Development of Nano-Bio hybrid material based on CdTe Quantum Dots and Bacteriorhodopsin protein for future technologies

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7th September 2010

Outline

Motivation & Description of the project

Bacteriorhodopsin/Semiconductor QDs hybrid development

1. Complex formation
2. Energy transfer
3. Proton pumping efficiency

Conclusions

Motivation

- Current technologies are semiconductor based
- Considerable interest in e.g. nanotech during the last decade
- Future technologies most likely based on *HYBRID* materials
- Interface between nano- and bio- technologies is very appealing

Protein-based devices

- **Bioelectronics** and **biophotonics** have shown considerable promise
- Most of research in these fields is concentrated on:
    1. Self-Assembled Monolayers (SAMs)
    2. Protein-based photonic devices

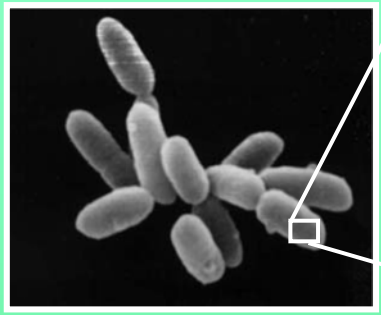
- **Bacteriorhodopsin** (bR) has received most attention due to its unique properties
- Substantial number of publications and patents exist on technical applications of bR
- These are based on the **photochromic** or the **photoelectric** properties of the protein

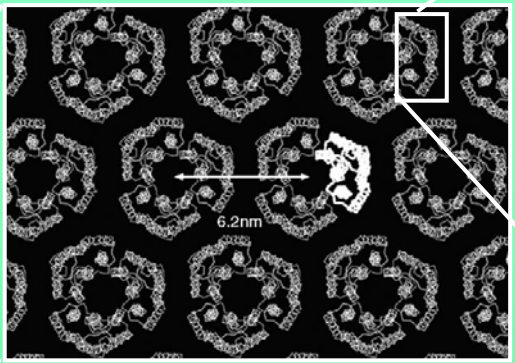
Applications include:

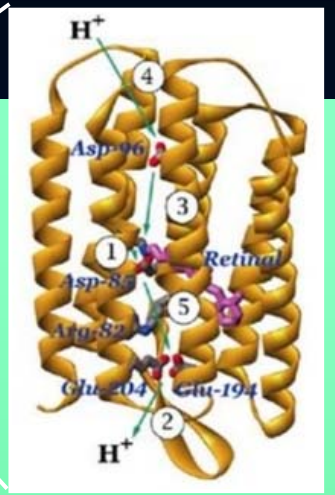
- Real time holographic image analysis systems
- Artificial retinas
- Photodetectors
- 3D (holographic/volumetric) memories
- Logic gates
- Optical switches
- Eye protection filters
- Neural networks
- Molecular sensors

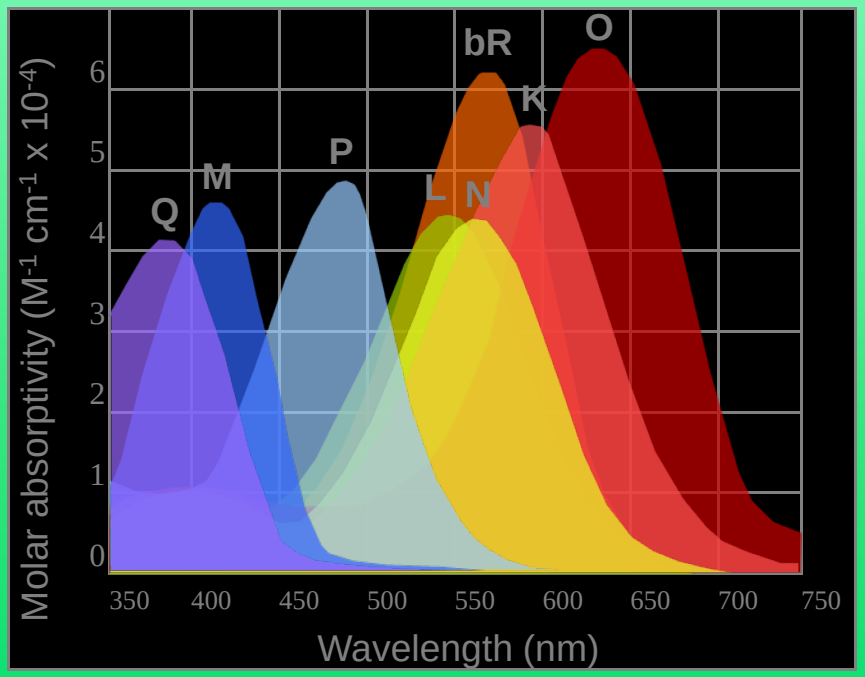
Birge, R. R. *et al*. Biomolecular electronics: Protein based associative processors and volumetric memories. *J. Phys. Chem. B* **103,** 10746-10766 (1999).

