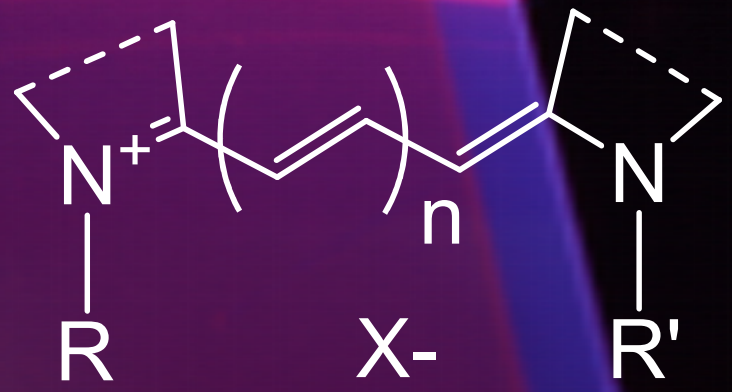
(Novel Organic Material for PV Applications)

Solution-Processable, Small Molecules for All-Organic Solar Cells



Roland Hany

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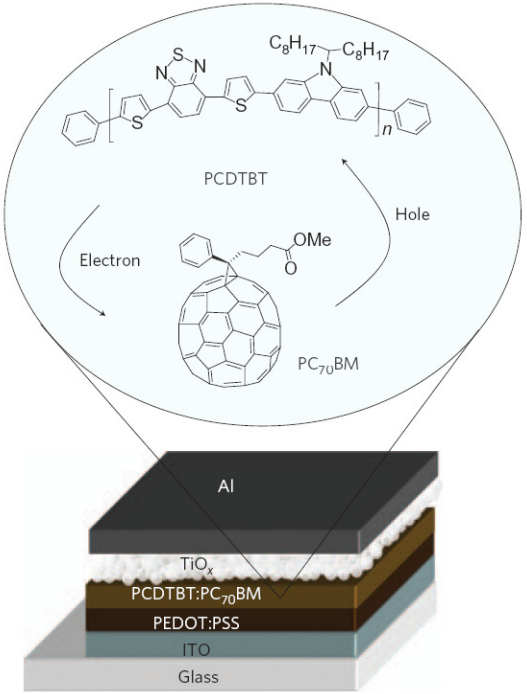
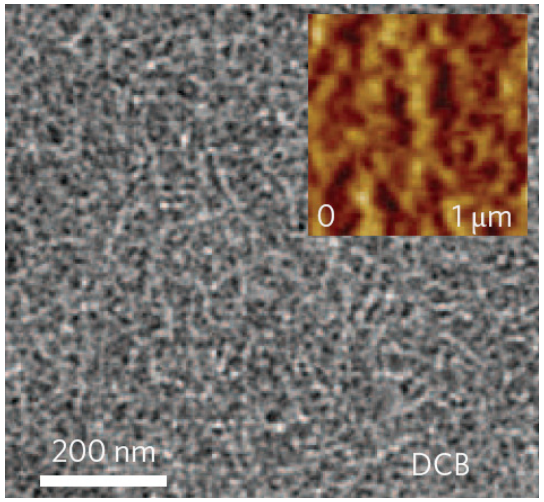
EMPA

Materials Science & Technology

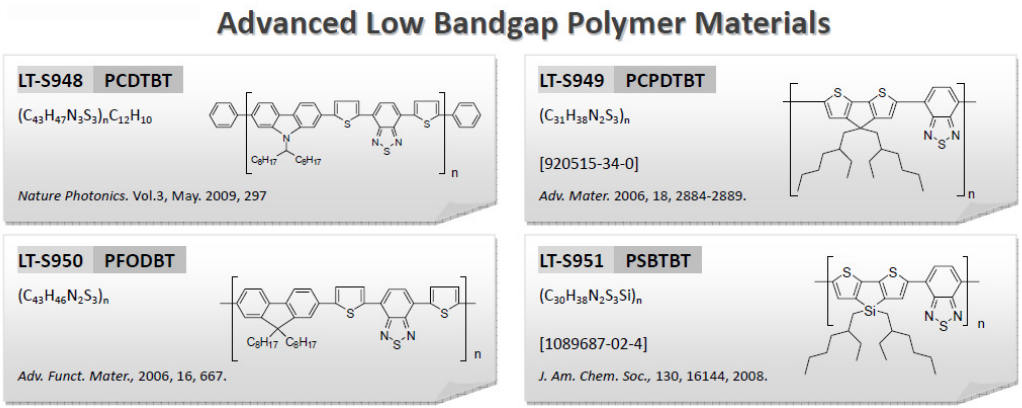
State-of-the-Art: Polymer-PCBM Bulk OPV



η = 6%



A. J. Heeger et al., *Nature Photonics*, **3**, 297 (2009)



Morphology

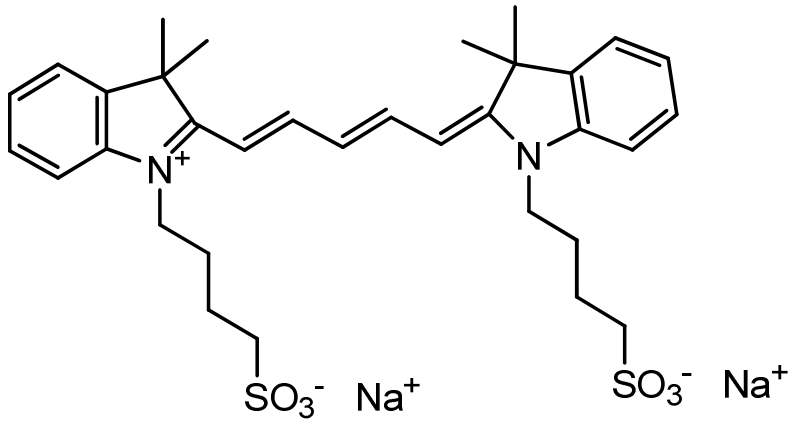
Polymer Synthesis

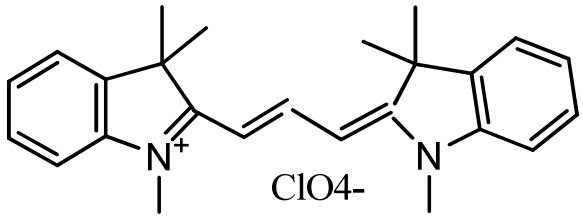
OPV with solution-processable small molecules

