

Measuring charge mobilities in discotic liquid crystals

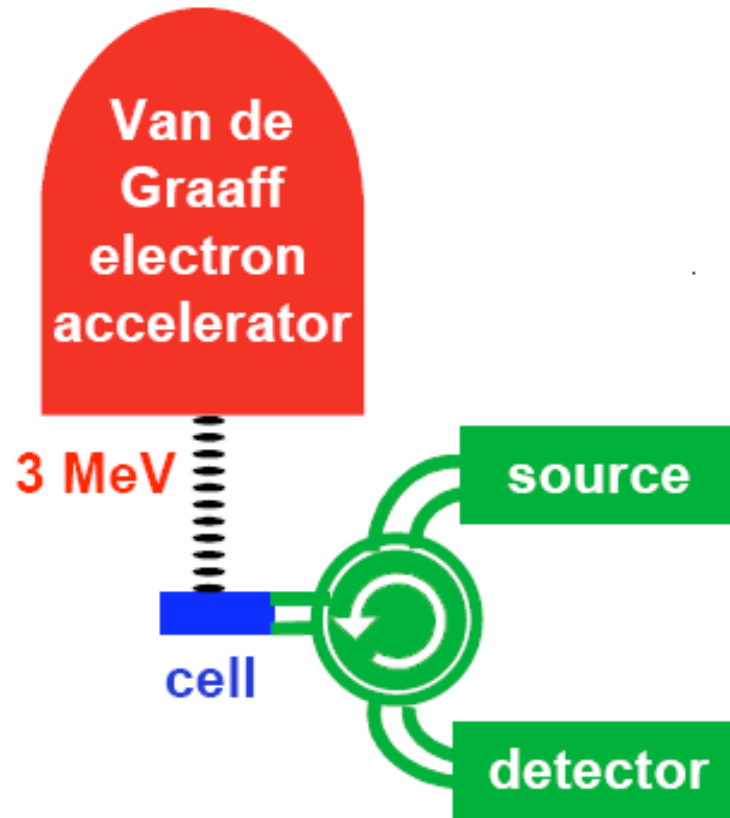
PR-TRMC

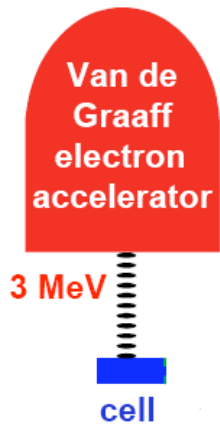
Pulse Radiolysis – Time Resolved
Microwave Conductivity

Introduction

- The measure doesn't perturb the system
- The measures are insensitive to the colour or the morphology of the sample
 - There is no need of a single crystal
 - The mobility derived refers usually to the maximum that could be obtained in a 2-electrode cell with a perfectly oriented monodomain

Experimental setup





Pulse-Radiolysis

- **Pulse source :** Van de Graaf accelerator
Kinetic Energy = 3 MeV
pulse duration between 0.2 and 250 ns
penetration depth (15mm) \gg sample size (3mm)
- **Energy Deposition :** Energy transfer from high- energy electron to the medium occurs in discrete excitation and ionization along the track of the electron.
- **Beam profile :** Lateral loss is less than 10%
Vertical loss is negligible in a 3 mm sample



