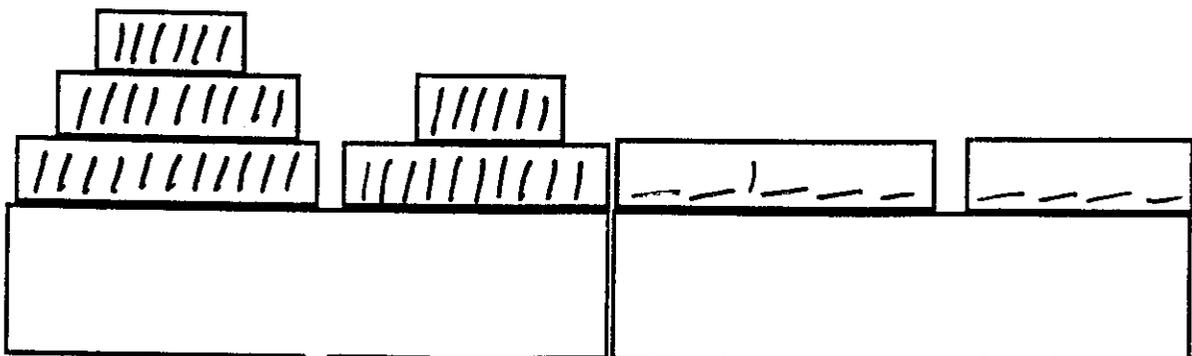
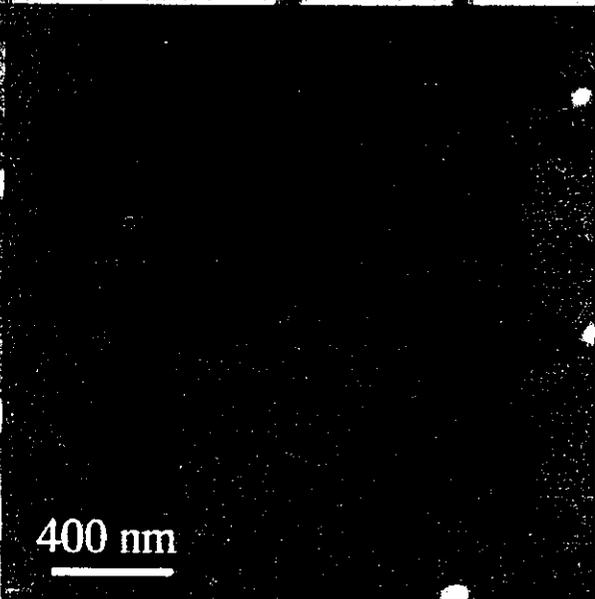
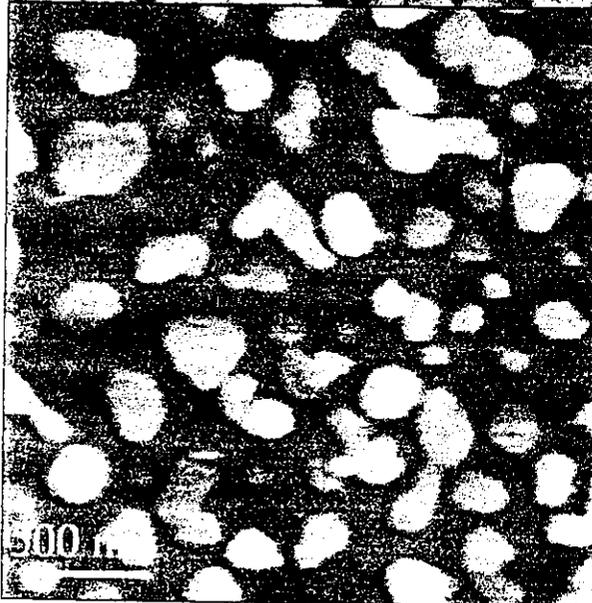
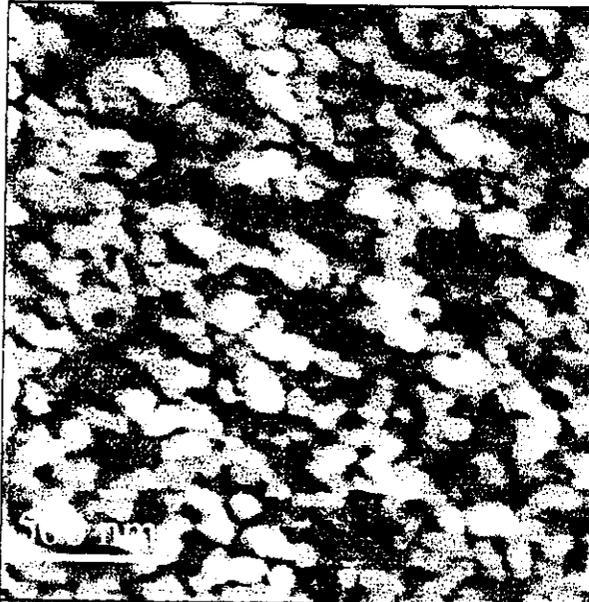
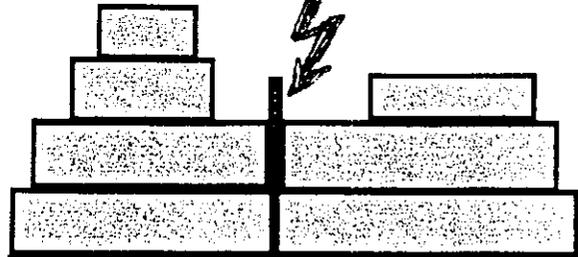
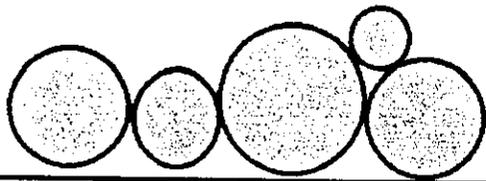
540 560 580 600 620 640 660 680 700



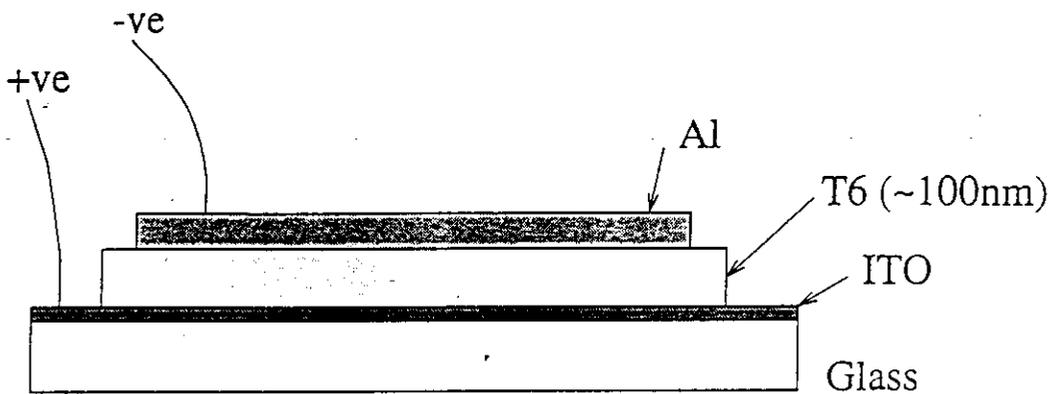
R. N. Marks et al. C.P. ('98).