Small molecules tend to crystallize – poor film formation

Review Materialstoday 10(11), 2007, 34	η(max)	= 1.3%
Chem. Commun. 2008, 6489		= 1.7%
JACS 2008, 130, 17640		= 1.2%
Org. Electronics 2008, 9, 85		= 1.2% (Empa)
Chem. Mater. 2009, 21, 1413		= 1.5%
Int. J. Photoenergy 2009, in press		= 1.0% (Empa)
Adv. Mater 2009, submitted		= 2.6% (Empa)

Cyanine Dyes





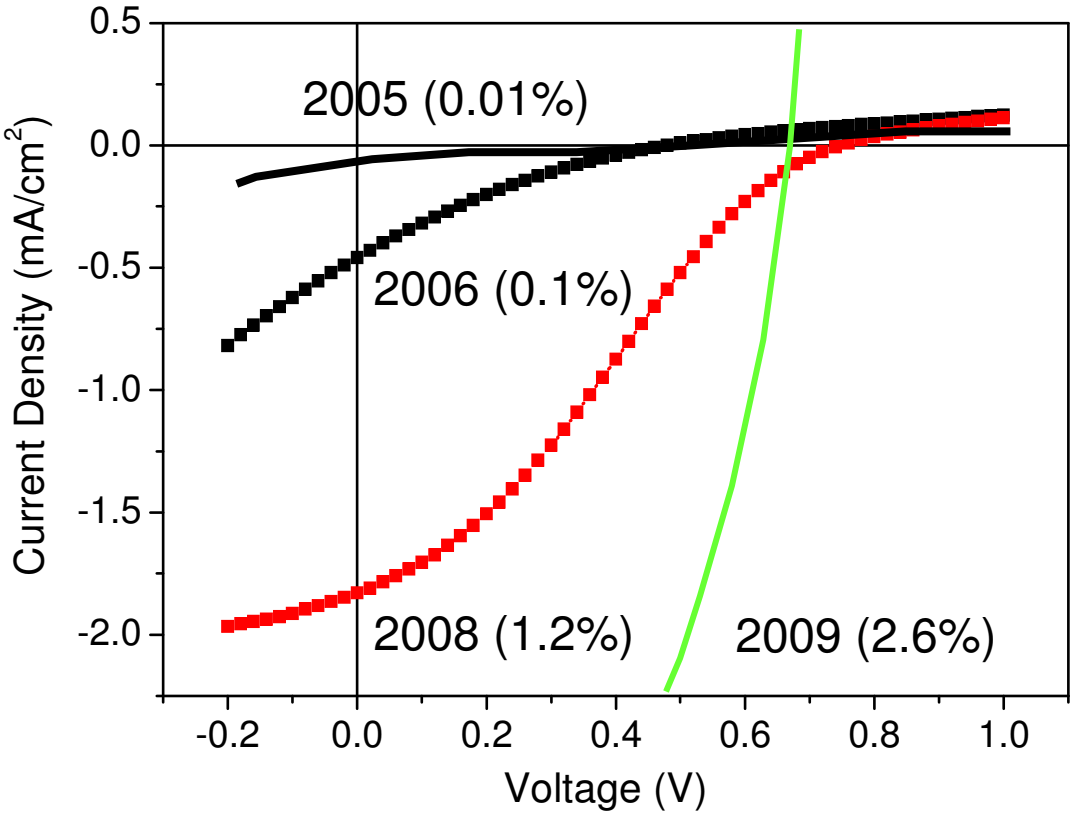
Very high extinction coefficient

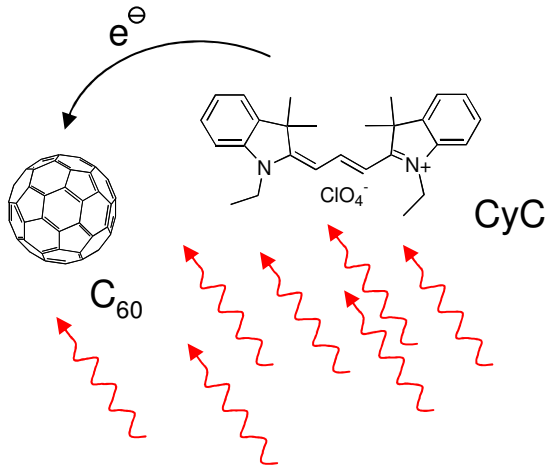
Tunable absorption from the UV to the NIR

