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Quantum dots and their photoluminescence properties

Markéta Vaculovičová

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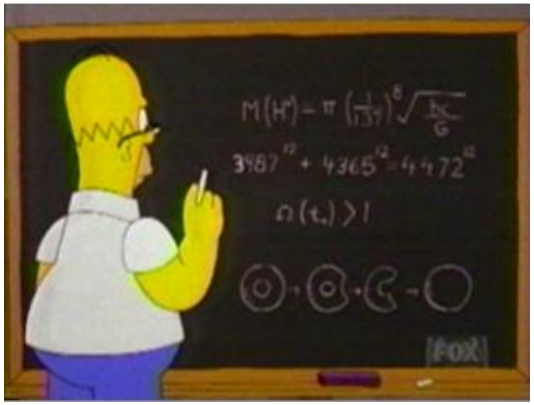
Název projektu: Partnerská síť centra excelentního bionanotechnologického výzkumu

NanoBioMetalNet

final expression for the energy of an absorbed or emitted photon

$$\Delta E = \frac{hc}{\lambda} = E_{BG} + \frac{h^2(n_1^2 + n_2^2 + n_3^2)}{8m_e^* d^2} + \frac{h^2(n_1^2 + n_2^2 + n_3^2)}{8m_h^* d^2}$$



$$V = \frac{-e^2}{4\pi r \varepsilon}$$

$$a = \frac{v^2}{r}$$

$$\frac{e^2}{4\pi\varepsilon r^2} = m_e^* \frac{v^2}{r}$$

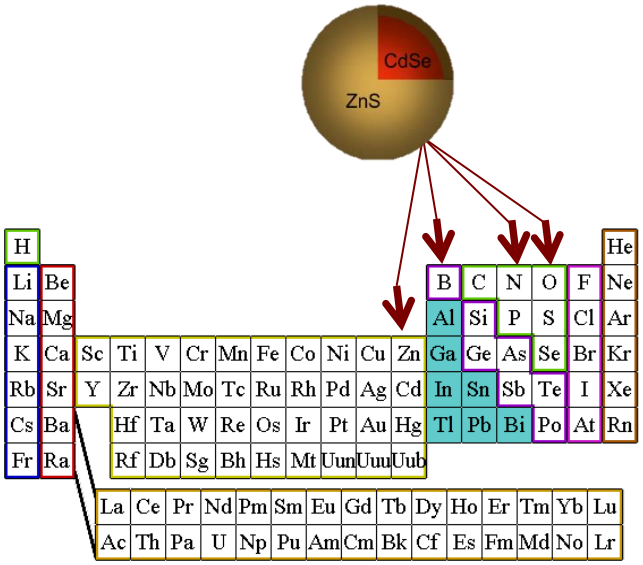
$$\frac{1}{2}mv^2 = \frac{e^2}{8\pi\varepsilon r} = KE$$

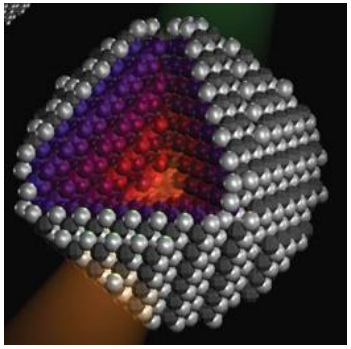
$$E_x = KE + V = \frac{e^2}{8\pi\varepsilon} - \frac{e^2}{4\pi\varepsilon}$$

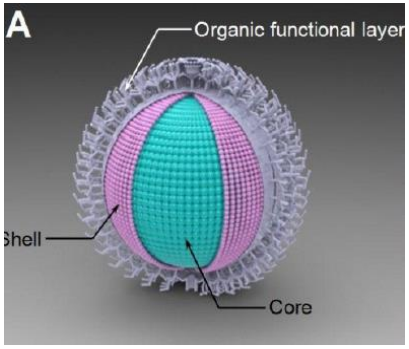
$$\frac{hc}{\lambda} = E_{BG} + \frac{h^2(n_1^2 + n_2^2 +}{8m_e^* d^2} + \frac{}{8m_h^* d^2} - \frac{e^2}{8r\pi\varepsilon}$$

