(iv) Quantum dots

Lit.: Tuan Vo-Dinh, Biomedical Photonics, p. 58-1, CRC press

- electron in box potential:

$$V(x) = 0 \quad |x| < a$$
$$= \infty \quad \text{otherwise}$$

$$-\frac{\hbar^2}{2m}\frac{d^2u(x)}{dx^2} + V(x)u(x) = E\,(u(x))$$

$$u(x \geq |a|) = 0$$

$$|x| < a \Rightarrow \frac{d^2u(x)}{dx^2} + \frac{2mE}{\hbar}u(x) = 0$$

unsymmetric solutions:

$$u_n^{(-)}(x) = \frac{1}{\sqrt{a}}\sin\frac{n\pi x}{a} \qquad E_n^{(-)} = \frac{n^2\pi^2\hbar^2}{2ma^2}$$

symmetric solutions:

$$u_n^{(+)}(x) = \frac{1}{\sqrt{a}}\cos\frac{[n-\frac{1}{2}]\pi x}{a} \qquad E_n^{(+)} = \frac{(n-\frac{1}{2})^2\pi^2\hbar^2}{2ma^2}$$

Quantum Dots

- semiconductor nanocrystals Ø < ~10 nm

  group I – VII

  II – VI

  III – V

- until 1993 fluorescence quantum yield < 20%
  reason: broad size distribution
  from aqueous buffer/micelle synthesis

- 1993 organometallic synthesis Bawendi
  perfect structure, narrow size range

  since 1998 development of biological labels

  very common: CdSe (Nie, Alivisatos)

further II – VI compounds CdTe, CdS, ZnSe

properties

- size increase leads to red shift of emission
  (~ 1 d box description)

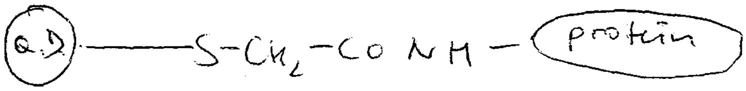
- photostability very high (4 size orders compared to 'chemical' fluorophores)

Surface chemistry

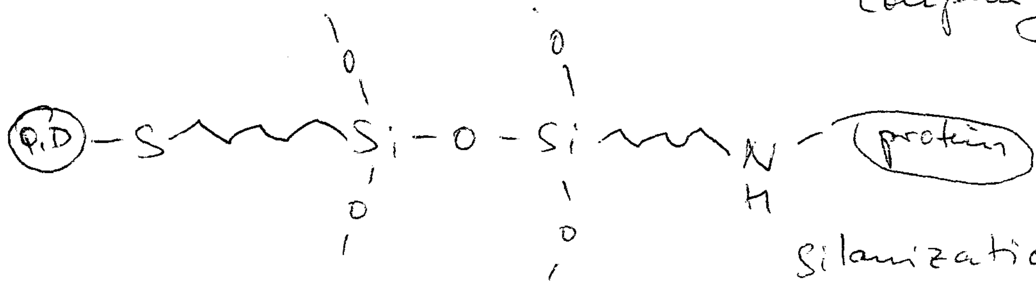
- 'water solubility' can be achieved by coupling to siloxanes or acetyl residues

Bioconjugation

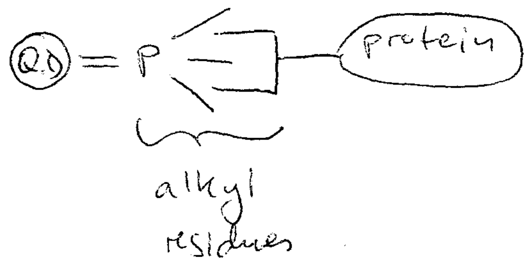
- placing of reactive groups on the surface of 'water-soluble' quantum dots, coupling to biomolecules (proteins)

A) 

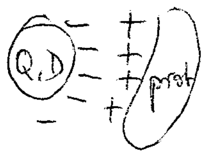
bifunctional coupling

B) 

silanization

C) 

hydrophobic attraction

D) 

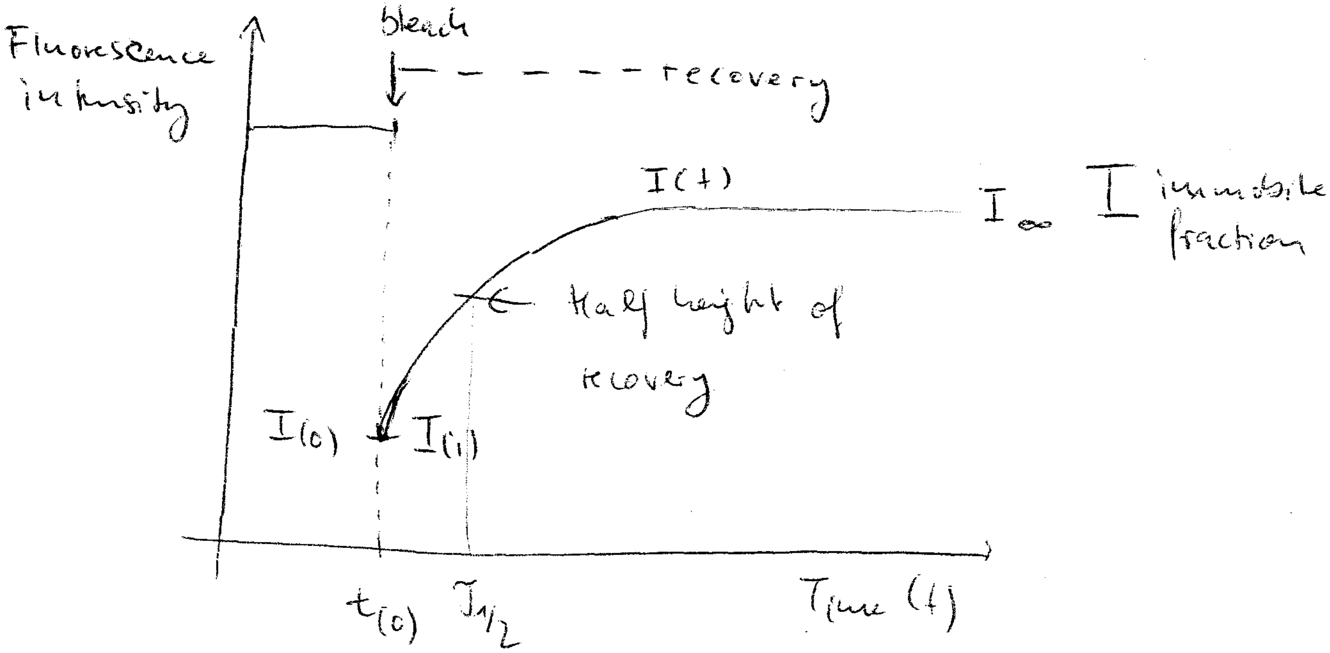
electrostatic

Fluorescent recovery after photobleaching (FRAP)

- measurement of diffusional mobility of membrane components, but also study of diffusion in cytoplasm is possible

- short pulse of intense laser light → destruction of fluorescence in a small area (micron size).
- Fluorescently-labeled lipids or proteins used

- Recovery of the fluorescence occurs by diffusional exchange between bleached and unbleached molecules, rate is characterized by the lateral diffusion constant D



Diffusion coefficient from $\tau_{1/2}$:

$\tau_D = \tau_{1/2} / \gamma$ $\quad$ γ = correction factor

$\tau_D = \omega_r^2 / 4D$ $\quad$ ω_r = e^{-2} - beam radius
(~ half width of half height of spatial laser intensity)