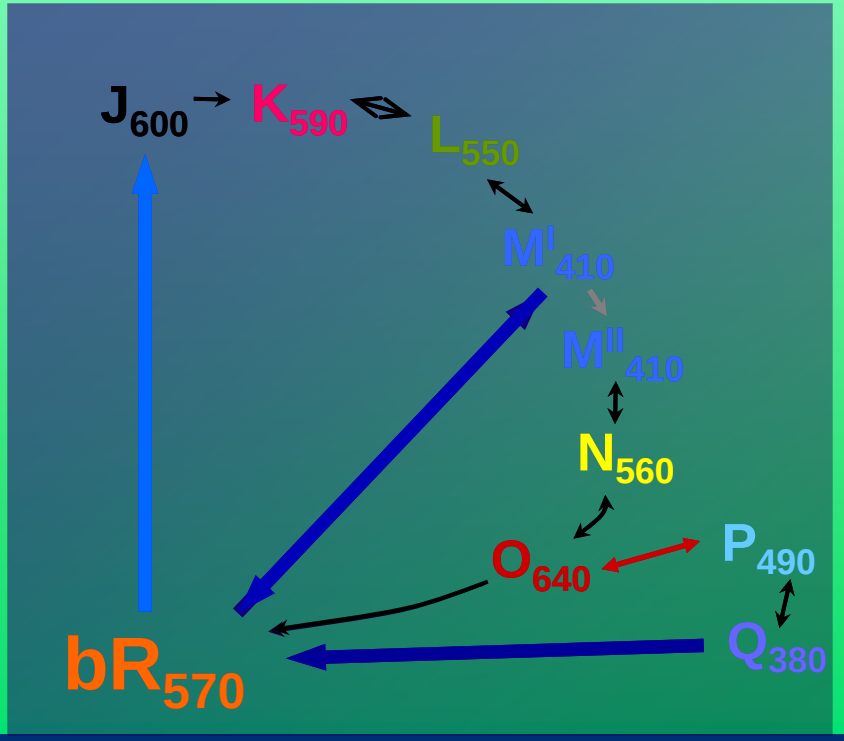
Bacteriorhodopsin of *Halobacterium Salinarum*











Adapted from Birge et al. 1999

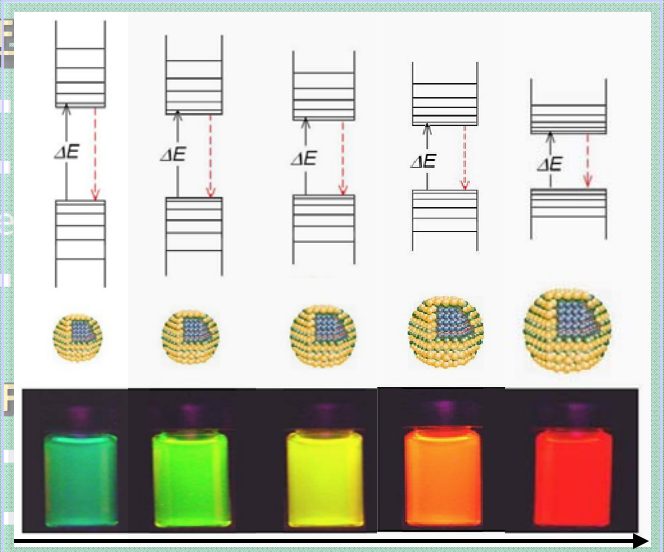
FRET in NCs systems

Semiconductor Nanocrystals (NCs/QDs):

- Nanosized crystals of semiconductors
- High QY at room temperature
- High photostability
- Chemical properties adjustable