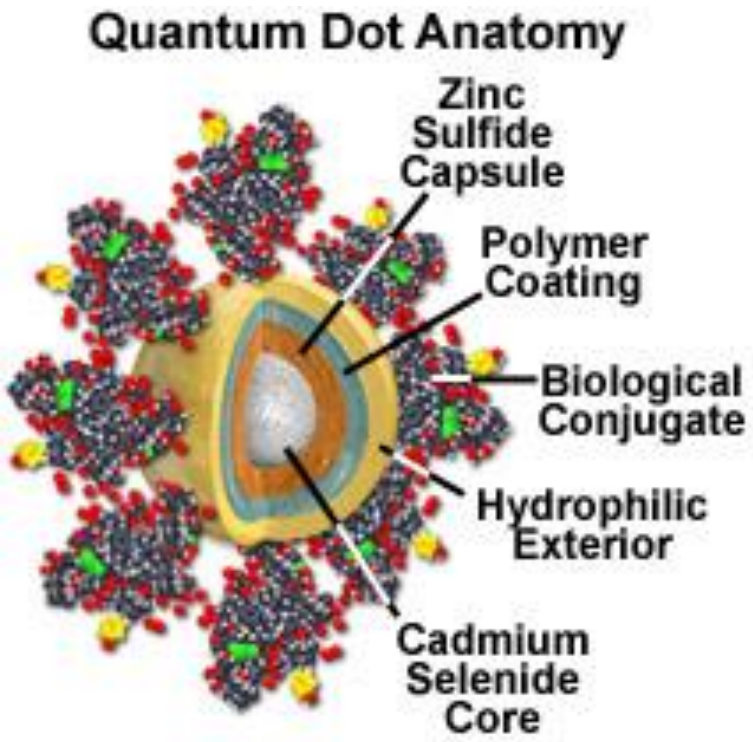
Quantum dots

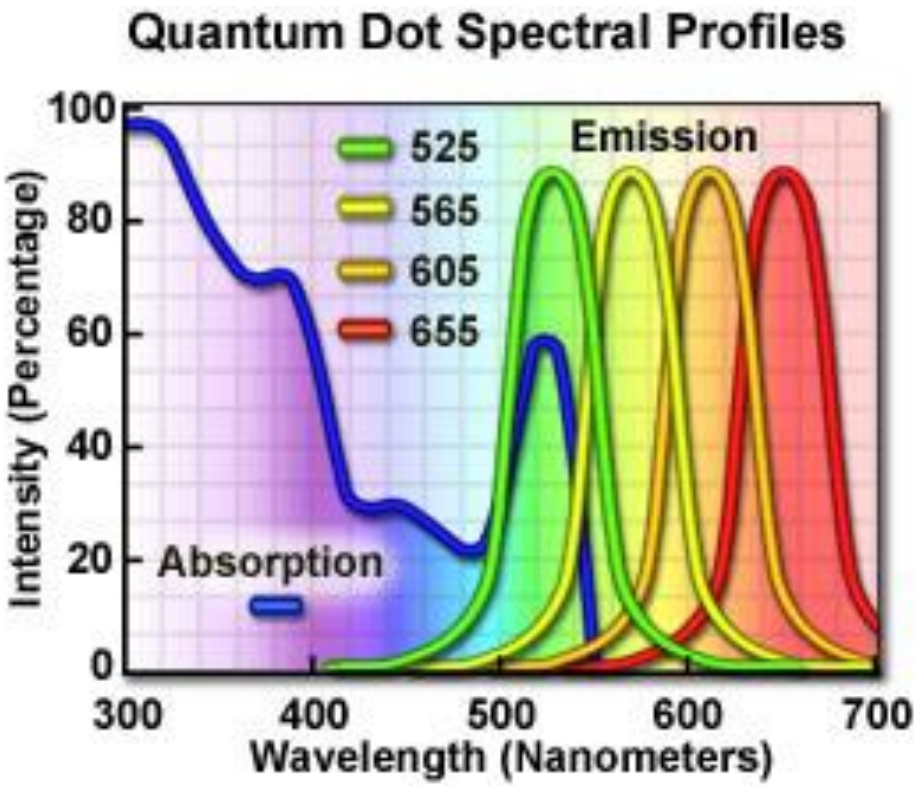
- Semiconductor nanocrystals synthetized from II and VI or III and V elements of PSE
- 1970 developed first low dimensional structures quantum well (QW)
- 1980 – Ekimov, Efros – first description of quantum dots