Processable in many organic solvents, good film-forming properties

Commercial available, “simple” synthesis and purification

Towards high performance bilayer cyanine OSC





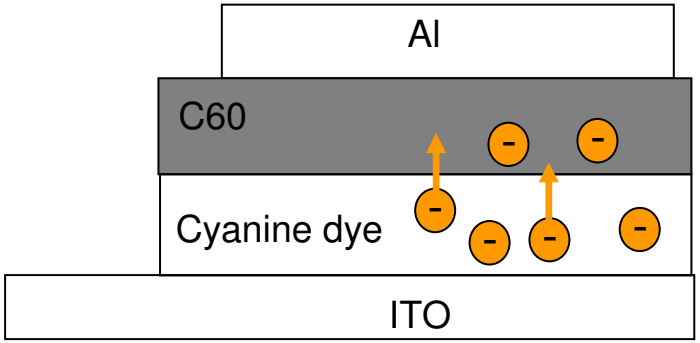
- ♦ - Undoped

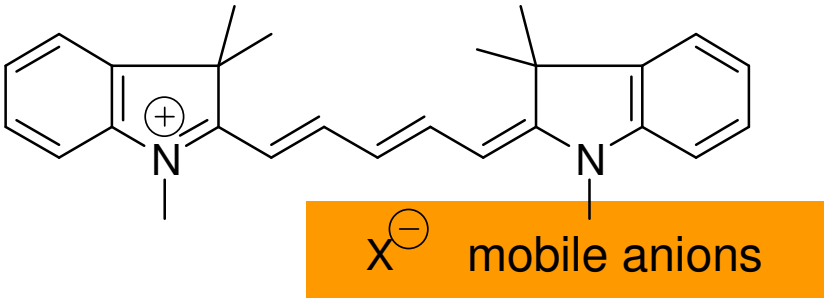
- ♦ - Doped with O_2, light and water

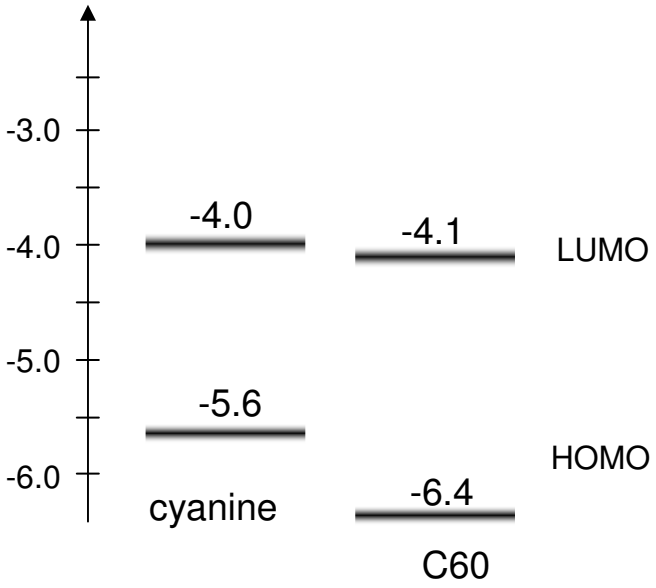
- ♦ - Doped with $NO^+BF_4^-$

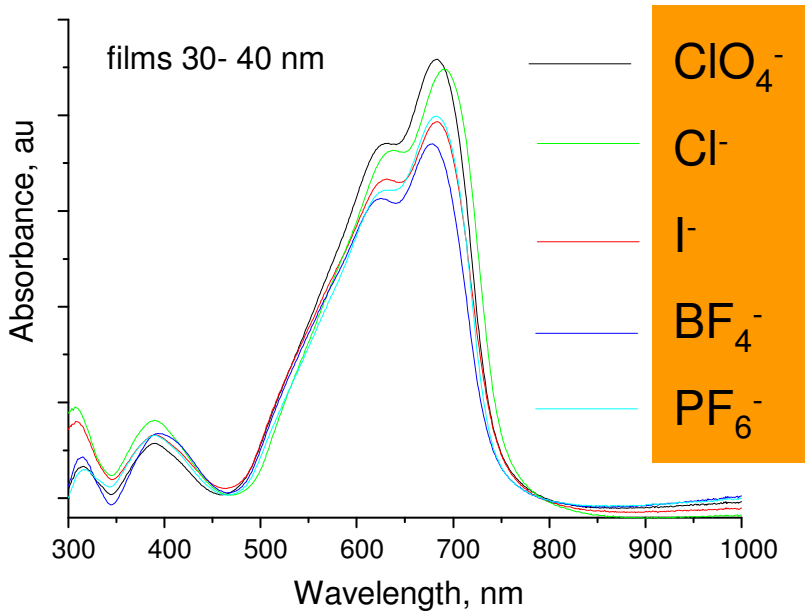
Latest news: η = (3.5 – 4.5)%

Ionic space charge driven devices

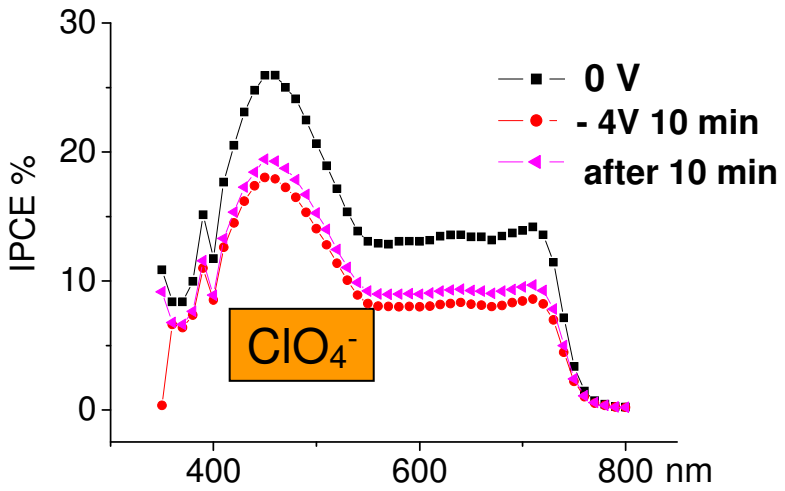


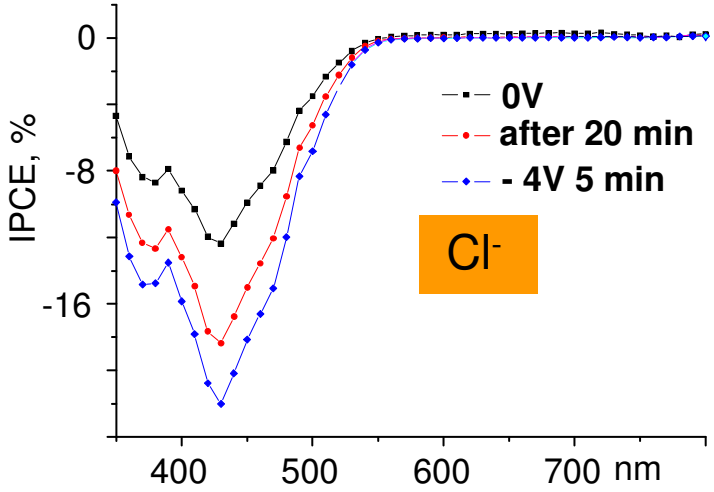


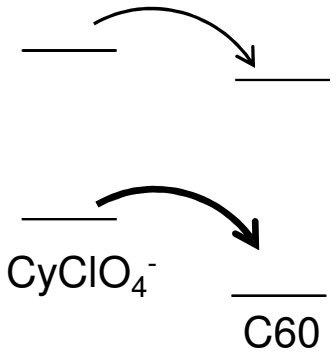


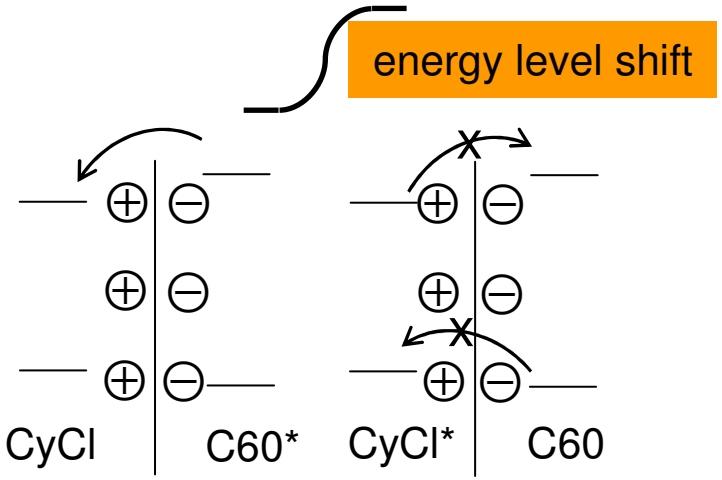


Ionic charge controls flow of electronic current