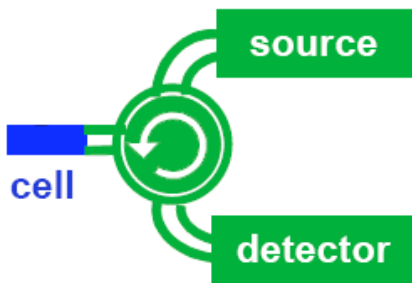
cell

Sample Cell

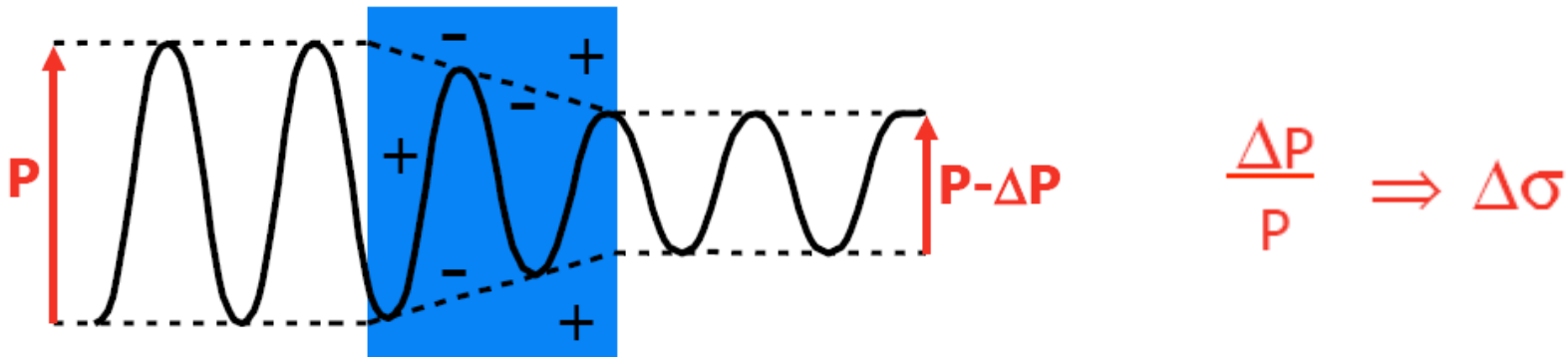
- Copper cell : maximal fill 200 mg
 - if less sample available, smaller cavity obtained by filling the cell with polyimide or PMMA till a 30 mg size.
 - (PMMA or polyimide don't give conductivity signal.)
 - Temperature range -100°C to $+200^{\circ}\text{C}$
(PMMA limit the measure at 120°C)

Microwave conductivity

1. Microwaves (in the Ghz range) produced by a source propagate in a waveguide to a circulator which directs the wave to the cell
3. The waves propagate through the sample and are reflected at the end of the cell by a metal plate
5. The microwaves are directed by the circulator to the detector.



Microwave conductivity



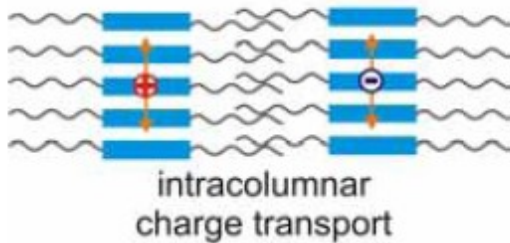
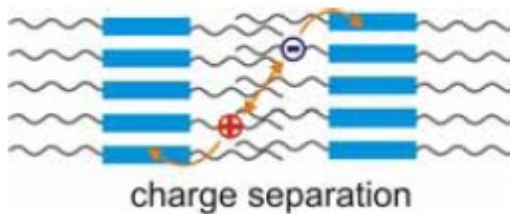
- **A** : sensitivity parameter which depends on the geometry of the sample and its dielectric properties.

Dielectric constant is obtained by measuring the conductivity change as a function of the frequency

- **Fill-factor** : takes in account that the cell is not completely filled with material

Microwave conductivity

Physical model for charge carrier formation in discotics (Schouten et al. , JACS, 1994, 116, 6880)



1. Electron-hole pairs which are formed in the same stack undergo sub-nanoseconds recombination and therefore don't contribute to conductivity
3. Electron-hole pairs which are formed in the hydrocarbon region can fast react or move to the aromatic core and get separated.

Microwave conductivity

$$\Delta\sigma = e N_p \Sigma\mu_{TRMC}$$

measured

elementary
charge

concentration
of charge
carrier

$$\Sigma\mu_{TRMC} = \mu_+ + \mu_-$$

$$N_p = \frac{W_{eop} D}{e E_p}$$

End of pulse survival
Probability (<1)

Dose of energy

Energy required to form
one hole-electron pair

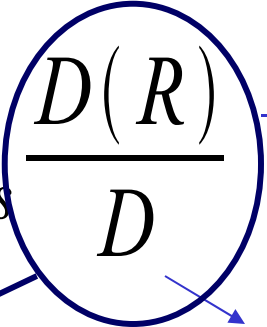
$$\Delta\sigma = \frac{W_{eop} D}{E_p} \Sigma\mu_{TRMC}$$

$$\Sigma\mu_{TRMC} = \frac{E_p}{W_{eop} D} \Delta\sigma_{eop}$$

Microwave conductivity

$$\Sigma\mu_{TRMC} = \frac{E_p}{W_{eop} D} \Delta\sigma_{eop}$$

What is exactly W_{eop} ?