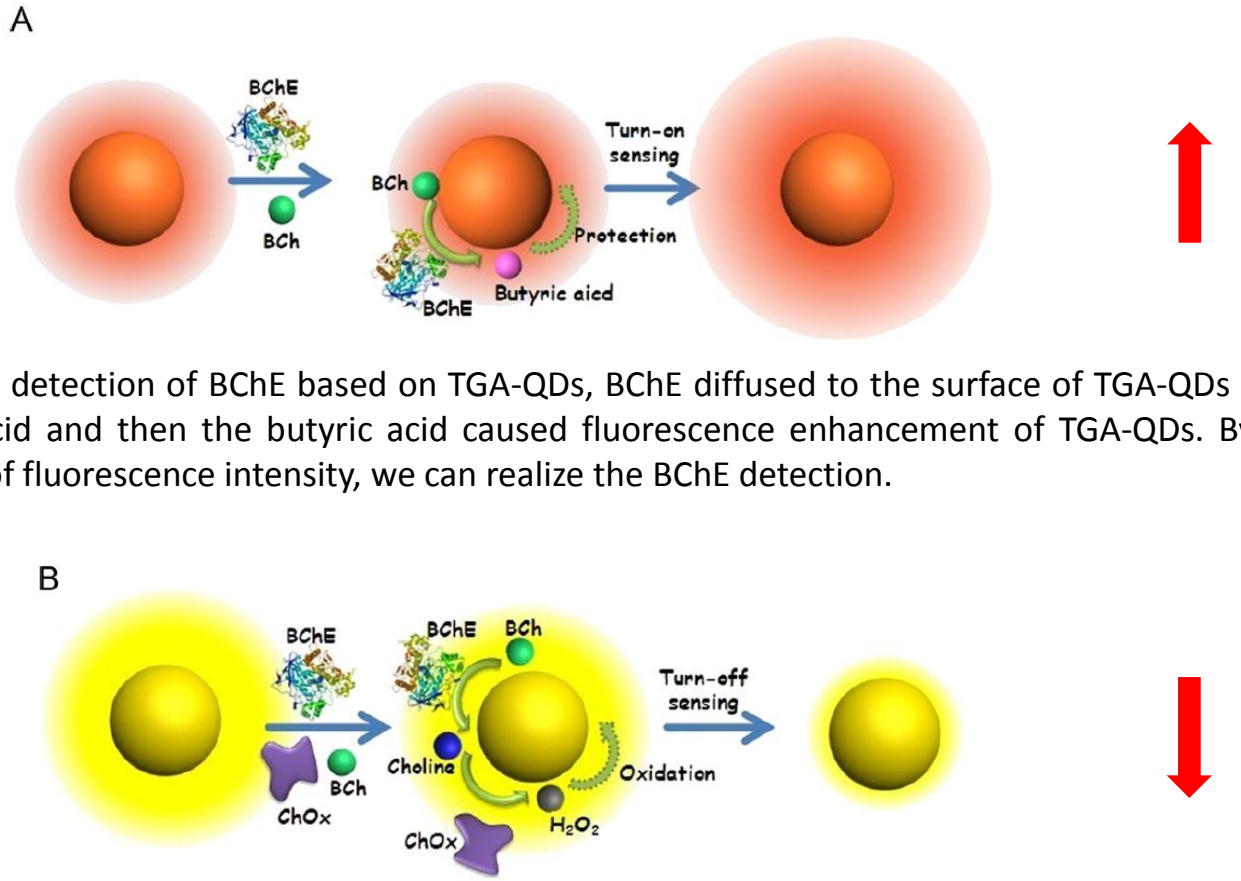





Quantum Dot Anatomy
Zinc Sulfide Capsule
Polymer Coating
Biological Conjugate
Hydrophilic Exterior
Cadmium Selenide Core


Quantum Dot Spectral Profiles
Intensity (Percentage)
100
80
60
40
20
0
525
565
605
655
Emission
Absorption
300
400
500
600
700
Wavelength (Nanometers)

Turn-on /Turn-off Butyrylcholinesterase Sensor



Scheme 1. Schematic principle for assay of BChE by TGA-QDs (A) or MGA-QDs (B).

During the turn-on detection of BChE based on TGA-QDs, BChE diffused to the surface of TGA-QDs and catalyzed BCh to produce butyric acid and then the butyric acid caused fluorescence enhancement of TGA-QDs. By the analysis of the change regularity of fluorescence intensity, we can realize the BChE detection.

BChE turn-off detection system is based on MGA-QDs show that the fluorescence intensity of MGA-QDs changed slightly in the presence of BCh, ChOx and BChE. The results proved that the formations of H_2O_2 are essential to quench the fluorescence maximum of MGA-QDs. During the BChE detection by MGA-QDs, BCh was catalyzed by BChE and ChOx to produce H_2O_2. Then H_2O_2 diffused to the surface of MGA-QDs and carries out the oxidation process with QDs. The fluorescence of the MGA-QDs was quenched. With the increase of BChE, the quenching effect of the QDs has been enhanced, because the produced H_2O_2 was increased.