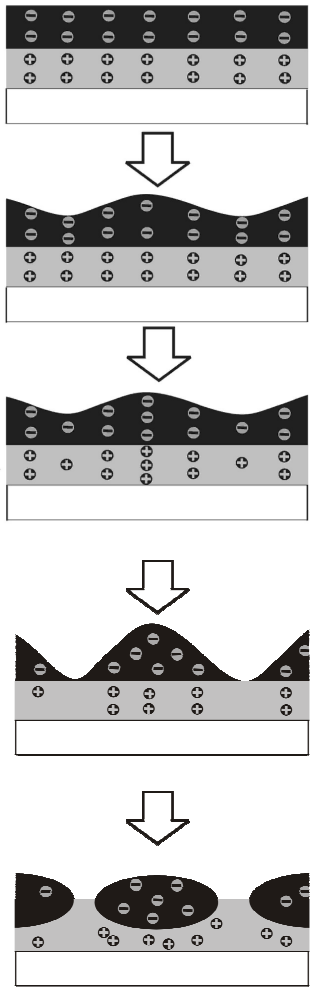




Chimia 2007, 61, 787

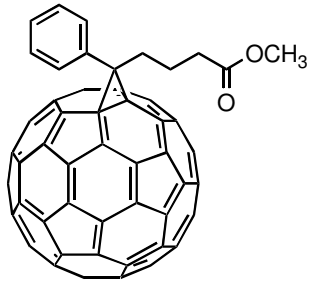
PCCP, 2009, DOI:10.1039/B909512H

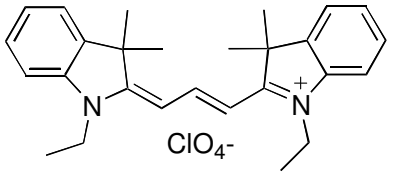
Liquid-liquid dewetting in evaporating Cyanine dye – PCBM film



Transient bilayer

Electrostatic disjoining pressure - Fluctuations are amplified – Spinodal dewetting

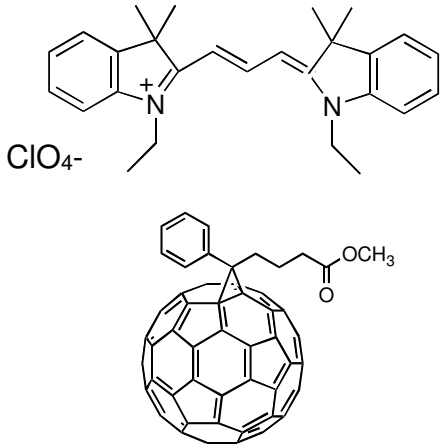


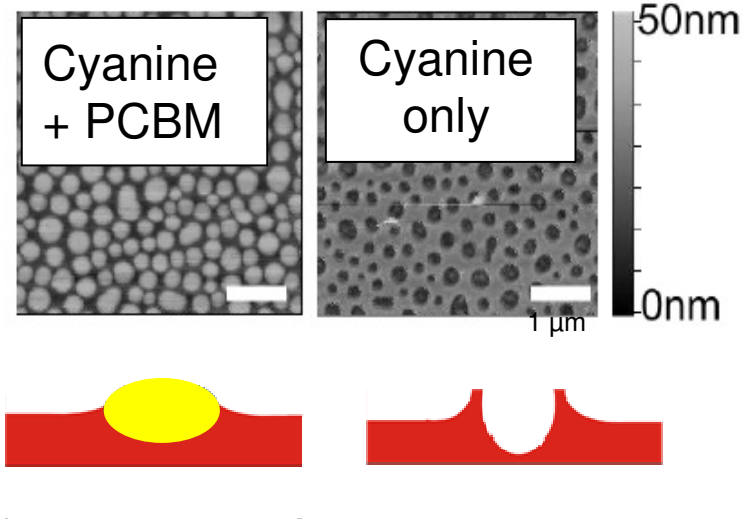


Charged domains

Langmuir 2008, 24, 7316

Liquid-liquid dewetting: Tuning of morphology





Parameters

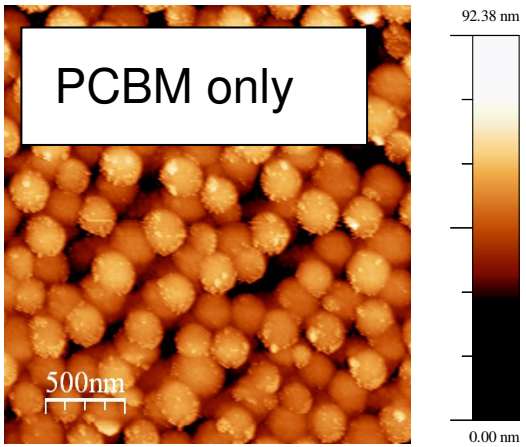
Counter Anion

Cyanine Dye

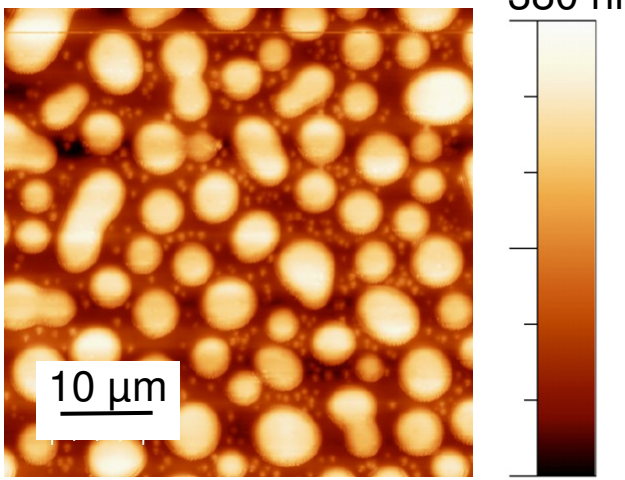
[PCBM] / [Cyanine]