Luminescence quenching:

A process that results in a decrease of fluorophore's emission upon addition of quencher



$$\frac{d\,m_{QD}}{dt} = \sigma_{QD}(\lambda_{exc}) \cdot \frac{Flux}{\hbar\omega_{exc}} - \tau_{QD}^{-1} \cdot m_{QD} - k_{FRET} \cdot m_{QD}$$

Excitation of QDs	Decay of QDs' fluorescence in a pure solution (i.e. in the absence of acceptors)	Change in the rate of fluorescence decay due to FRET – results in decreased lifetime

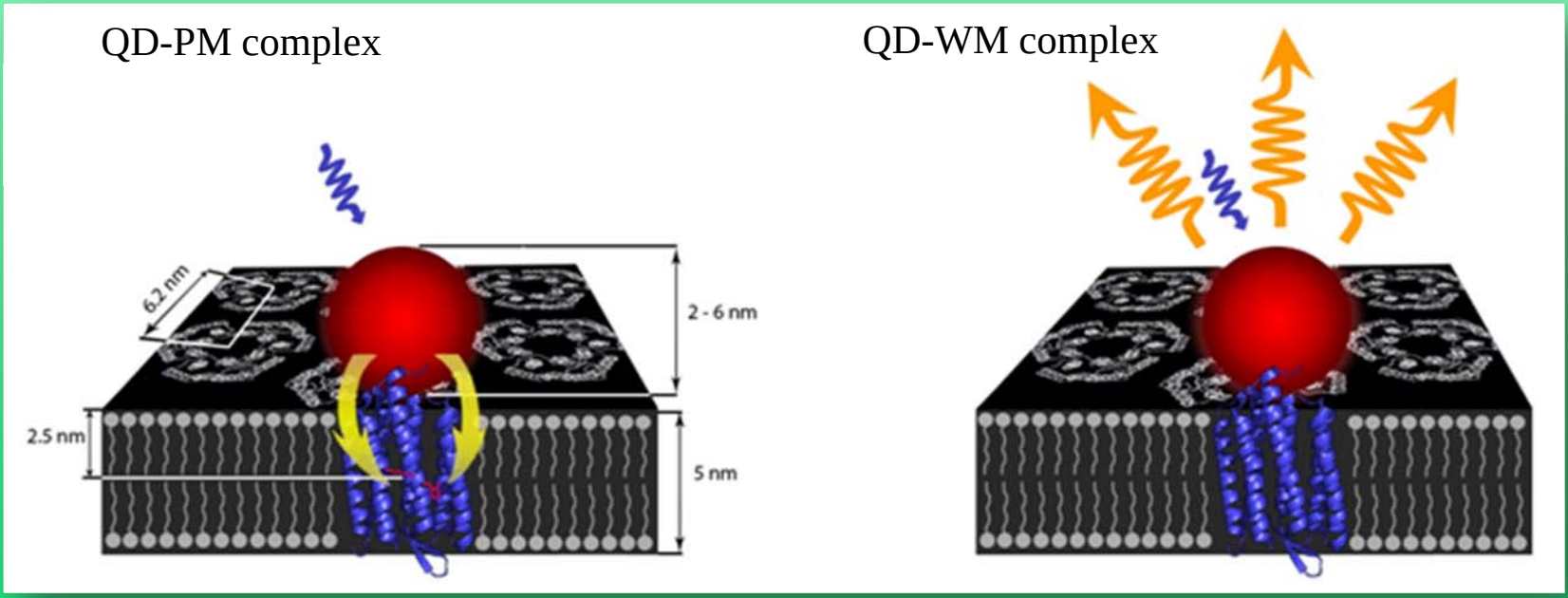
bR-QD complexes

bR-QD complexes formed by:

- Electrostatic assembly

For control experiments, white membranes (WM) were used:

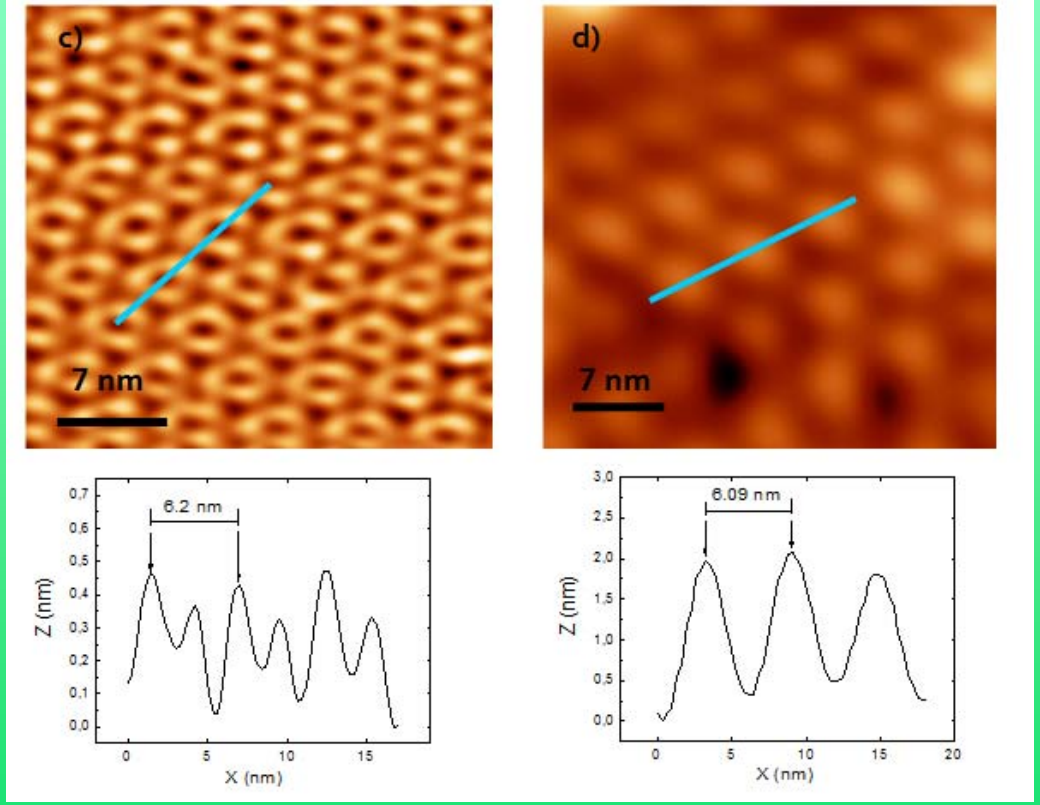
- Produced when retinal molecule is removed from purple membranes (PM)

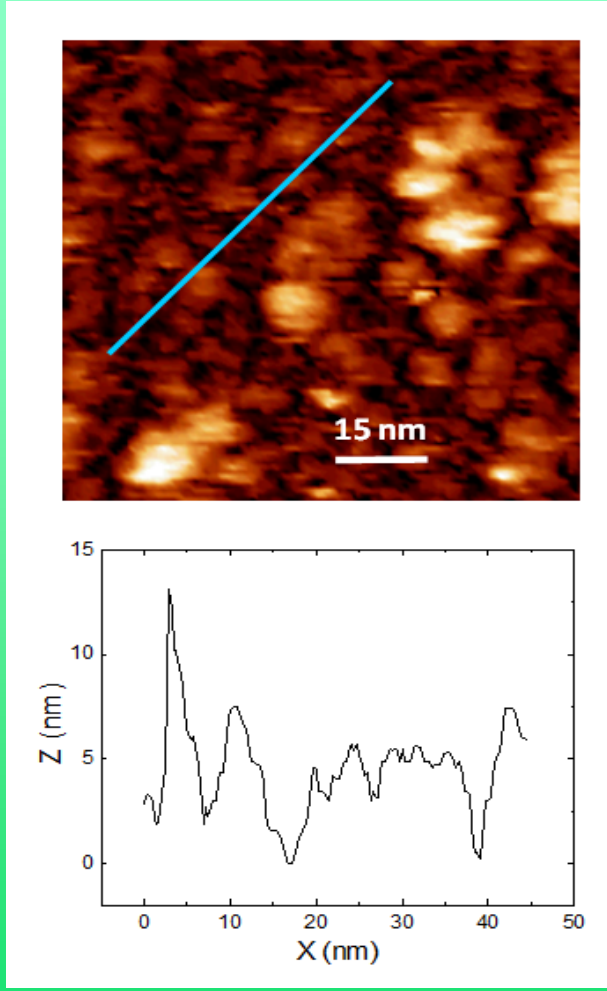


Electrostatic assembly of QDs on PMs

Nicolas Bouchonville

- PMs deposited on mica for 20 min, excess washed off
- Small amount of QDs was placed on top
- Sample rinsed to remove non-attached QDs