QDs-based xRET

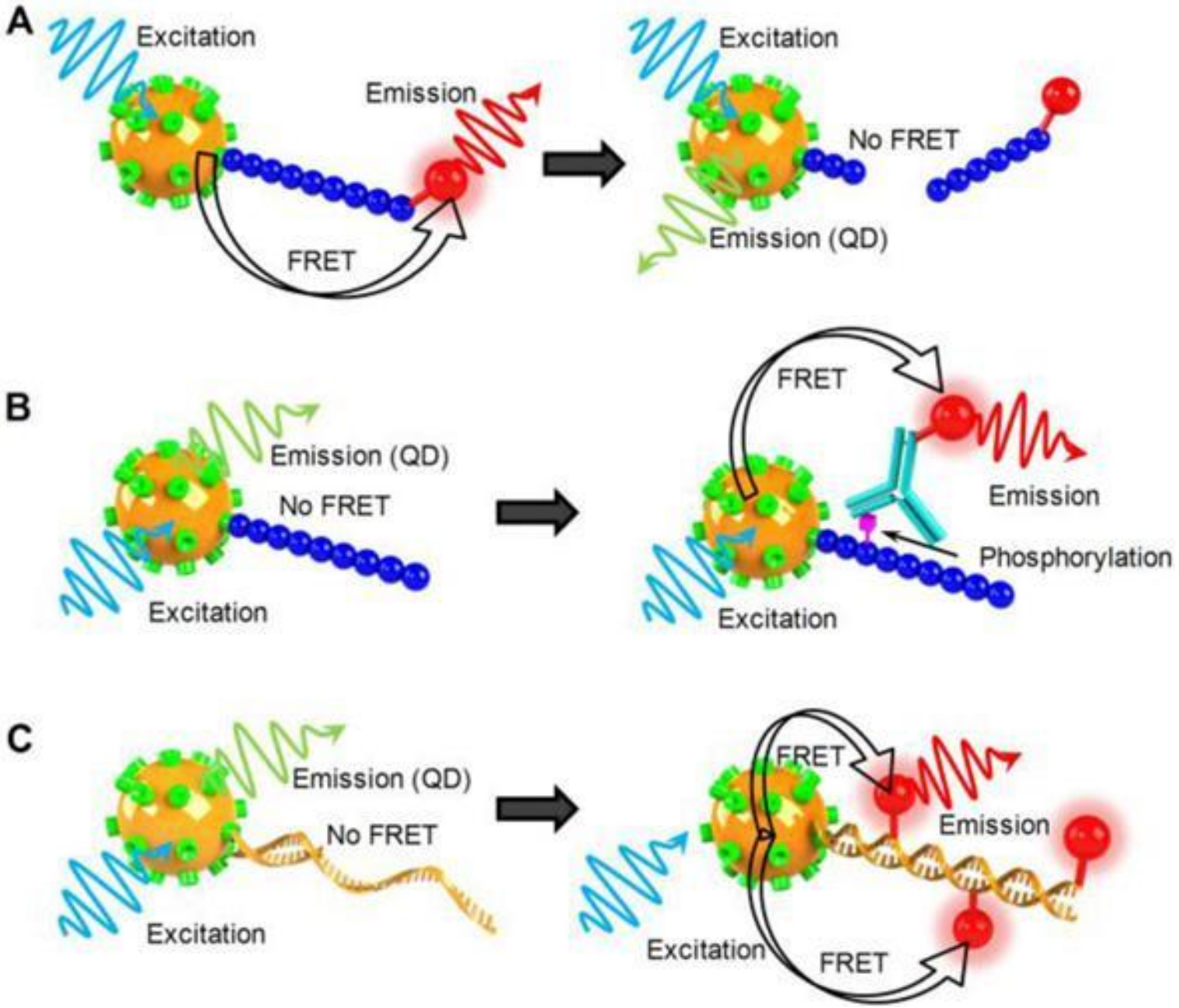
x = F, B, C, P

FRET – fluorescence resonance energy transfer

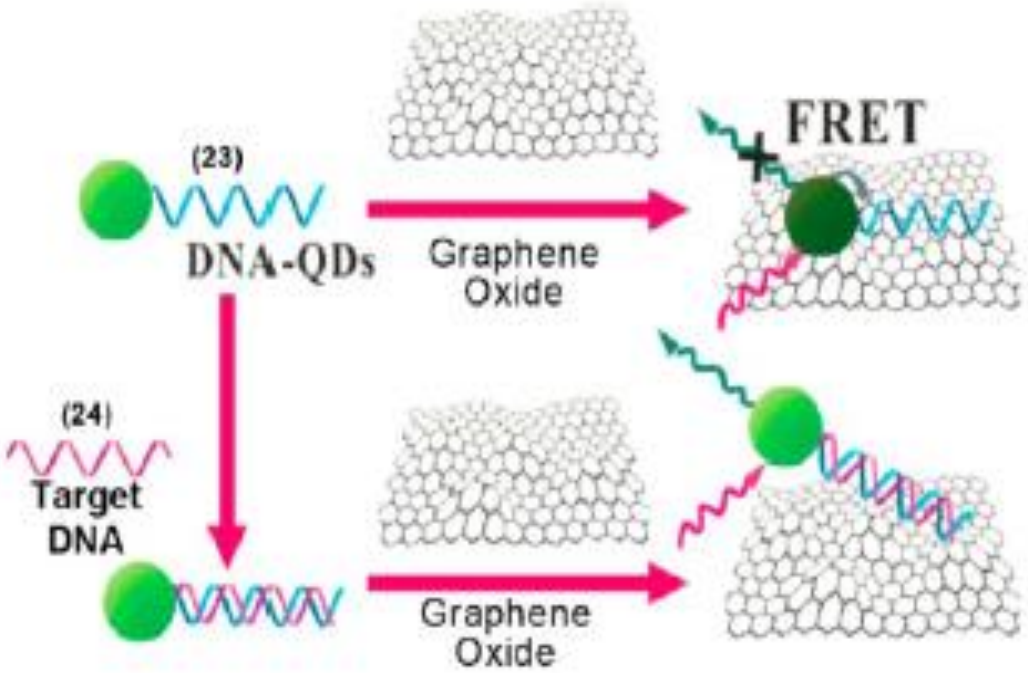
BRET – bioluminescence resonance energy transfer

CRET – chemiluminescence resonance energy transfer

PRET – plasmon resonance energy transfer

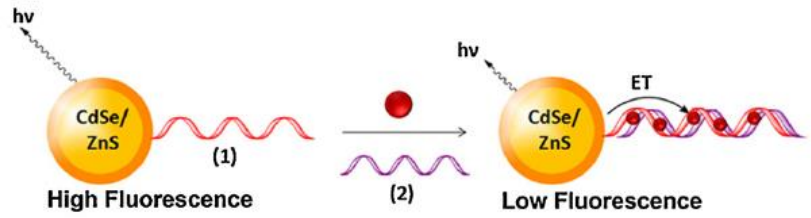

A
Excitation
Emission
FRET
Excitation
No FRET
Emission (QD)
B
Emission (QD)
No FRET
Excitation
FRET
Emission
Phosphorylation
Excitation
C
Emission (QD)
No FRET
Excitation
FRET
Emission
Excitation
FRET