E. Lunedei et. al. *Synth. Met.*

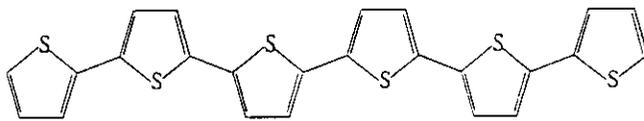


Organic Light Emitting Diode O-LED



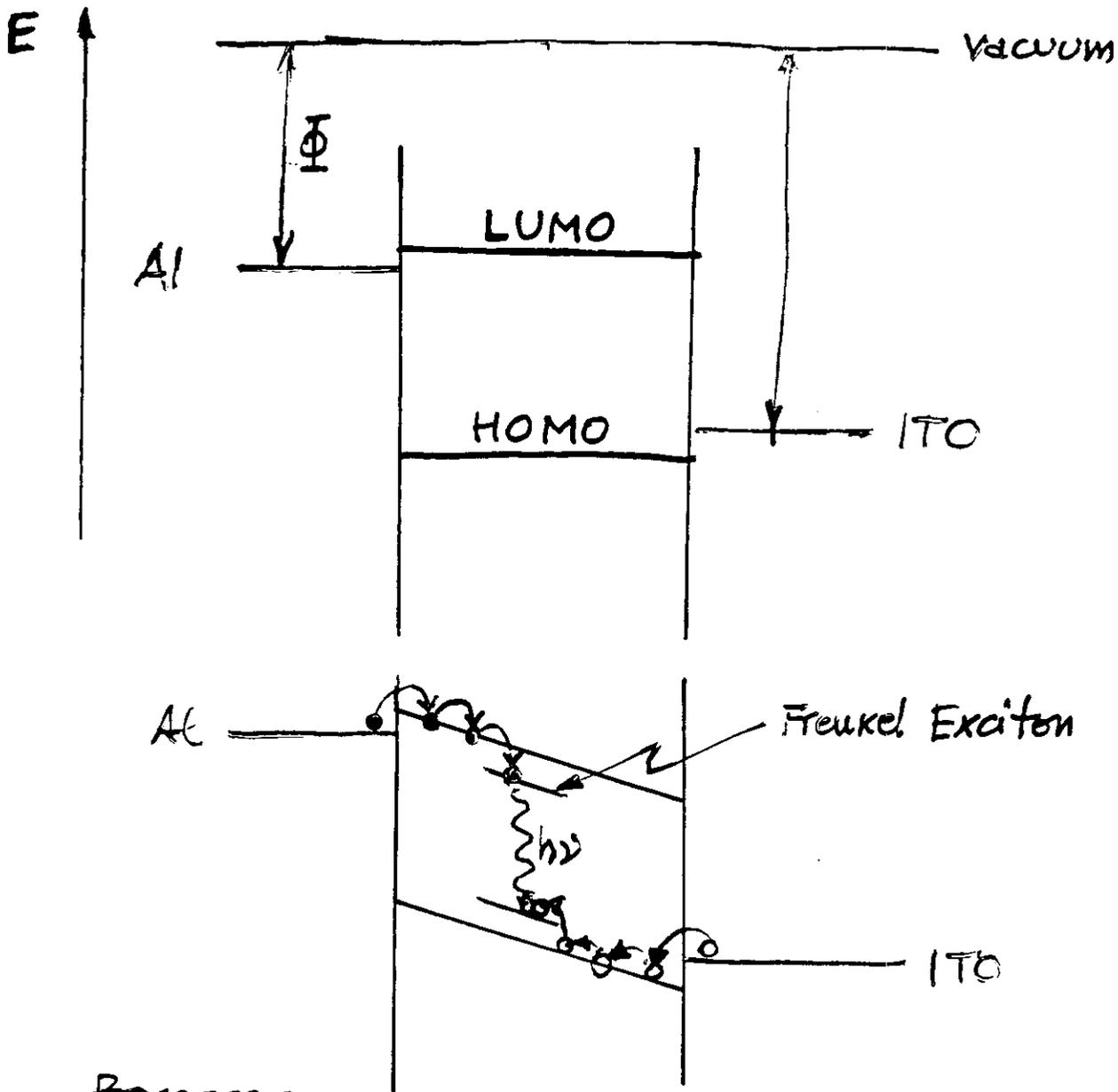
Device area $\sim 6\text{mm}^2$

Sexithiophene(T6) :



- Turn on voltage : 2 - 2.5 V
- Operating voltage 2 - 8 V ($\sim 5 \times 10^5 \text{ V/cm}$)
- External quantum efficiency $\sim 0.1\%$
(\sim same as Al/PPV/ITO)
- Lifetime $\sim 10^4$ h in 10^{-2} Torr vacuum.

OLED



Processes

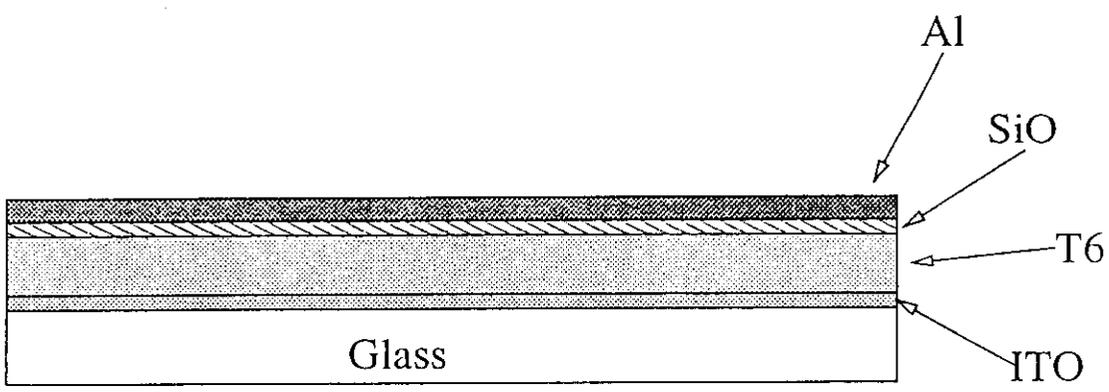
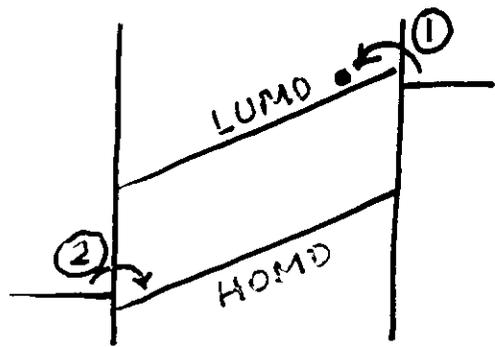
charge injection	electrons *	Shottky barrier → Tunneling
	holes	Thermionic injection
charge transport	holes	majority carriers
	electrons *	
charge trapping		oxygen, defects
recombination	exciton	
transport	" diffusion	
radiative emission		