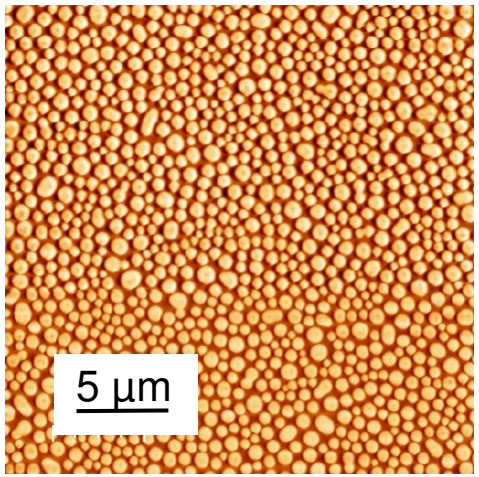
Solvent

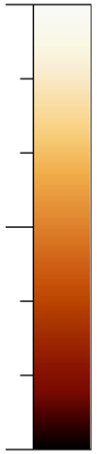
Temperature…

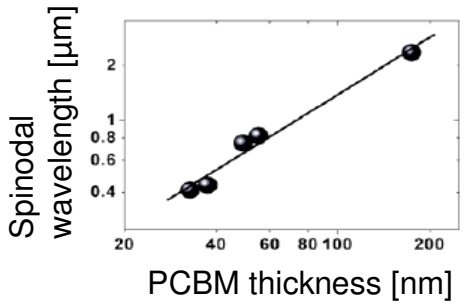


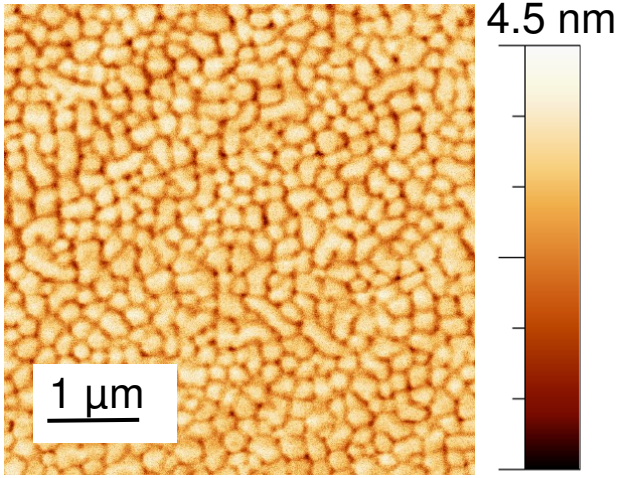
Liquid-liquid dewetting: Tuning of morphology

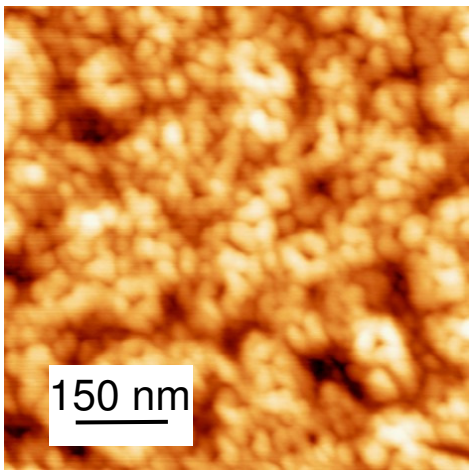


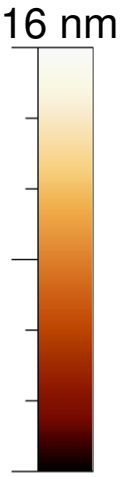






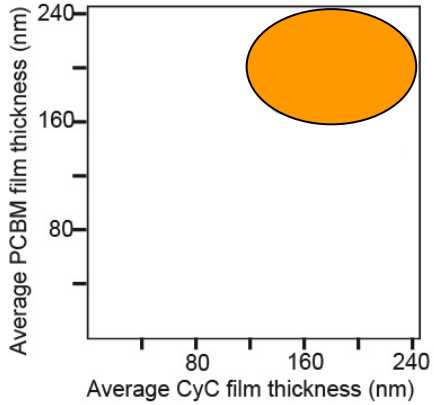


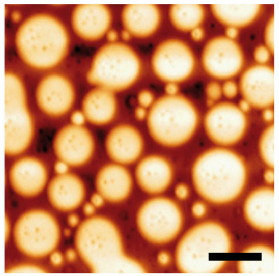




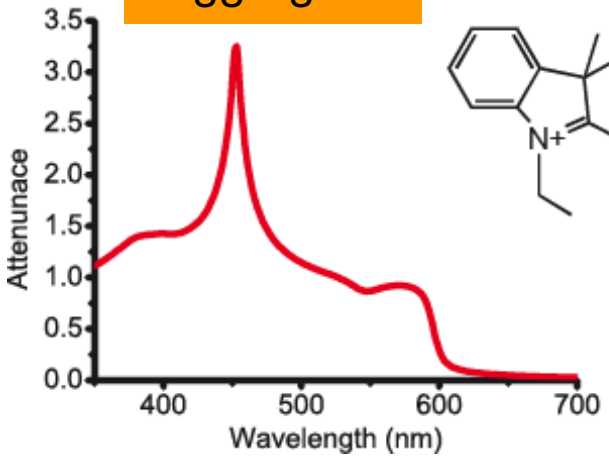
Work in progress: Bulk cyanine-PCBM solar cells with *known* morphology