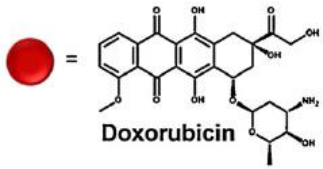
Detection of target DNA



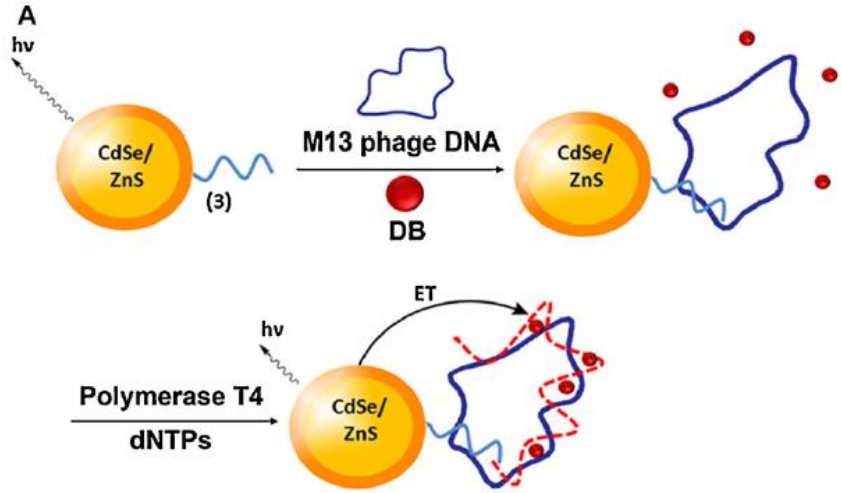
Detection of a target DNA (24) using probe functionalized QDs and graphene oxide as FRET quencher.

Detection of target DNA





- Sensing the target DNA (8) by the probe nucleic acid (9)-modified QDs, using doxorubicin (7) as an electron transfer quencher for the luminescence of the QDs.



- Amplified detection of M13 DNA by the (**3**)-modified QDs through the replication of the analyte DNA and the incorporation of DB into the resulting duplex

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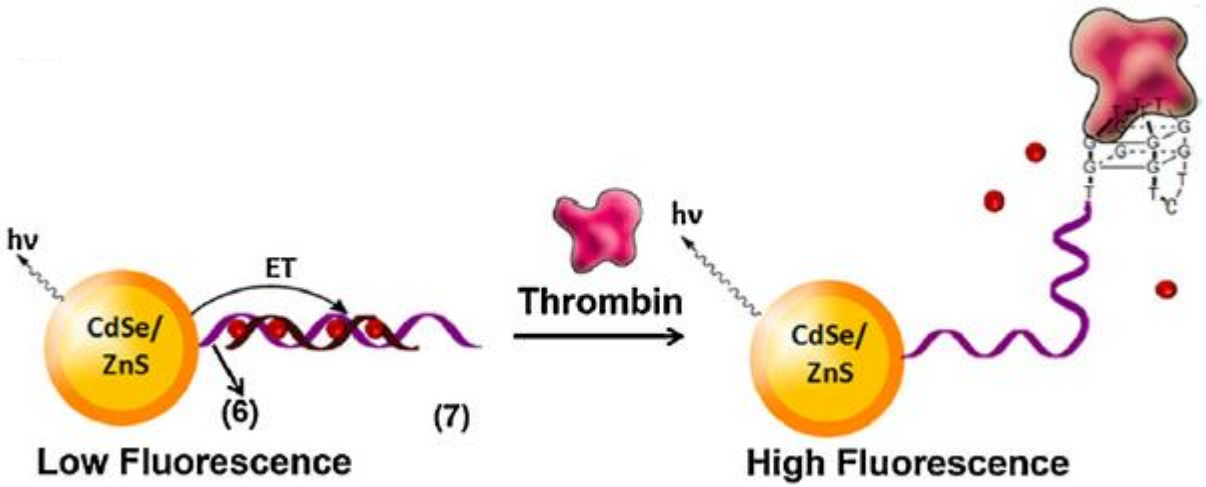
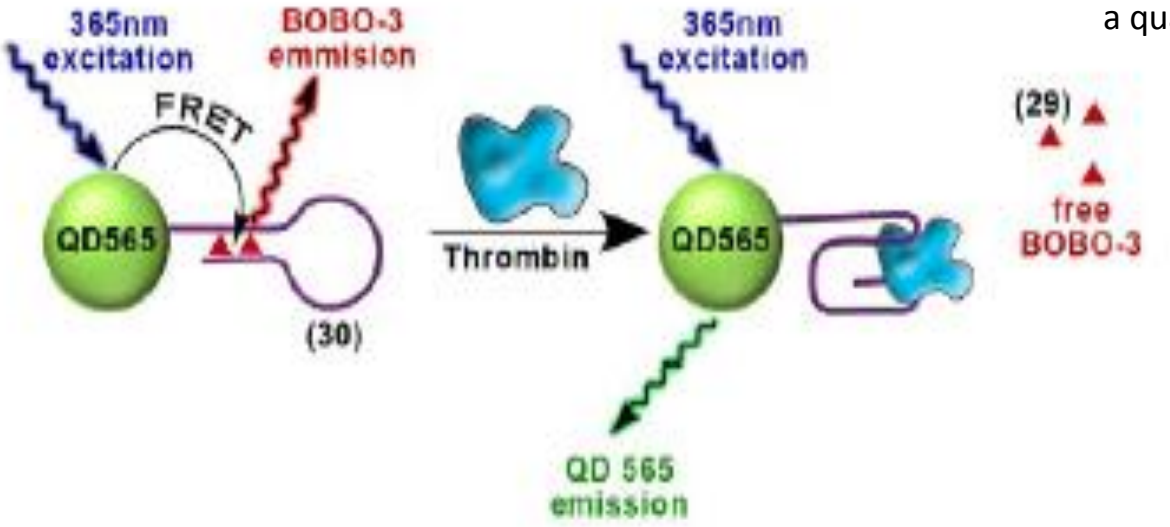
Thrombin detection