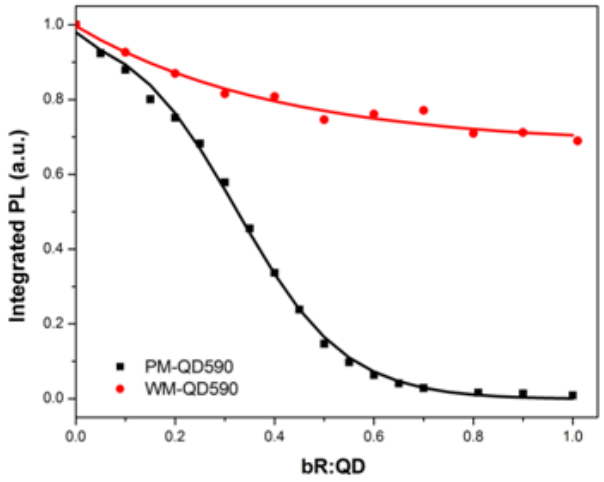


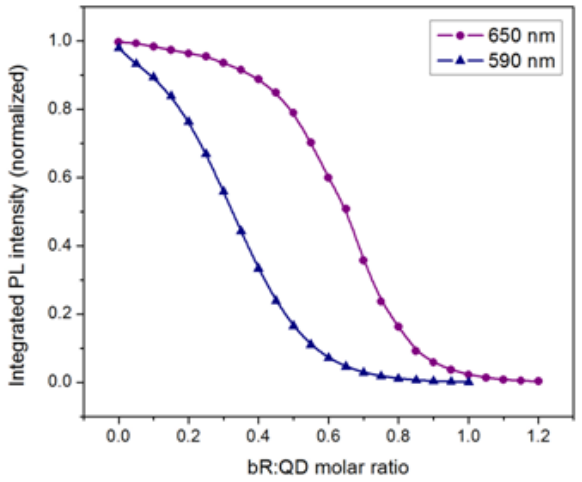
PMs only

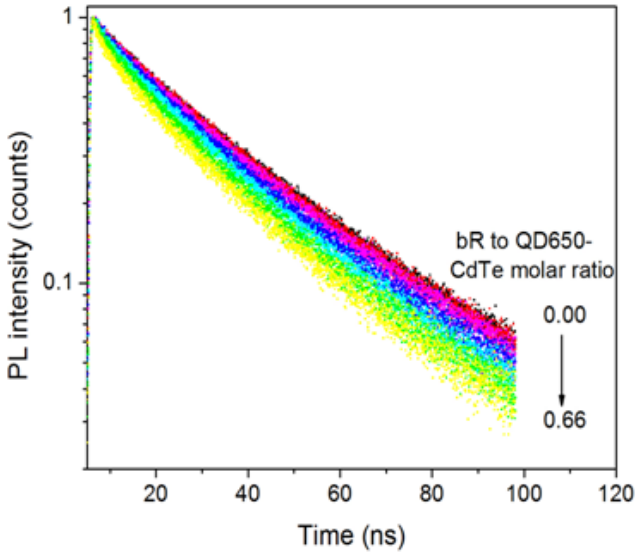
Low QD to bR molar ratio (1:2)

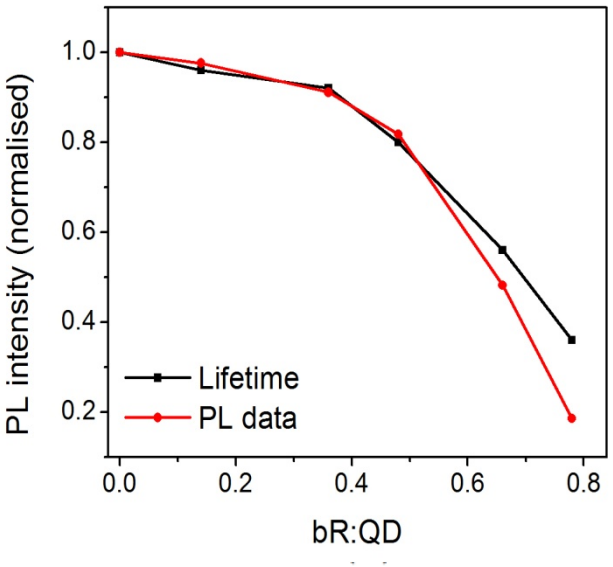
High QD to bR molar ratio (3:1)

