Quantum dot based sensor for detection of mechanical loads

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Outline

- Motivation
  - Why do we need load detection in lightweight structures?
    - Basics on nanocrystals (quantum dots)
      - What are quantum dots?
      - What is quantum confinement?
        - Concept of load detection sensor
          - Sensor setup, materials
          - Influence of charges on quantum dot fluorescence
            - Summary and outlook

Motivation

Mechanical behaviour of metals

www.steinhart-metall.de

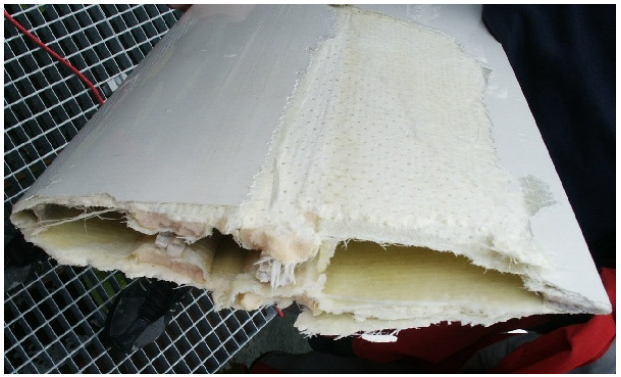
- bendable
- elastic

www.tabtech.de

Mechanical behaviour of reinforced plastics

www.fibre-lyte.co.uk

- fragile
- hidden delamination
- unpredictable failure



www.sailinganarchy.de

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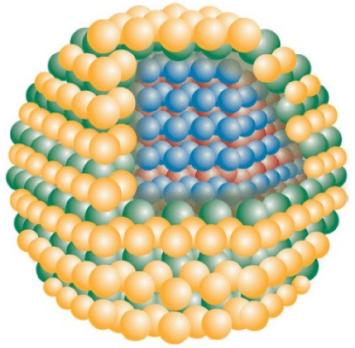
Basics

What are quantum dots?

- ***Materials***
  semiconductors: e.g. CdSe, Silicon, PbS, InP
- ***Dimensions***
  typical diameters in the range of 5 nm,
  coorespondingly some 100 atoms
- ***Electronic structure***
  different compared to bulk-material