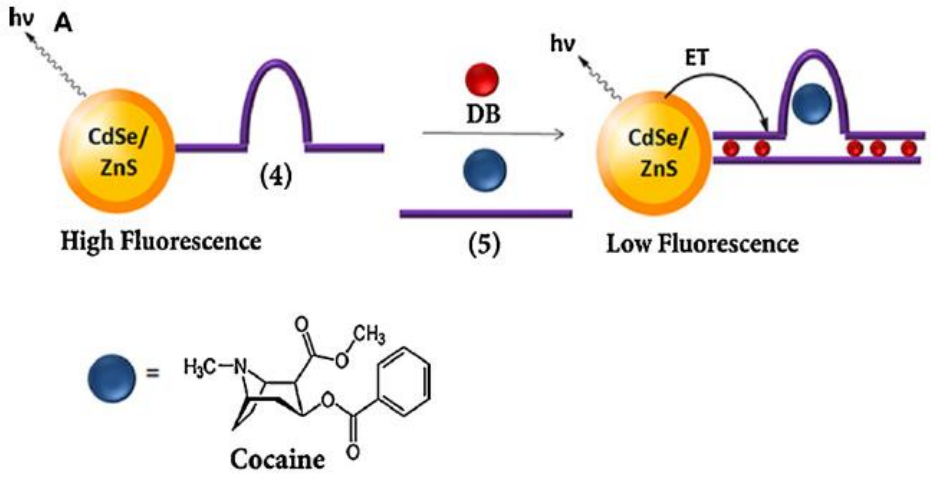
- Analysis of thrombin through the separation of (7) from the (10)/(11) duplex DNA associated with the QDs through the formation of the aptamer-thrombin complex.

Thrombin detection

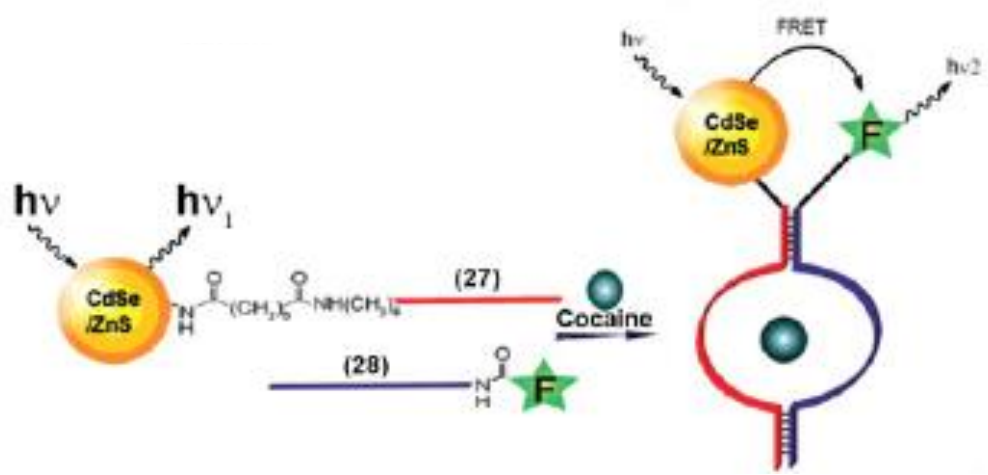
A single-stranded anti-thrombin aptamer probe, requiring neither fluorophore nor quencher end-labeling, is covalently conjugated to Qdot 565 (peak emission at 565 nm). Then BOBO-3 that shows large fluorescence enhancement when it is intercalated into a double helix, is used to stain the duplex regions of the unfolded aptamer on QD to result in the QD-apt:B beacon. (Note: dash and colon in QD-apt:B stand for a covalent linkage and affinity adsorption, respectively.) Before thrombin binding, a FRET-mediated emission of the stained BOBO-3 can be observed while QD is illuminated at 365 nm. When thrombin binds to aptamer, the induced conformational change, from a stem-loop to a quadruplex