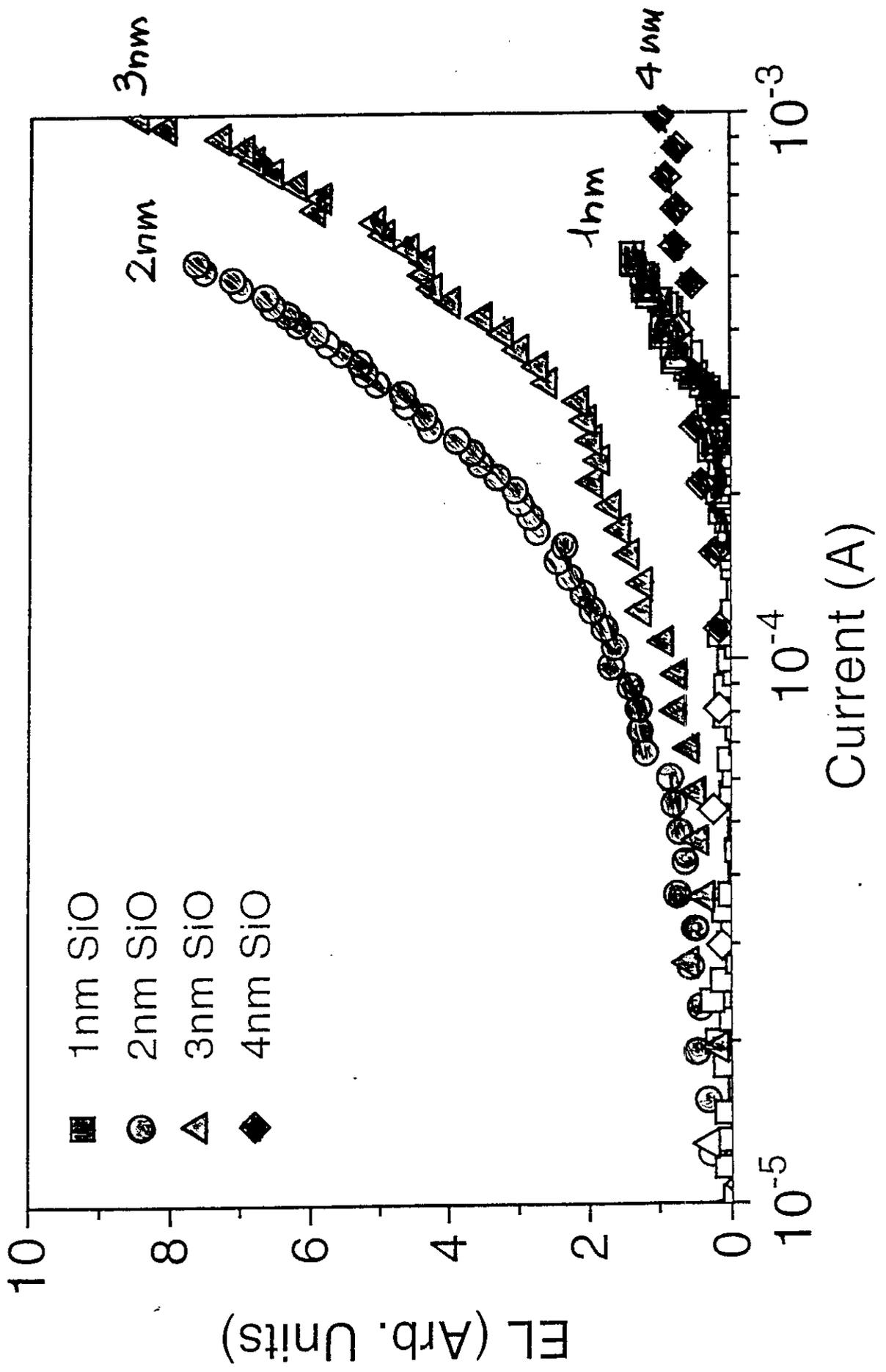
Review article

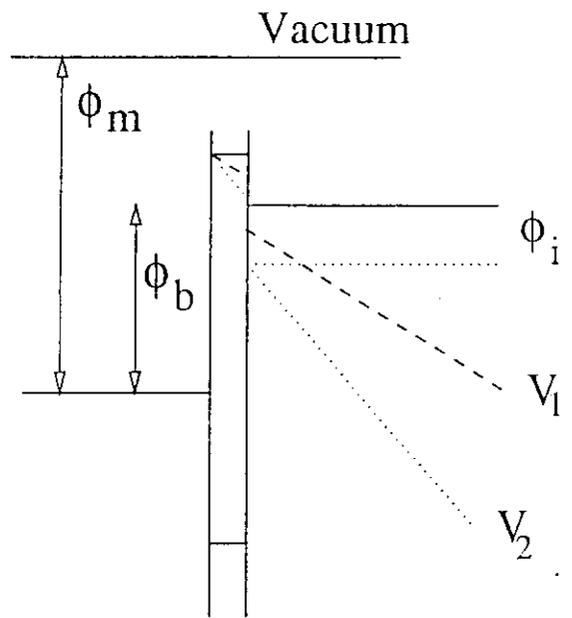
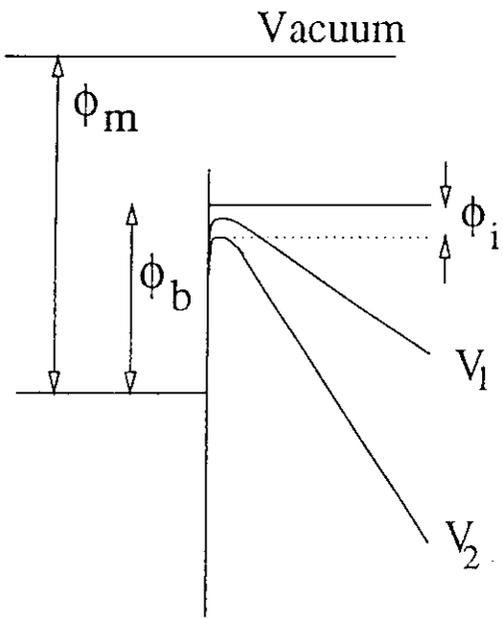
R. H. Friend et. al. Nature 397, 121 (1999)