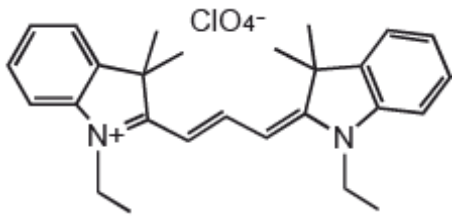
Cyanine Aggregates via Liquid-Liquid Dewetting

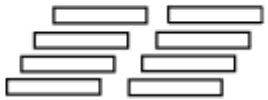


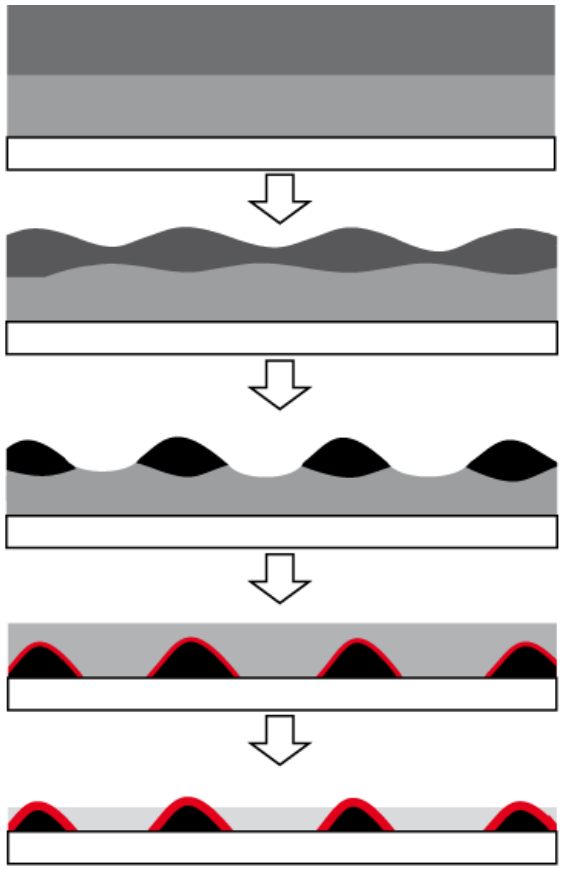


aggregate

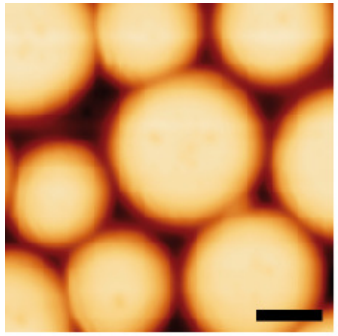
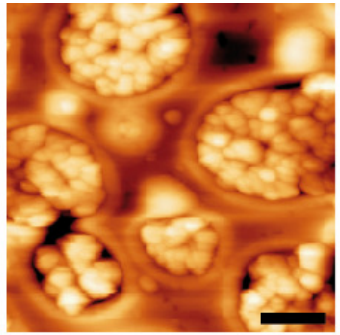
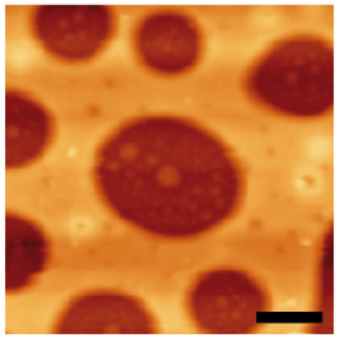


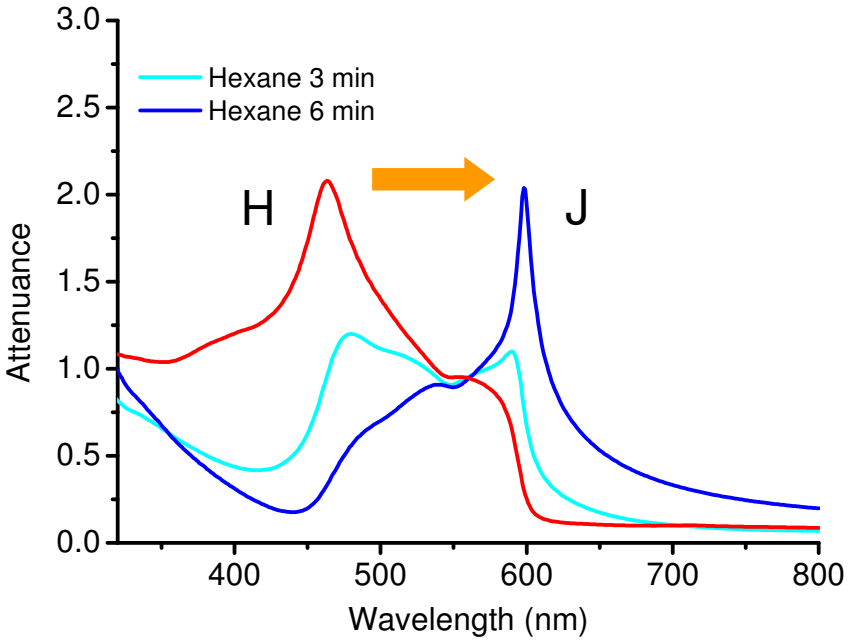


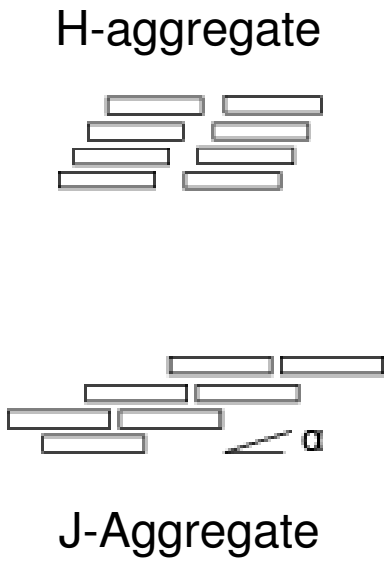




Cyanine Aggregates via Liquid-Liquid Dewetting





Cyanine Aggregates via Liquid-Liquid Dewetting

Merits

Aggregation from aprotic, apolar solvents

Aggregation is very, very fast

H- and J-aggregates of high quality

Patent www.switt.ch

„J-aggregates of cyanine dyes by self-assembly“, R. Steiger et al, Colloid & Interfaces B, December 2009

Work in progress

Light-harvesting and charge-transporting aggregates in OSC.