$$W_{eop} = W_s \left(\frac{D(R)}{D} \right)$$


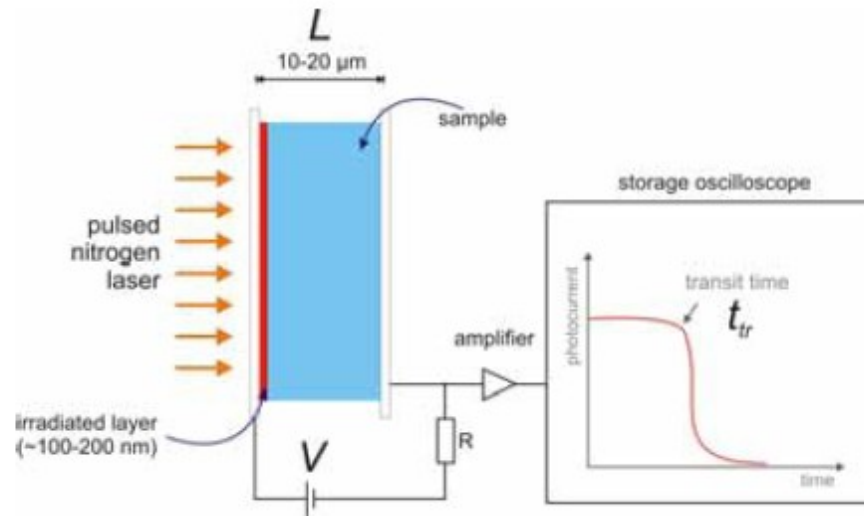
Dose of energy deposited on the hydrocarbon side chains

Dose of energy deposited on the whole system

$$\frac{D(R)}{D} \propto \frac{\Sigma Z(R)}{\Sigma Z(\text{Molecule})}$$

The energy deposited in a given region is proportional to the electronic density

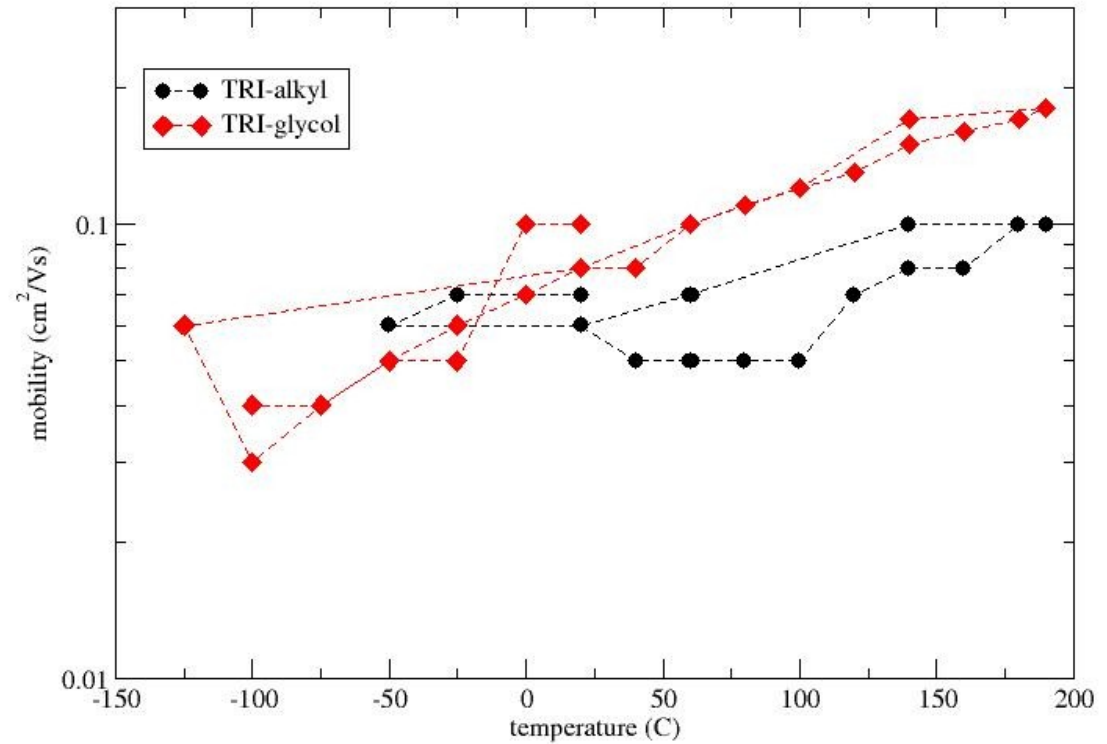
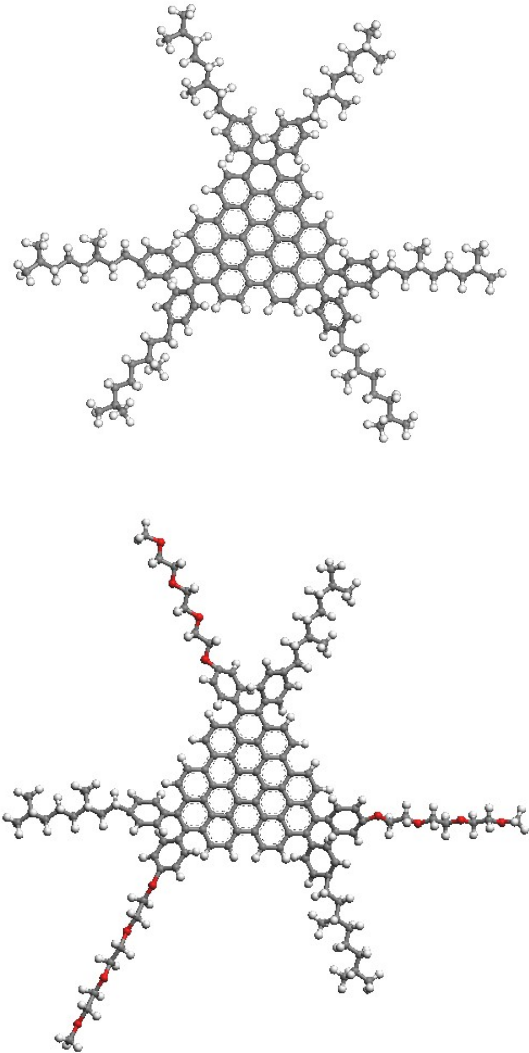
Time of flight