Cocaine detection

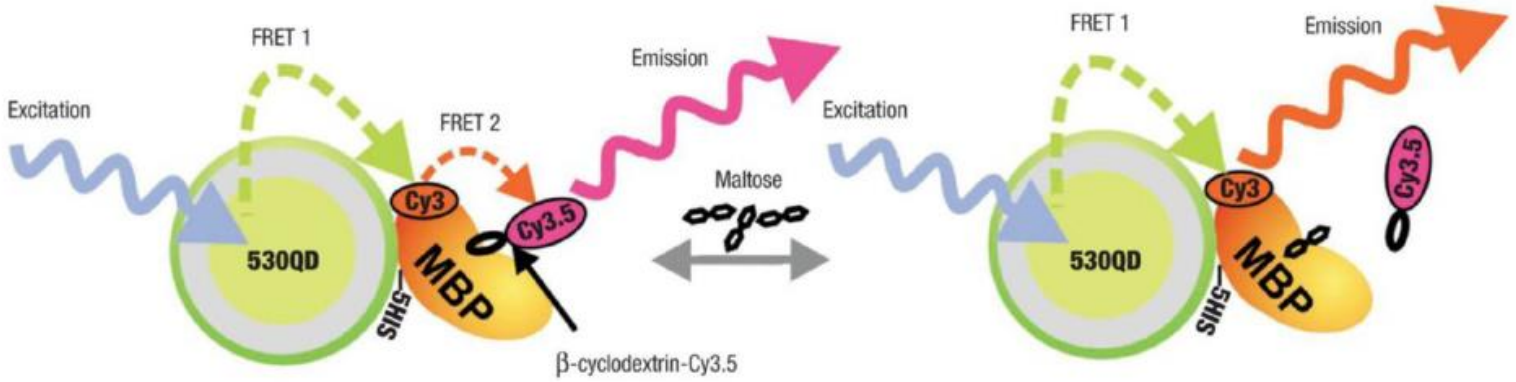


Analysis of cocaine through the self-assembly of the anti-cocaine aptamer subunits complex on the QDs, and the incorporation of DB into the resulting duplex regions.



Analysis of cocaine by QD/dye aptamer subunits and the implementation of the FRET mechanism.

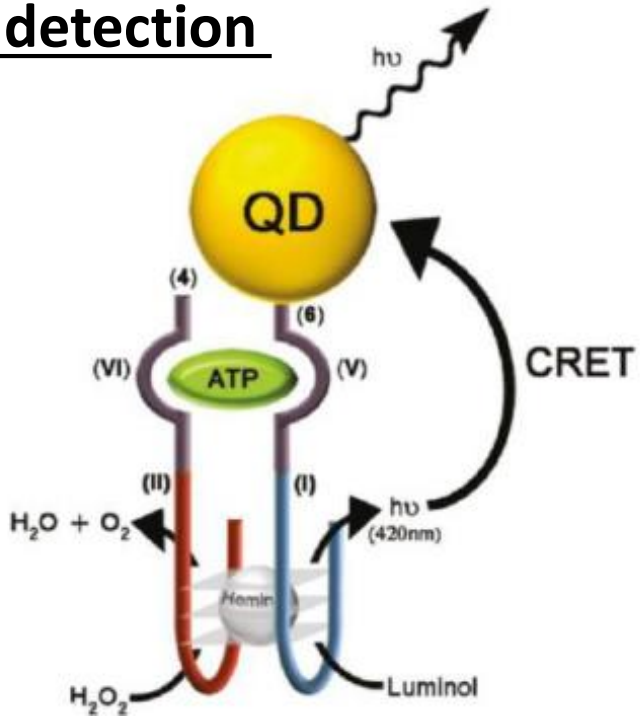
Maltose detection



QD-FRET for maltose detection. A) Schematic of a 530QD-MBP-Cy3-β-CD-Cy3.5 maltose sensor assembly. A 530-nm QD is surrounded by ~10 MBPs (only one shown for clarity), each monolabeled with Cy3 at cysteine 95 (maximum absorption ~556 nm, maximum emission ~570 nm). Specifically bound β-CD-Cy3.5 (maximum absorption ~575 nm, maximum emission ~595 nm) completes the QD-10MBP-Cy3-β-CD-Cy3.5 sensor complex. Excitation of the QD results in FRET excitation of the MBP-Cy3, which in turn FRET excites the β-CD-Cy3.5. Added maltose displaces β-CD-Cy3.5 leading to increased Cy3 emission. B) Maltose sensing of