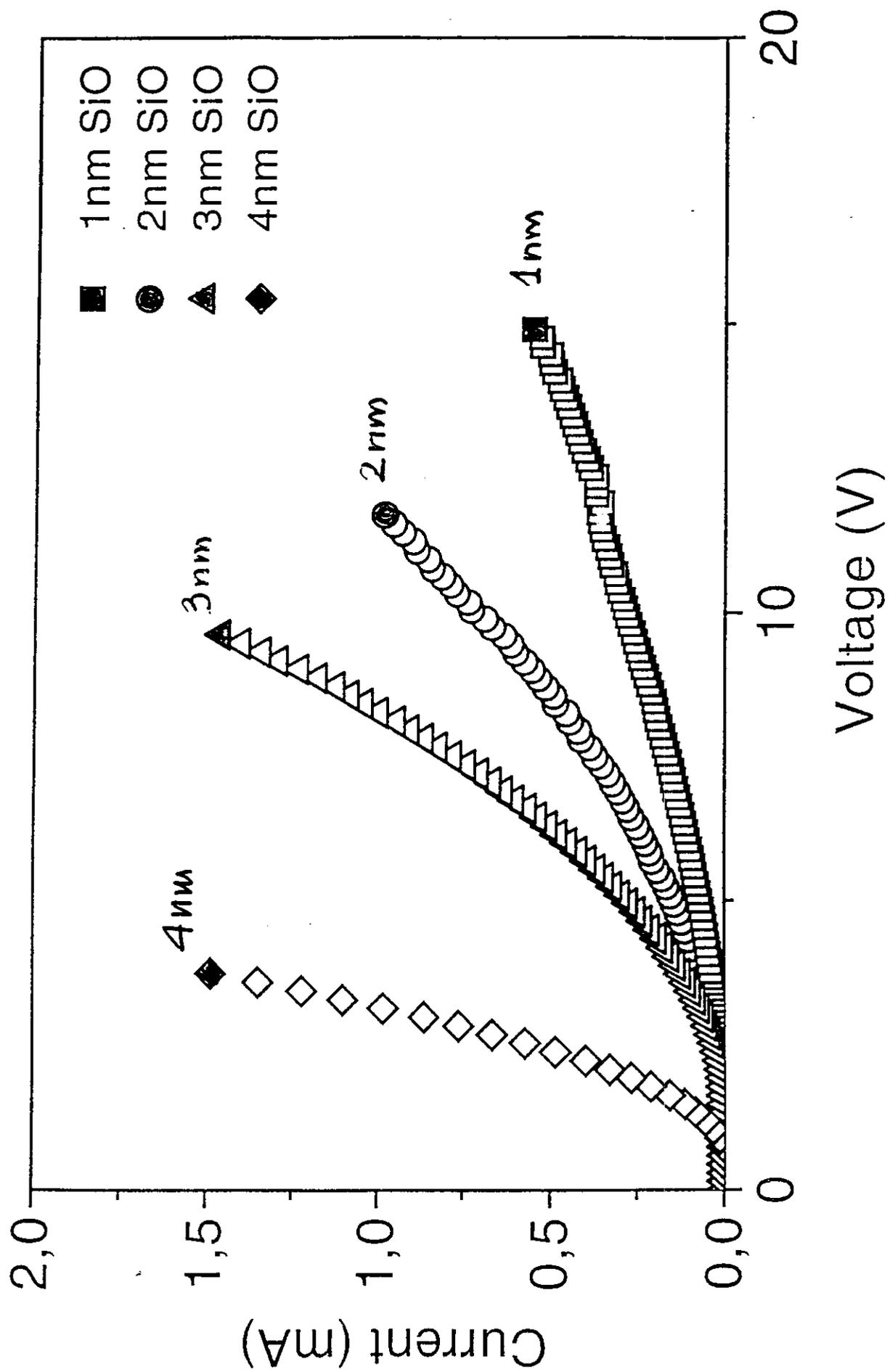
① electron injection

② hole injection

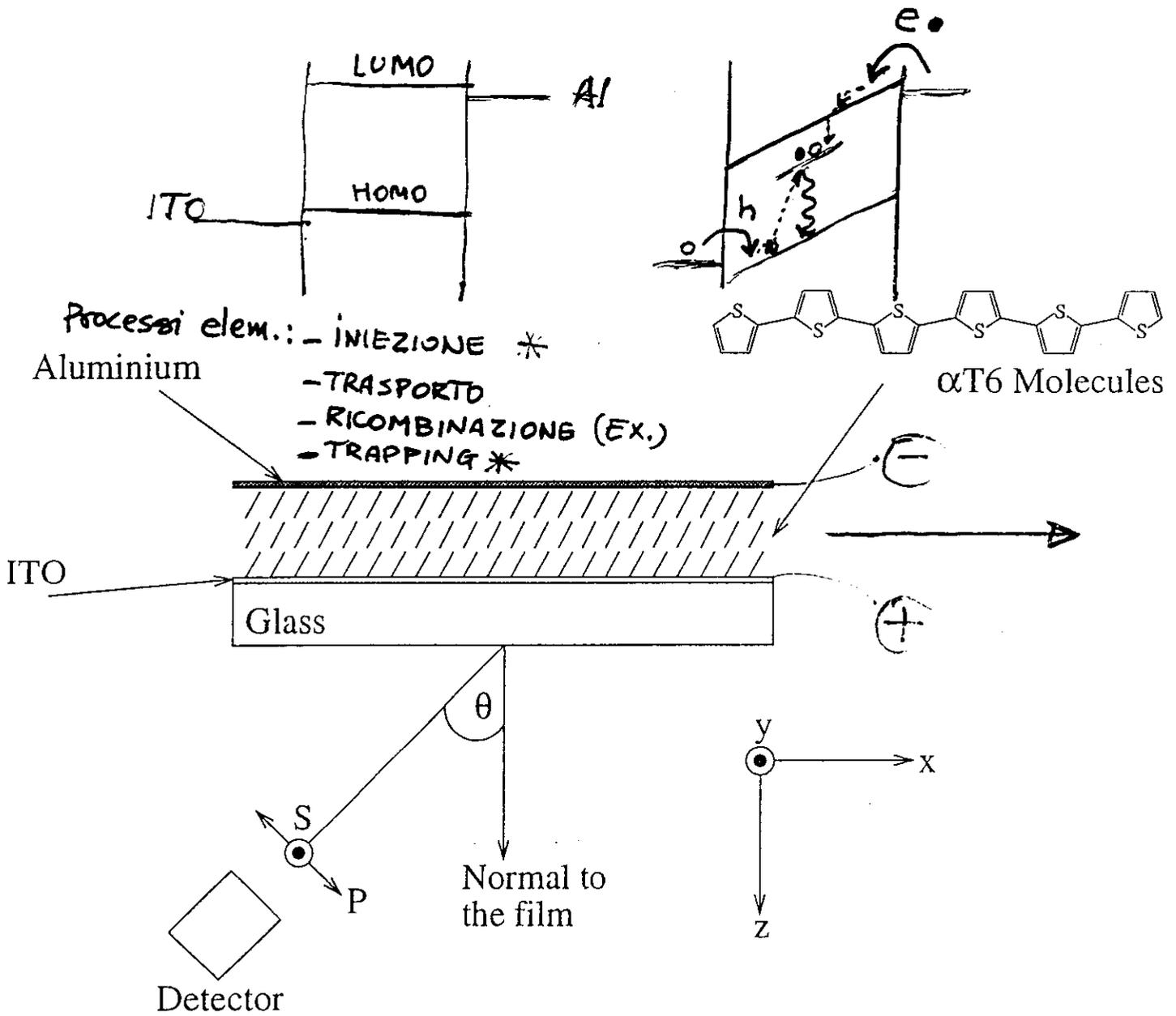






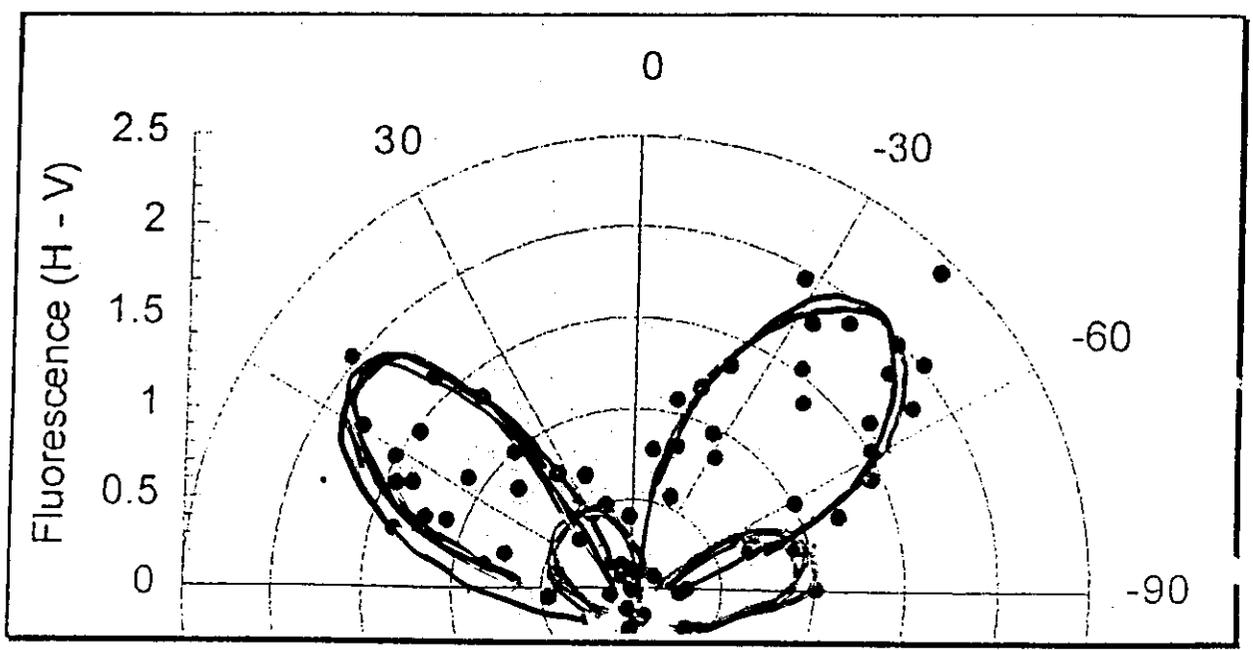


Polarized Electroluminescence

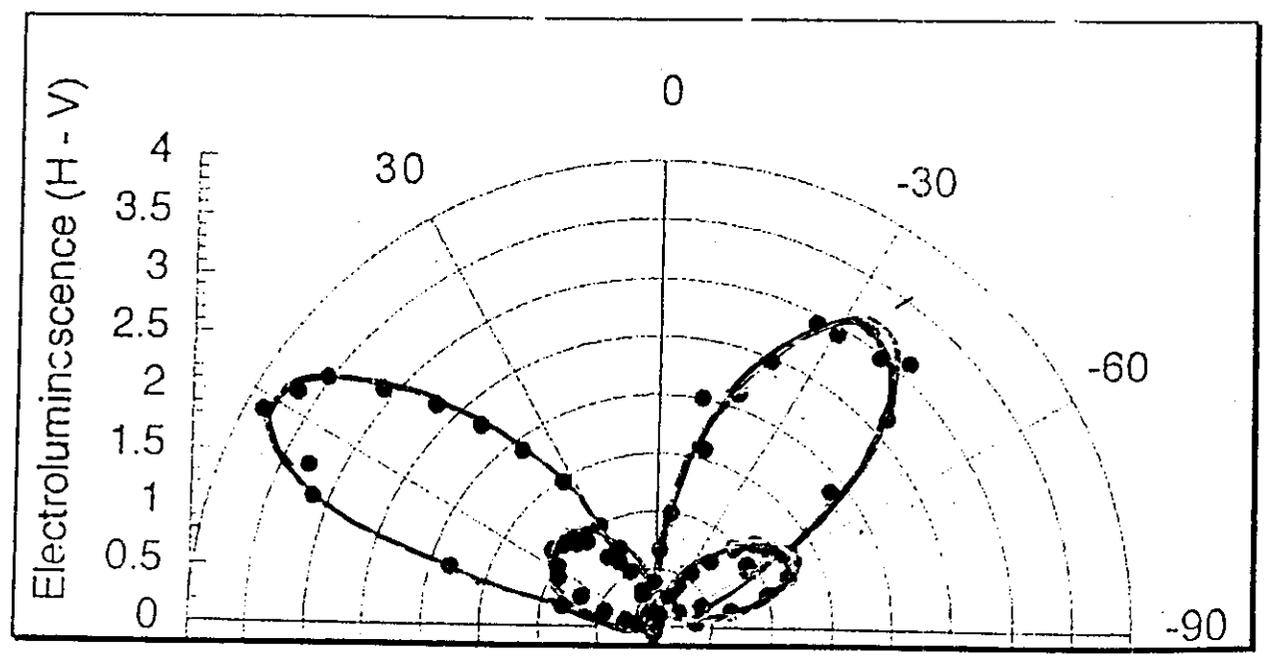


R. MARINIS et al.
 Europ. J. Phys. Lett. 32, 523 (1995)

a



b



\bar{D} 1400 nm
(Av. diameter) 620 " "
2.15 " "

OLED status

Patents



approach

polymeric mat. Cambridge
(~1990)

molecular mat. Eastman Kodak
(~1987)