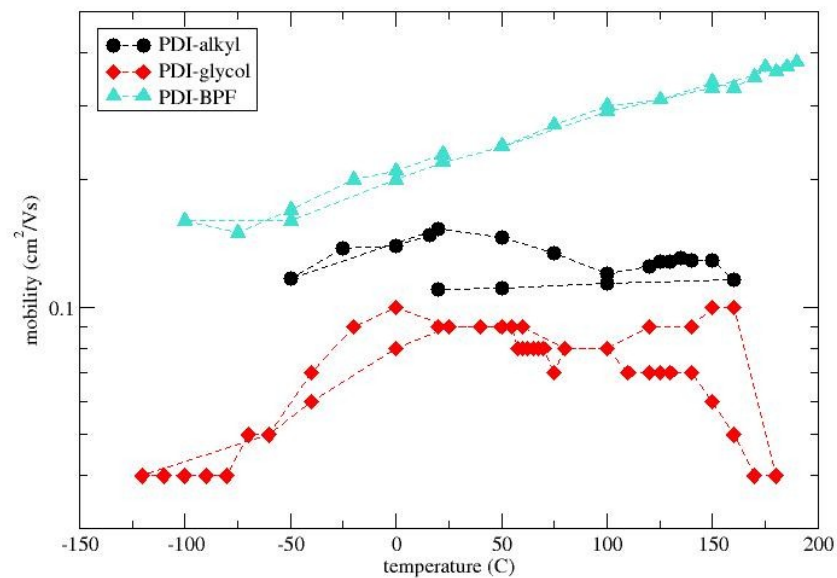
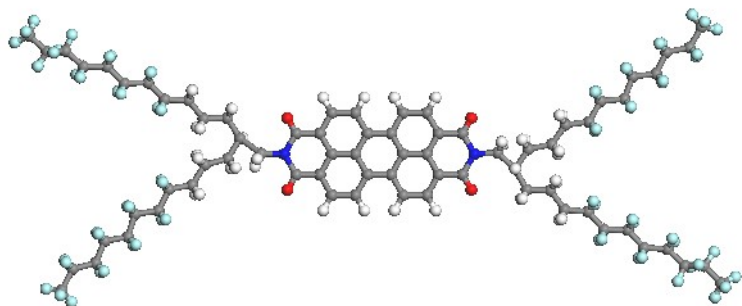
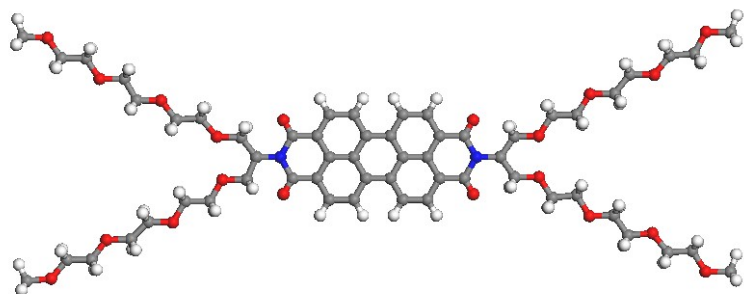
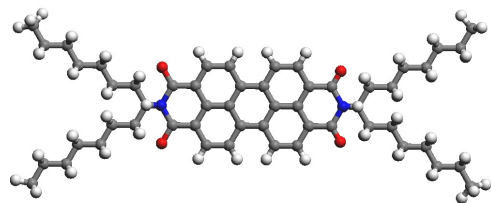
ADVANTAGE : you can separate hole and electron mobilities by inverting the polarity of the electric field