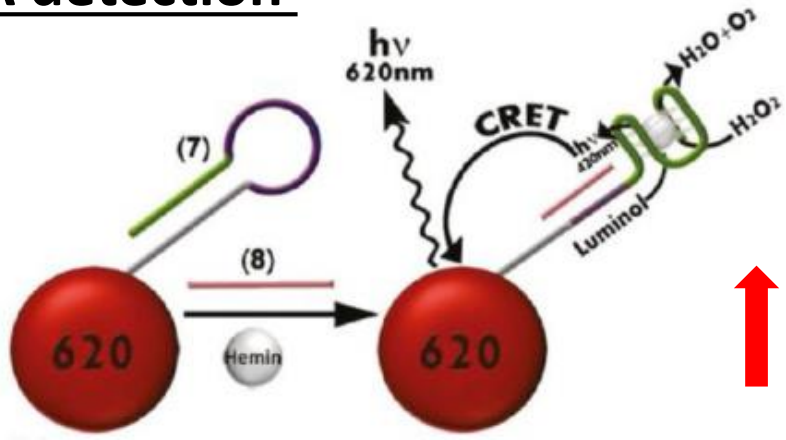
MBP = maltose binding protein

ATP detection



- QD-CRET detection of ATP by two subunits consisting of the conjugated anti-ATP and HRP-DNAzyme subunits. Upon the recognition of ATP by the aptamer, the chemiluminescence of luminol is activated and the energy is transfer to QD.

Target DNA detection

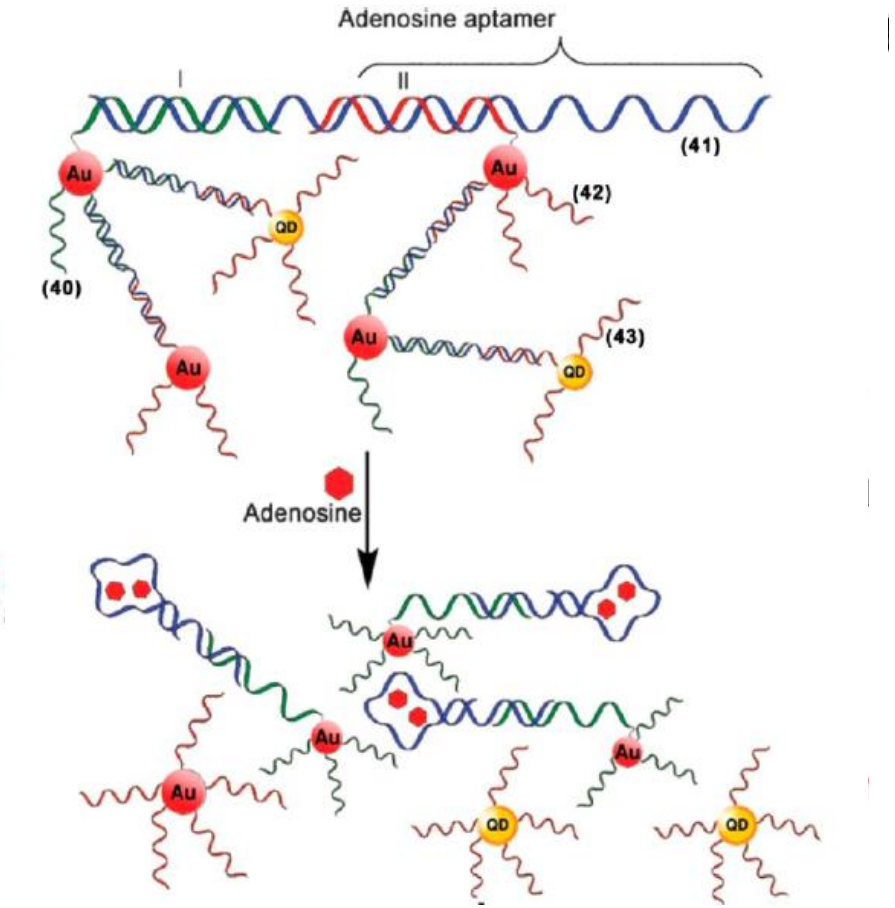


- QD-CRET detection of specific DNA sequence. The hybridization of DNA target to the hairpin opens the loop and allows the formation of hemin/G-quadruplex which gives rise to QD-CRET signals. D) (1) The luminescence spectrum of QDs mixture cor-responding to the CRET signal in the absence of DNA targets; (2) in the presence of the target 1; (3) in the presence of target 2; (4) in the presence of target 3; (5) in the presence of all three targets.

Summary

These examples were the simple ones….

There is much more to play with…



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Review

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Nucleic Acid/Quantum Dots (QDs) Hybrid Systems for Optical and Photoelectrochemical Sensing

Ronit Freeman, Julia Girsh, and Itamar Willner*

Institute of Chemistry, Center for Nanoscience and Nanotechnologhy, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

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Review

Quantum Dot Enabled Molecular Sensing and Diagnostics

Yi Zhang[1] and Tza-Huei Wang[2] ✉

1. Department of Biomedical Engineering, Johns Hopkins University School of Medicine, Baltimore, MD 21205, USA.
2. Department of Biomedical Engineering, Department of Mechanical Engineering, Sidney Kimmel Comprehensive Cancer Center, Center of Cancer Nanotechnology Excellence, Johns Hopkins University, Baltimore, MD 21205, USA.

✉ Corresponding author: Dr. Tza-Huei Wang. Address: 3400 North Charles Street, Latrobe 108, Baltimore, MD 21218. Tel: 410-516-7086. Email: thwang@jhu.edu.

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Thank you for your attention

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