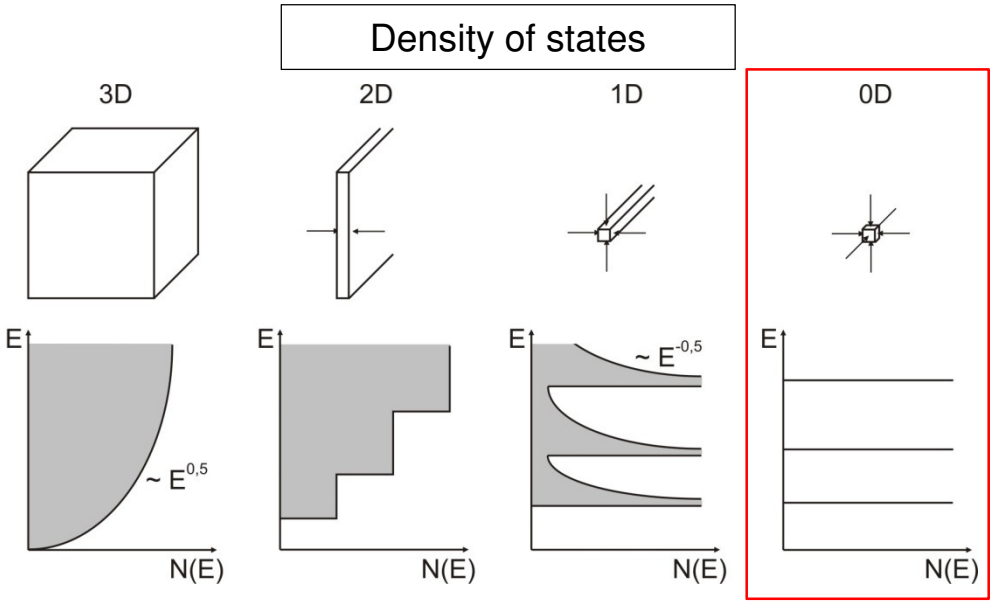


www.evidenttech.com

semiconductor-nanoparticles

=

artificial atoms

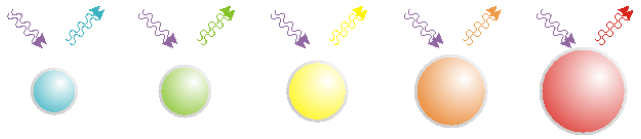


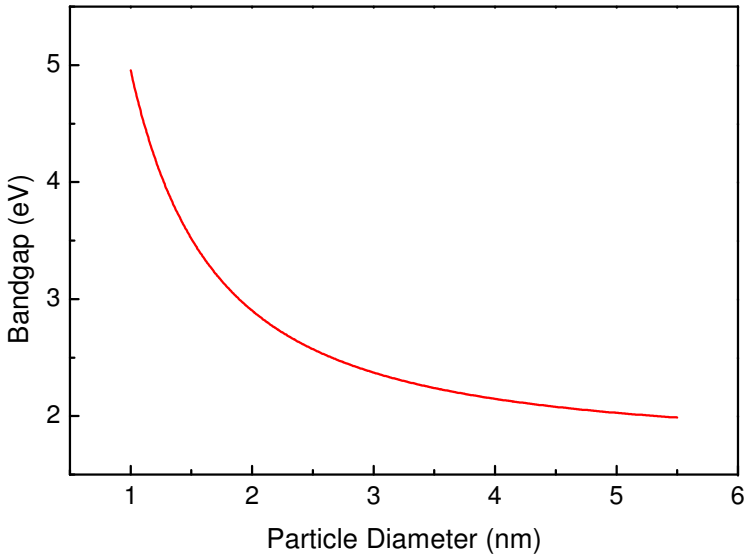
A. D. Yoffe, Adv. Phys. **42**, 173 (1993)

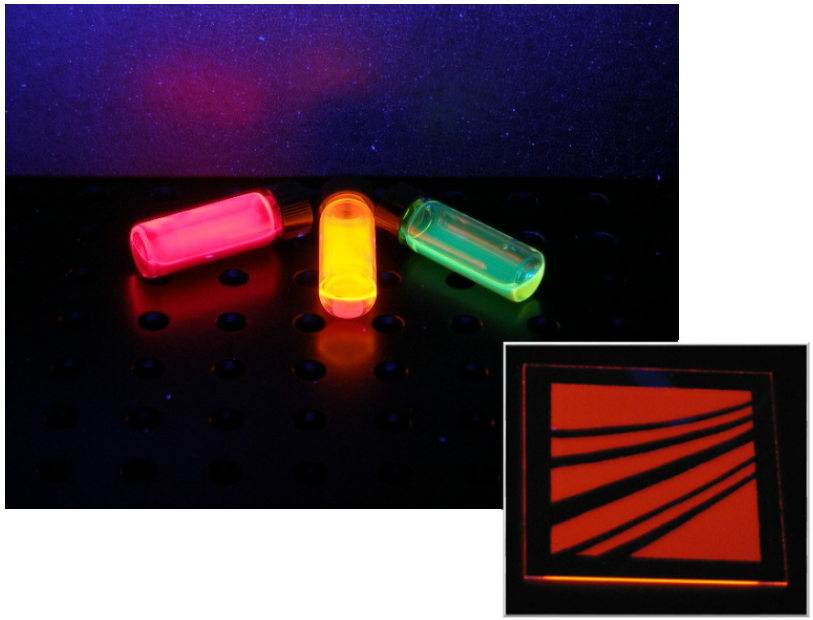
Basics

Fluorescence and quantum confinement

- fluorescence = recombination of electron-hole-pairs (excitons)
- quantum confinement = bandgap and photon energy depends on particle size







Wavelength of fluorescence also depends on particle size!

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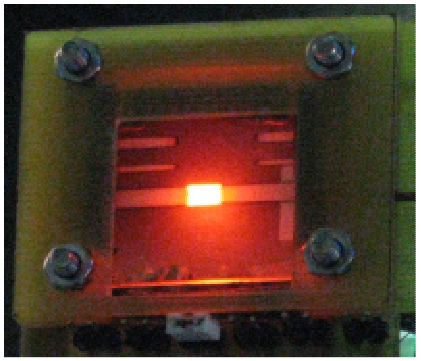
Application scenarios