brightness $\gg; \geq$ CRT

colours red, green, blue

stability $> 8'000$ h



Problems

electron \neq hole injection \rightarrow stable interfaces

better ^{electron} ~~hole~~ transport mat.

higher mobilities of e ... and h

better stability of charge carriers \rightarrow e



Opportunities

large area displays (\square 25% and more)

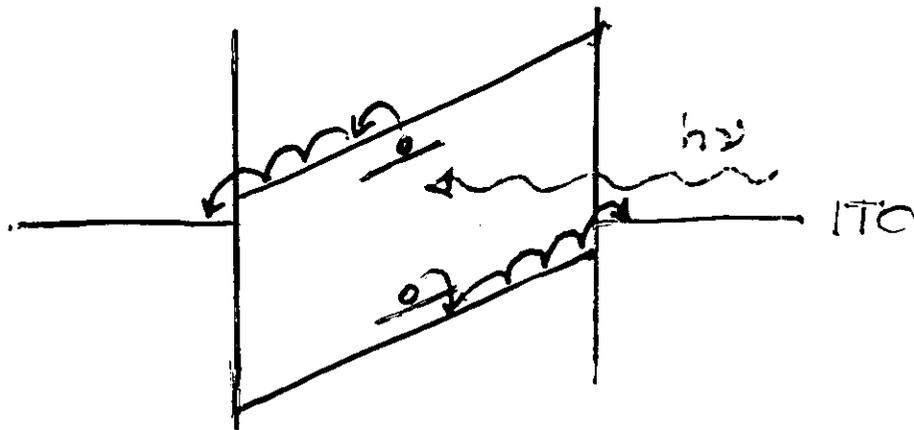
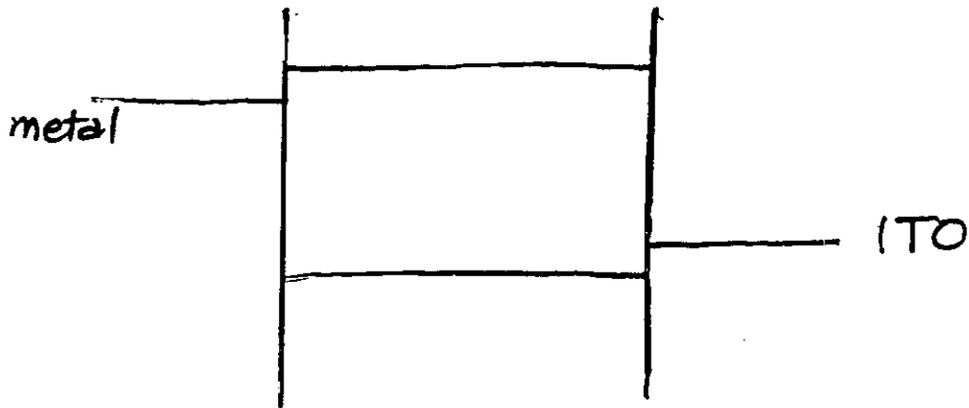
flexible substrate

- cellular telephones

- monochrome TV

- lap. top.