QDs' PL quenching



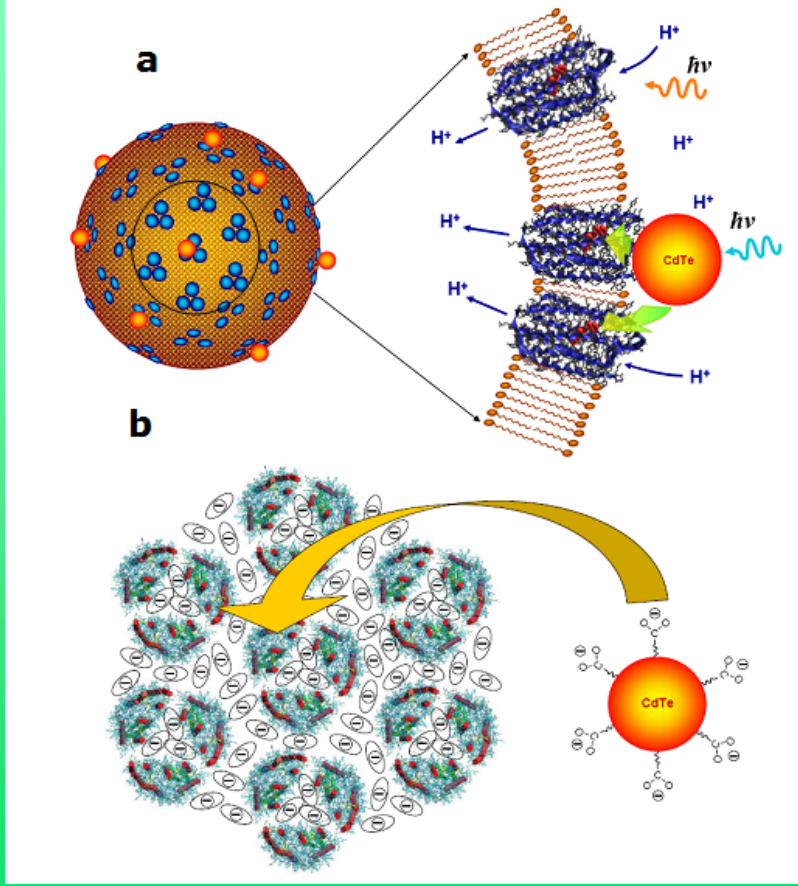


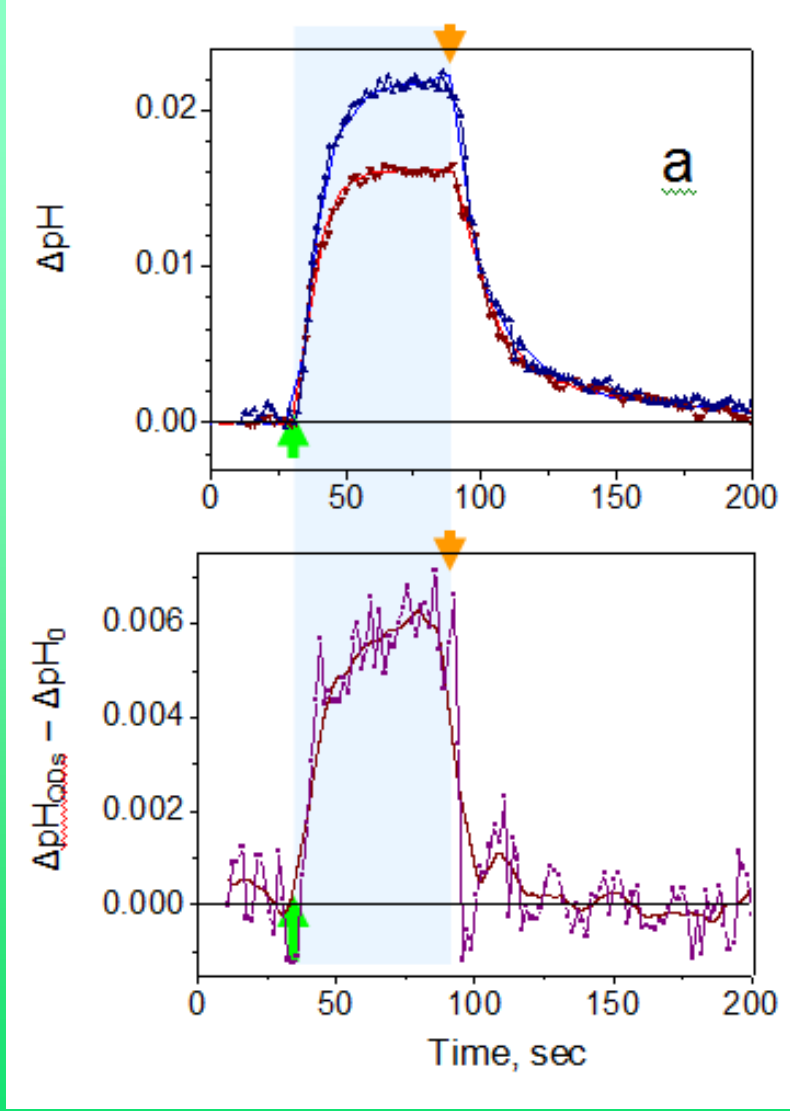




Proton pumping by QD-bR complexes

- PMs are assembled into spheres
- Upon excitation, bR pumps protons from outside to the inside of these spheres
- Monitor the pumping by measuring pH

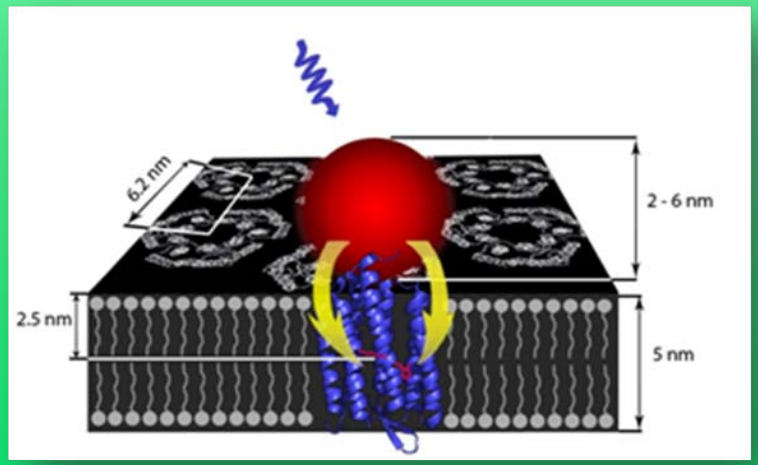




Nano Lett. 10 (7), 2640–2648 (2010)

Summary

- QDs adsorb and self-assemble on purple membranes
- Upon excitation of QDs, energy is transfer via FRET mechanism to the retinal of bR protein
- QD can also be attached covalently to PMs, with subsequent increase in FRET efficiency
- Presence of QDs does not disturb the proton pumping function of bR
- A 20% increase in proton pumping efficiency was observed of bR-QD complexes
- Developed hybrid can find many applications ranging from artificial retinas, artificial photosynthetic systems to photovoltaic devices and optical switches.



Acknowledgements

Integrated and Time-resolved PL measurements of Energy Transfer
Semiconductor Photonics Group (TCD)
John F. Donegan
Yury P. Rakovich

Covalent conjugation of bR and QDs / Liquid-AFM
Universite de Reims Champagne-Ardenne and nanoGune (San Sebastian) :
Igor Nabiev[1,2]
Alyona Sukhanova[1,2]
Nicolas Bouchonville[1]
Michael Molinari[1]
Michel Troyon[1]

Proton pumping by bacteriorhodopsin
Evgeniy Lukashev from Lomonosov Moscow State University
Vladimir Oleinikov from Russian Academy of Sciences

QDs synthesis:
Yury Gun'ko from School of Chemistry, TCD
Mikhail Artemyev from Belarusian State University, Belarus
Vladimir Lesnyak and Nikolai Gaponik from Technical University of Dresden, Germany

Thank you for your attention