DISADVANTAGE : you need good alignment in the sample

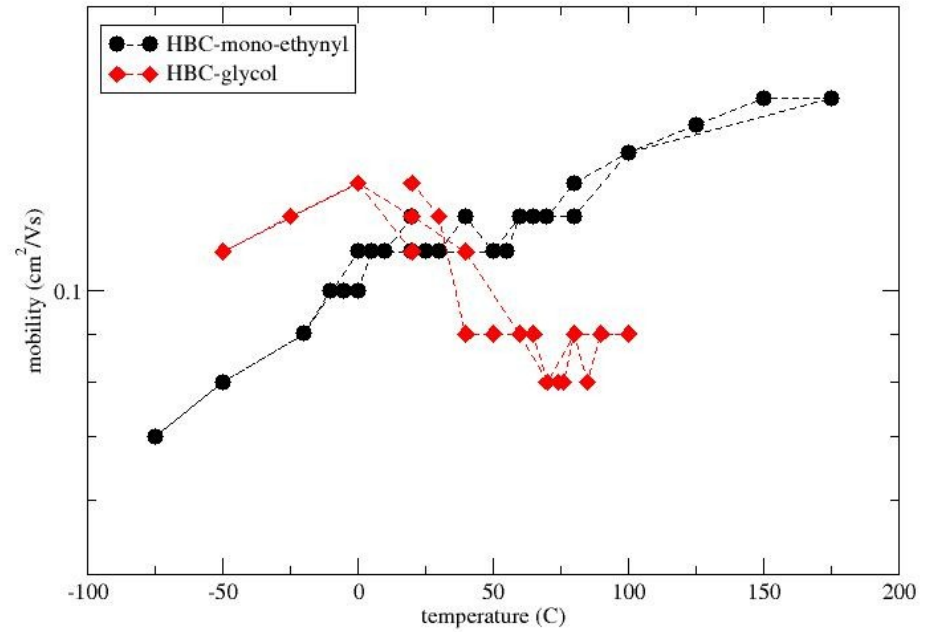
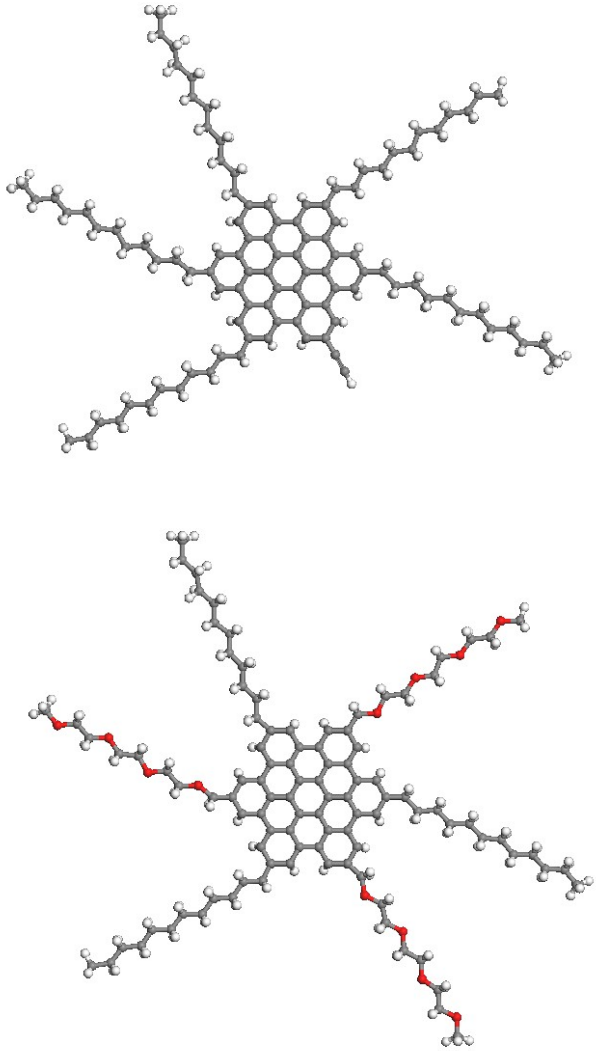
HBC - trizigzag