Conclusions

High cyanine *extinction coefficients* allow to use thin absorbing films in *bilayer* organic solar cell architecture

Small soluble molecules achieve *high efficiency* in organic solar cell devices

Cyanines are produced on large scales, are cheap and easy to purify

Mobile $Cy^{+}X^{-}$ anions offer advanced device functionalities, such as control of flow of electronic current, submicron patterning of blend films or aggregate formation from organic solvent

Acknowledgement

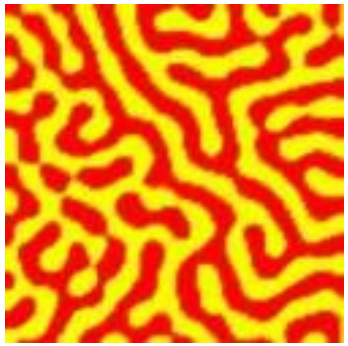
Jakob Heier
Hadjar Benmansour
Fernando Castro
Fan Bin
Ylenia Maniglio
William Kylberg
Frank Nüesch

Rolf Steiger
Tom Mates

Structure formation in evaporating blend film – driving forces

solvent vapor pressure – kinetically trapped structures

surface energies – wetting / dewetting

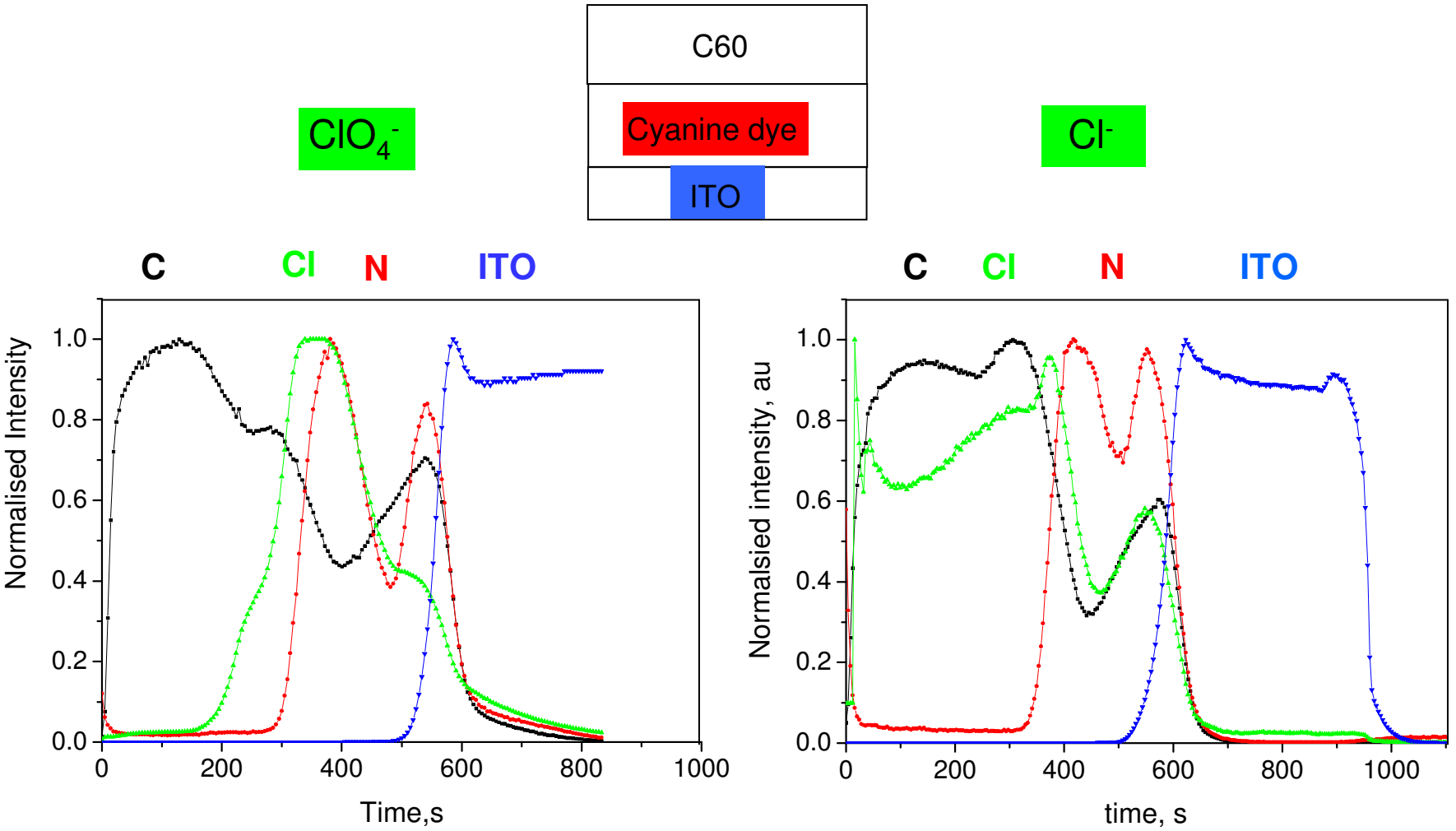


interaction parameters – polymer phase separation

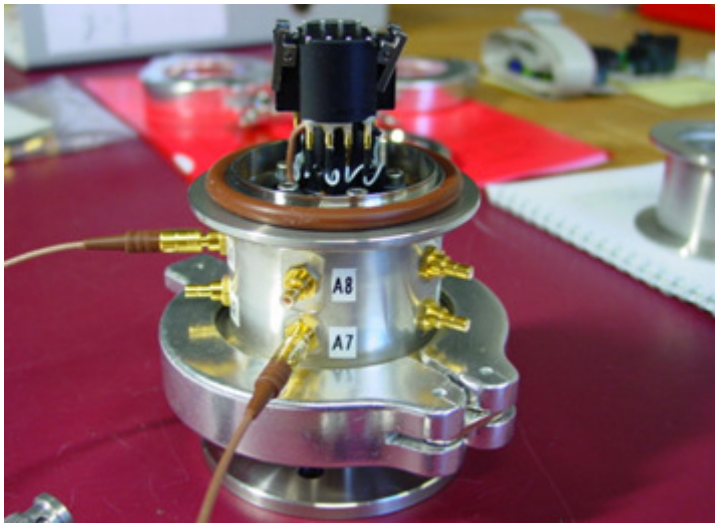
crystallization

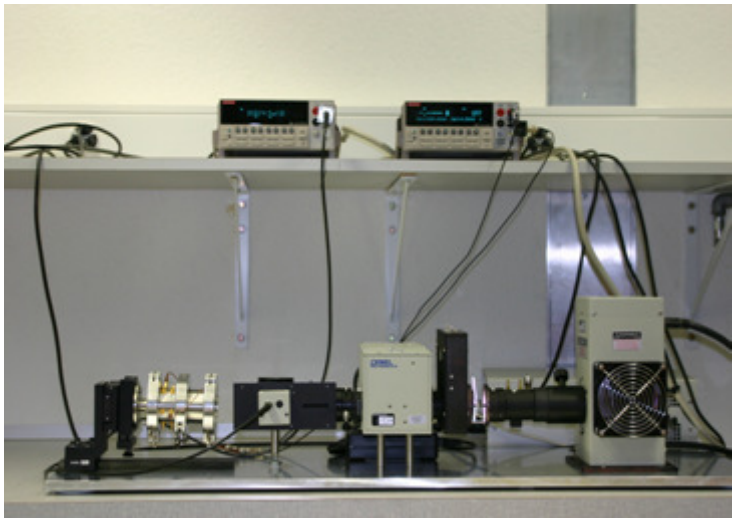
thin films – disjoining pressure

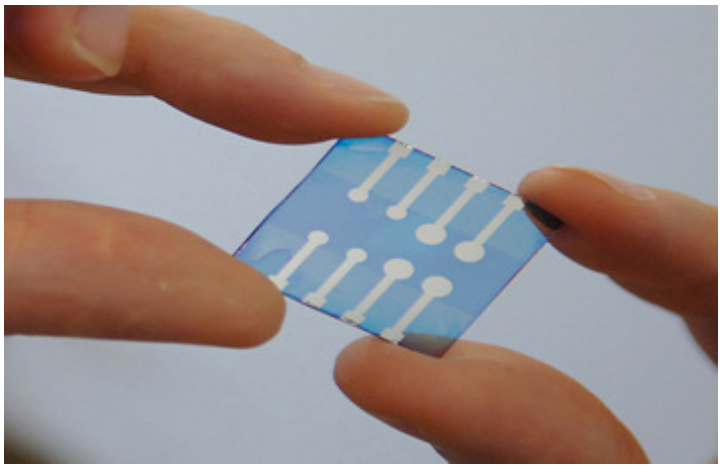
Ionic space charge: SIMS analysis



Fabrication process



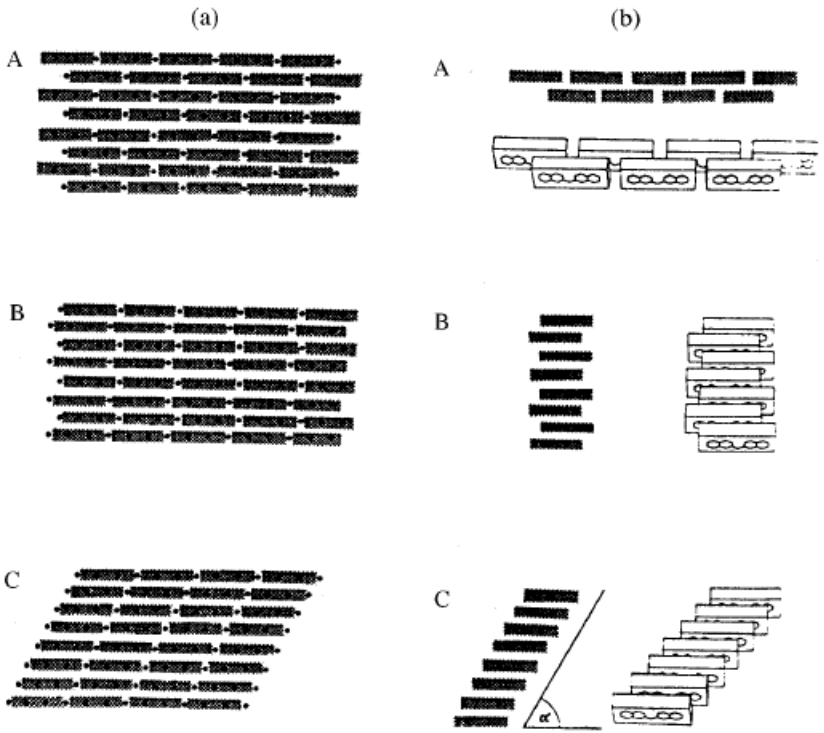


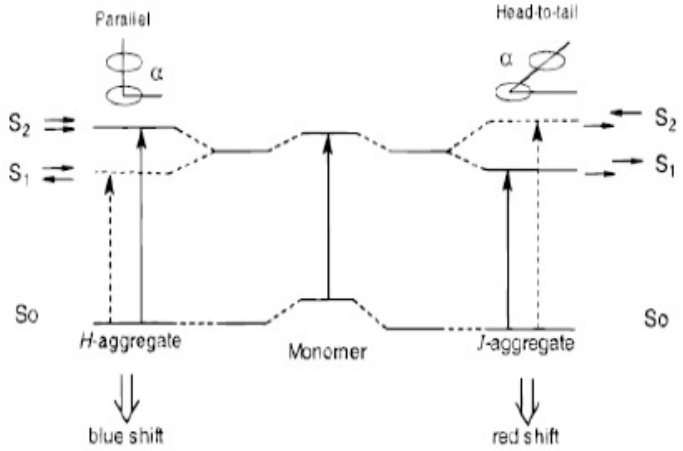


Aggregation of Cyanine Dyes:

Delocalization of the positive charge on one nitrogen atom
⇒ Strong intermolecular van der Waals attractive forces
⇒ Aggregation

Adsorbed on a surface: In solution:





Delocalized electron state
⇒change in absorption:

α < 32° (large molecular slippage):
⇒ Bathochromic shift (J-band)

α > 32° (small molecular slippage):
⇒ Hypsochromic shift (J-band)