Organic Photovoltaics



excitonic absorption
exciton dissociation
charge transport

electrode (interface transport)

large oscillator strength
 E_{ex} , disorder, int. E_f
collection *
large area interface
separate interconnects *
barriers *
ohmic contacts for e⁻ *

Strategies to Increase the Efficiency of p-n type Organic Solar Cells

Main problem:

extremely thin active layer

A inactive l.



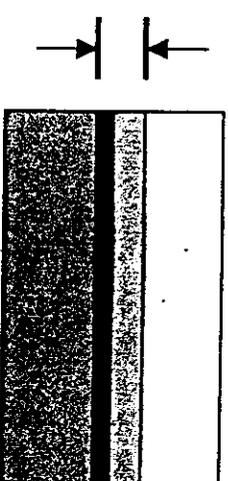
B inactive l.



A active l.



B active l.

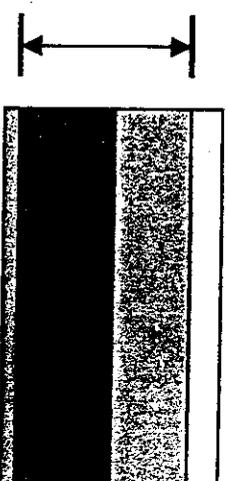


Solution I: Increase of active layer thickness

Pureness of material; Morphology;

Doping; Gradient films; Doping profiles;

Mixed Layers



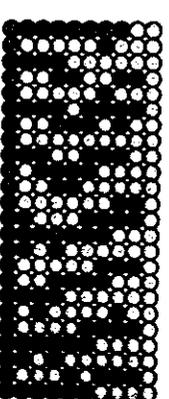
Solution II: New cell structure

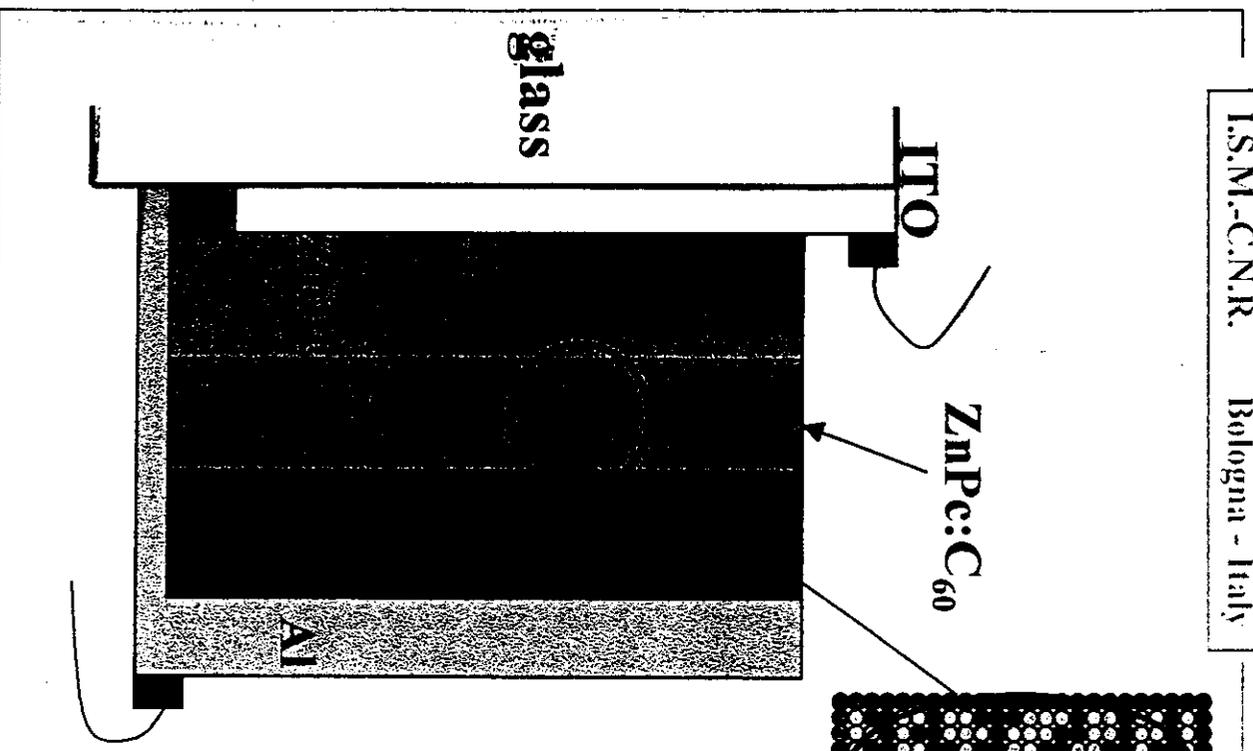
Multiple tandems;