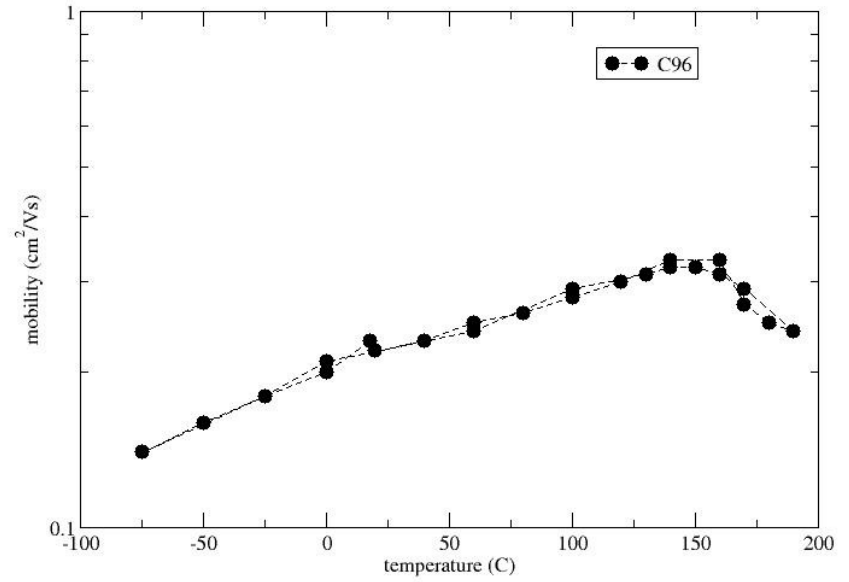
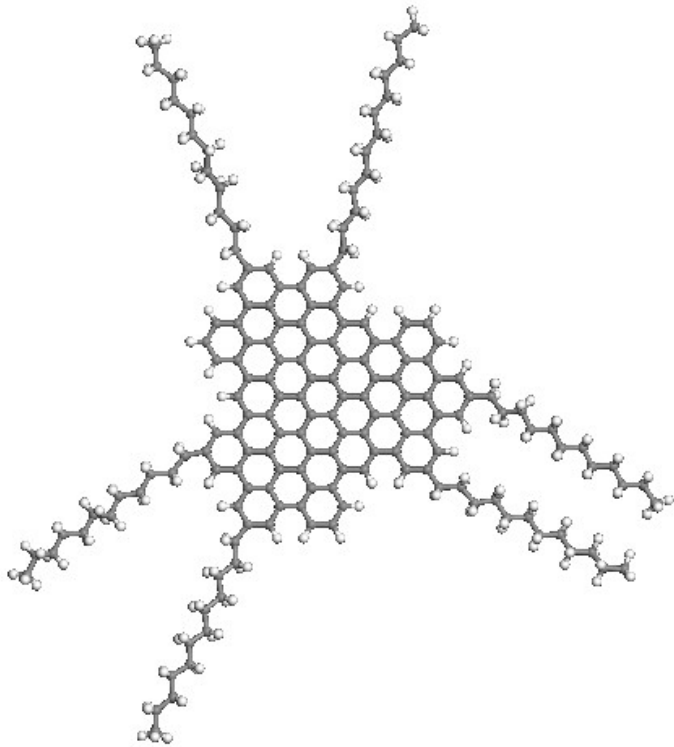
Perylene-diimides



HBCs



C96



Aknowledgments

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