active layers \perp incoming light



inter-digitated p-n junction



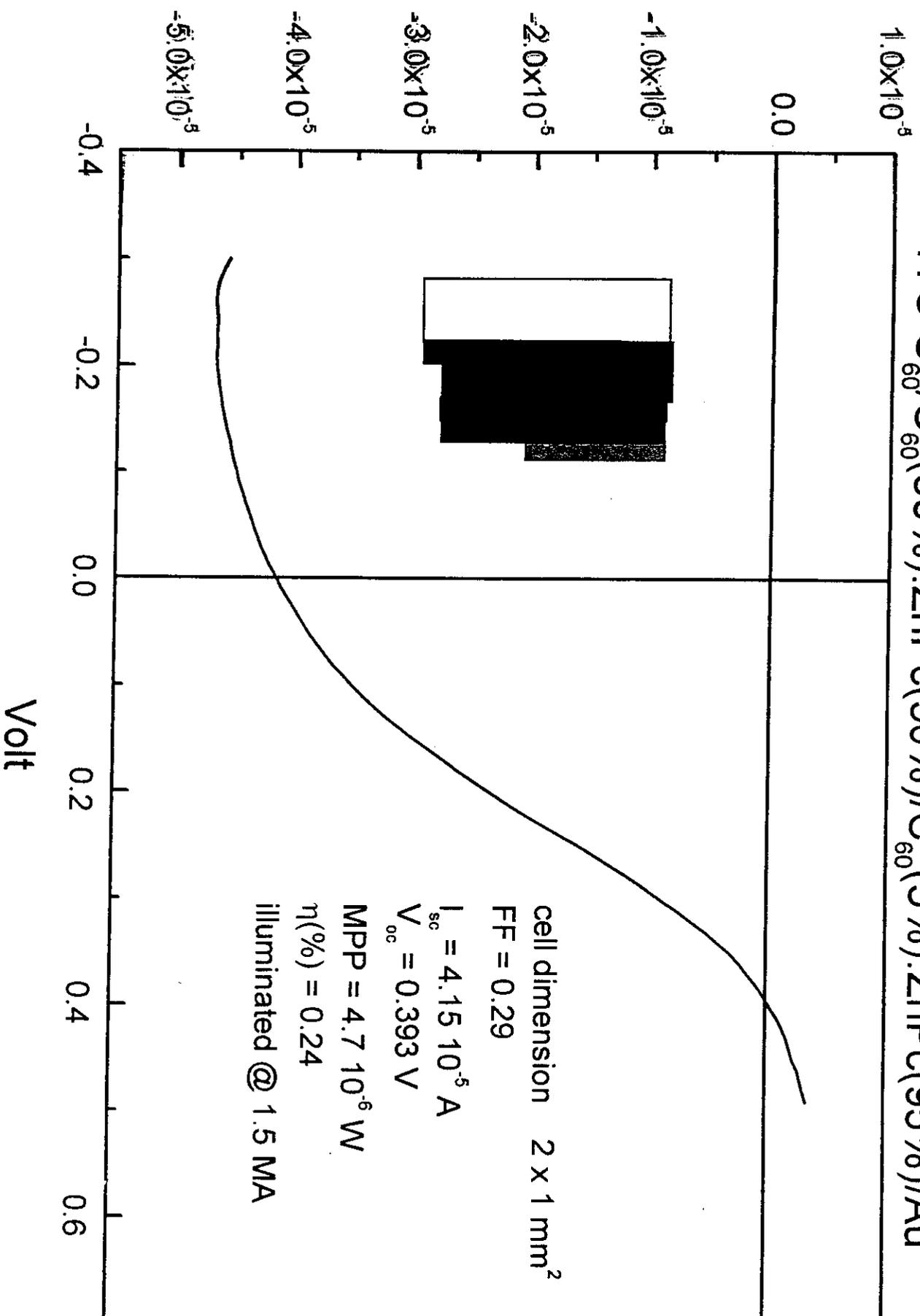


Interdigitated *p-n* junction

- ⇒ Increase *p-n* surface
- ⇒ Increase active layer thickness
- ⇒ Decrease of luminescence
- ⇒ Decrease of losses
- ⇒ C60 electron transport mat. ⇒
- ⇒ Increase of electron mobility in *p* active region?

ZnPc (40nm)/ZnPc:C₆₀(10nm)/C₆₀(40nm)

ITO C₆₀/C₆₀(50%):ZnPc(50%)/C₆₀(5%):ZnPc(95%)/Au



Organic Photovoltaics status

Approach thin films
electrochemical cells

Power Efficiency $\leq 1\%$

Stability ?

problems

better charge collection

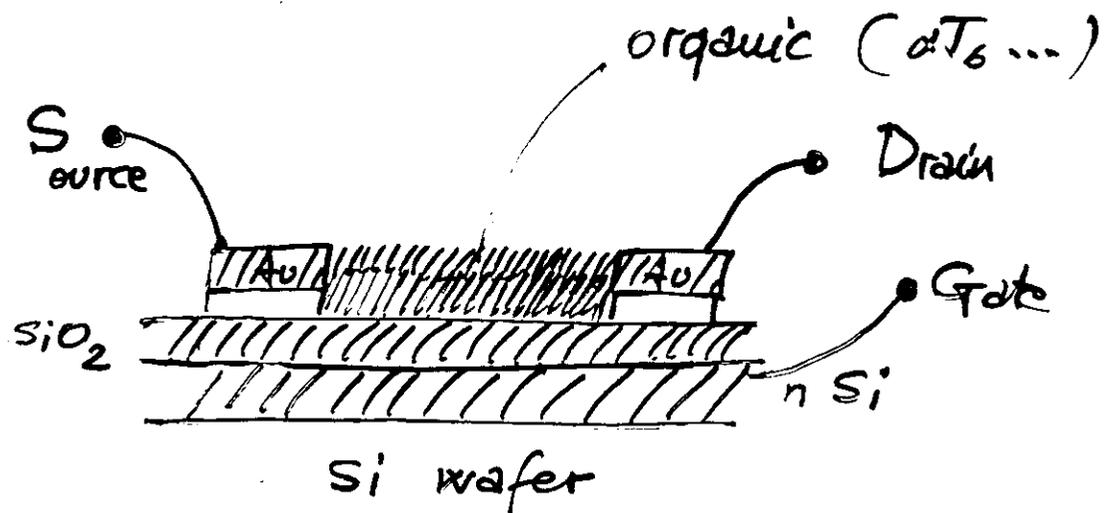
ohmic contacts - cathode!

better matching of electronic
levels of organics & electrodes

perspectives

integrated "all plastic" electronics.

Organic Field Effect Transistor



History

□ Thuisz (F. Garnier et. al. 1989)
first αT_6 based FET

Bologna 1991 confirmation (αT_6)

Japan, Sweden polymer FET 91 \rightarrow

AT \neq T Bell Labs. 1995

improved ON/OFF ratio

various logic circuits · molecular

Philips (Eindhoven)

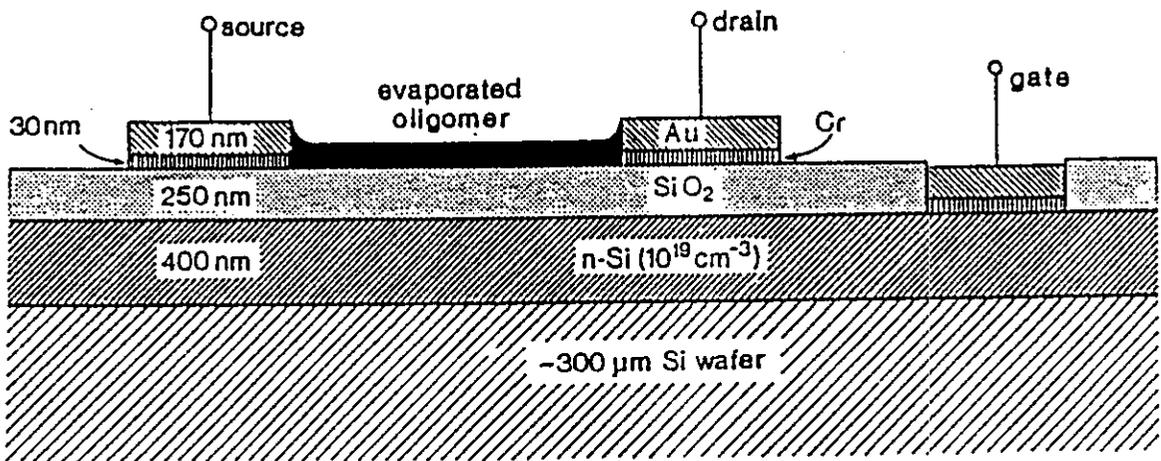
oscillators ~'96 polymer

$10^1 - 10^2 \dots \rightarrow 1^0$ of FET elements

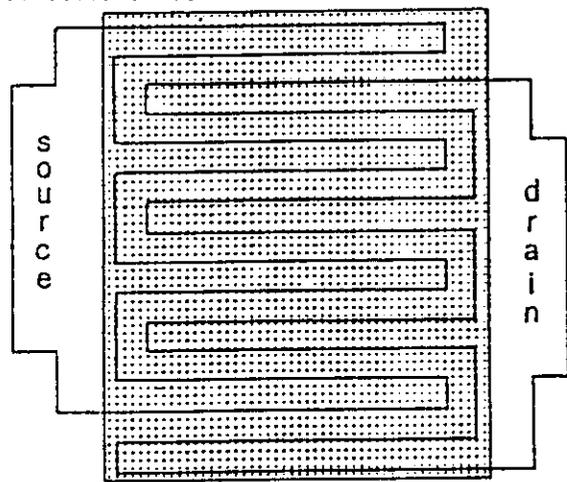
⋮
↓

market !!!

Disposable
Plastic Electronics

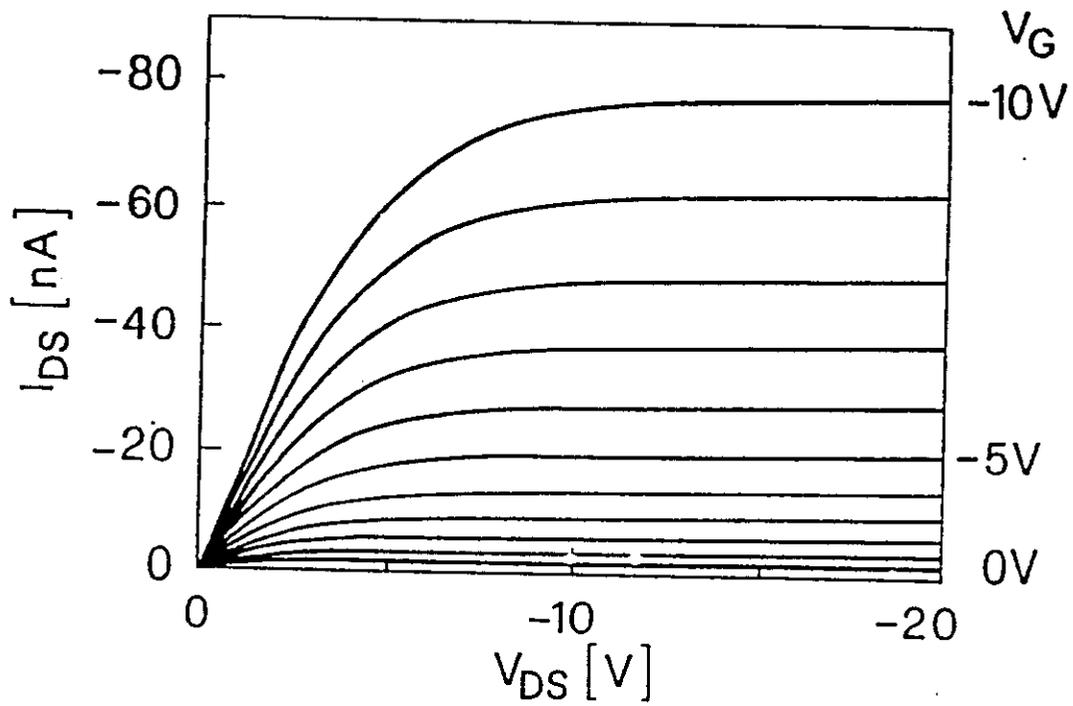


a)

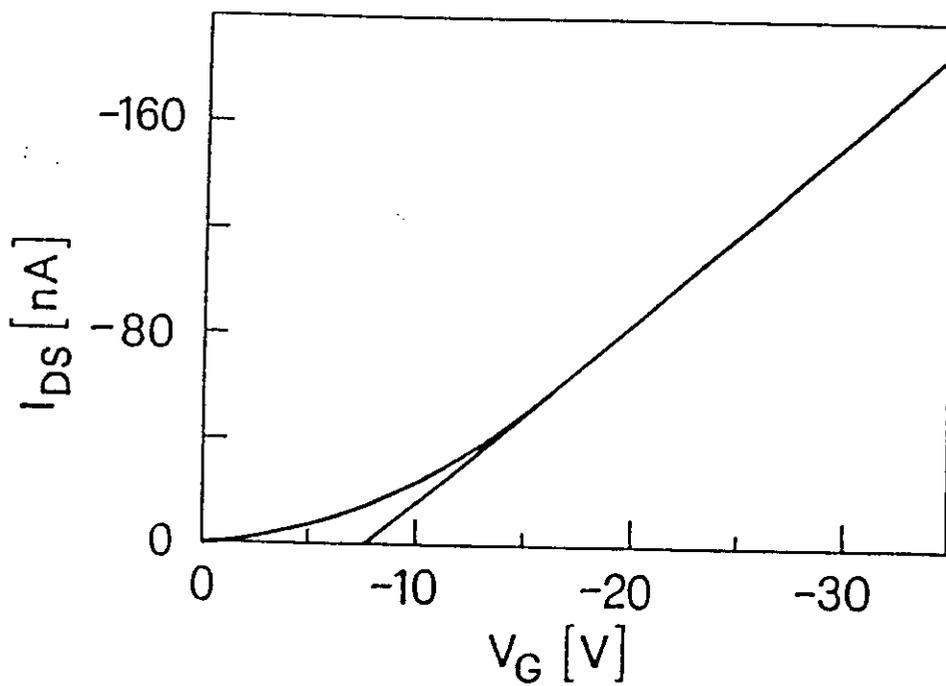


b)

P. Ostojja et. al.
Adv. Mat. Opt. Electr.
1, 127 (1992).



Output characteristics of the FET after heat treatment at 120°C for 30 min.



Transfer characteristic of the FET, from which a mobility of $7 \cdot 10^{-4}$ $\text{cm}^2/\text{V}\cdot\text{s}$ is calculated.

Organic FET

Approach

polymer

philips

molecular

AT ≠ T

On/off

$\geq 10^8$

mobilities

$10^{-2} \text{ cm}^2/\text{Vs}$

molecular

$\leq 10^{-5}$

polymer

Bologna - I.S.M. - CNR

M. Muccini, R. Zamboni, E. Wenedei

F. Biscarini, P. Samori, O. Greco, P. Moretti

R.N. Marks, W. Gebauer, R. Michel
growth, morphology, spectroscopy, LED, PV,

Merburg

R. Mohrt, M. Hopmeier, M. Oestreich, H. Baessler
time-resolved spectroscopy

Thuir

F. Garnier, G. Horowitz
single crystal growth

Mous

D. Beljonne, J. Coruil, J.L. Bredas
Quantum Chemical Calcul.

- TMR - SELOA (previous TMR SELMAT)
- Esprit LEDFOS (polarized LED, interface effects)
- C.N.R. Nanostructure Action (95/95).
(nanolithography)
- TMR - DRUM (Rotaxanes)
- TMR - ENBAC (Catenanes)
- TMR - FULPROP (Fullerenes)
- JOULE - THERMIE - EUROSCI (Organic Photovoltaics)
- BRITE - EURAM - MOLALC (Optical Limiting)
- CNR P.F. MATERIALS - DEMO (OLED)
- Fremo (Organic