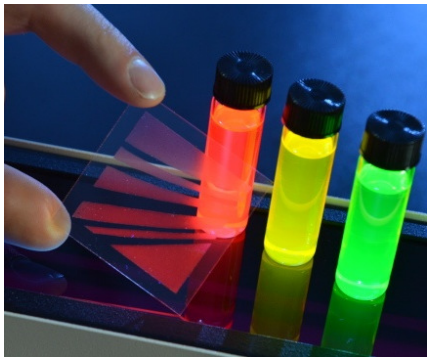
Semiconductor Nanocrystals



Special photophysical properties

Quantum Confinement

Sensitivity against electrical charges



Usage as light emitters

LEDs, displays

fluorescence markers

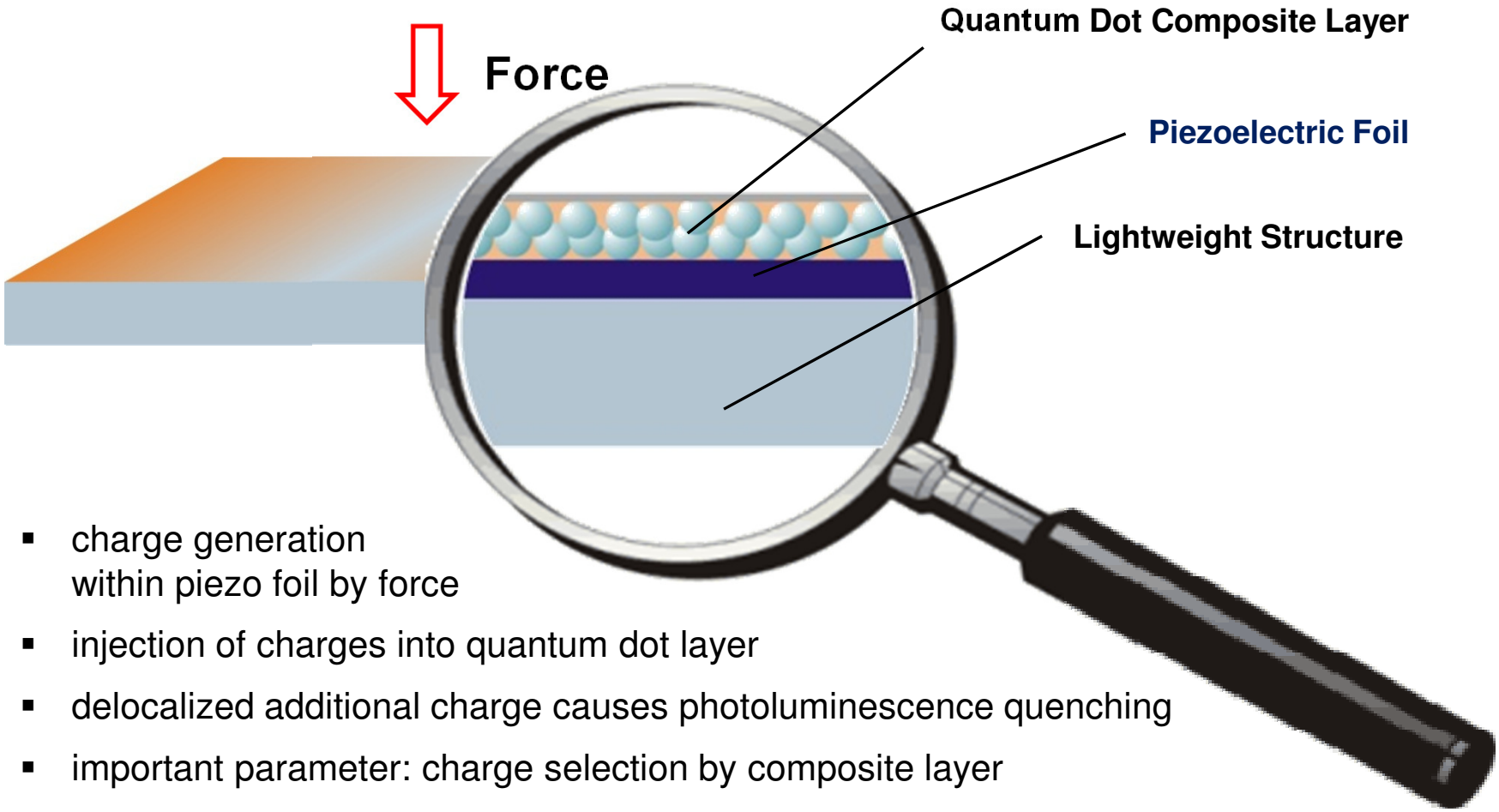
Usage as Nanosensors

Optical detection of

charges and electrical fields

Load detection sensor

Setup



- charge generation
  within piezo foil by force
- injection of charges into quantum dot layer
- delocalized additional charge causes photoluminescence quenching
- important parameter: charge selection by composite layer

Mechanical load results in permanent optical contrast pattern!

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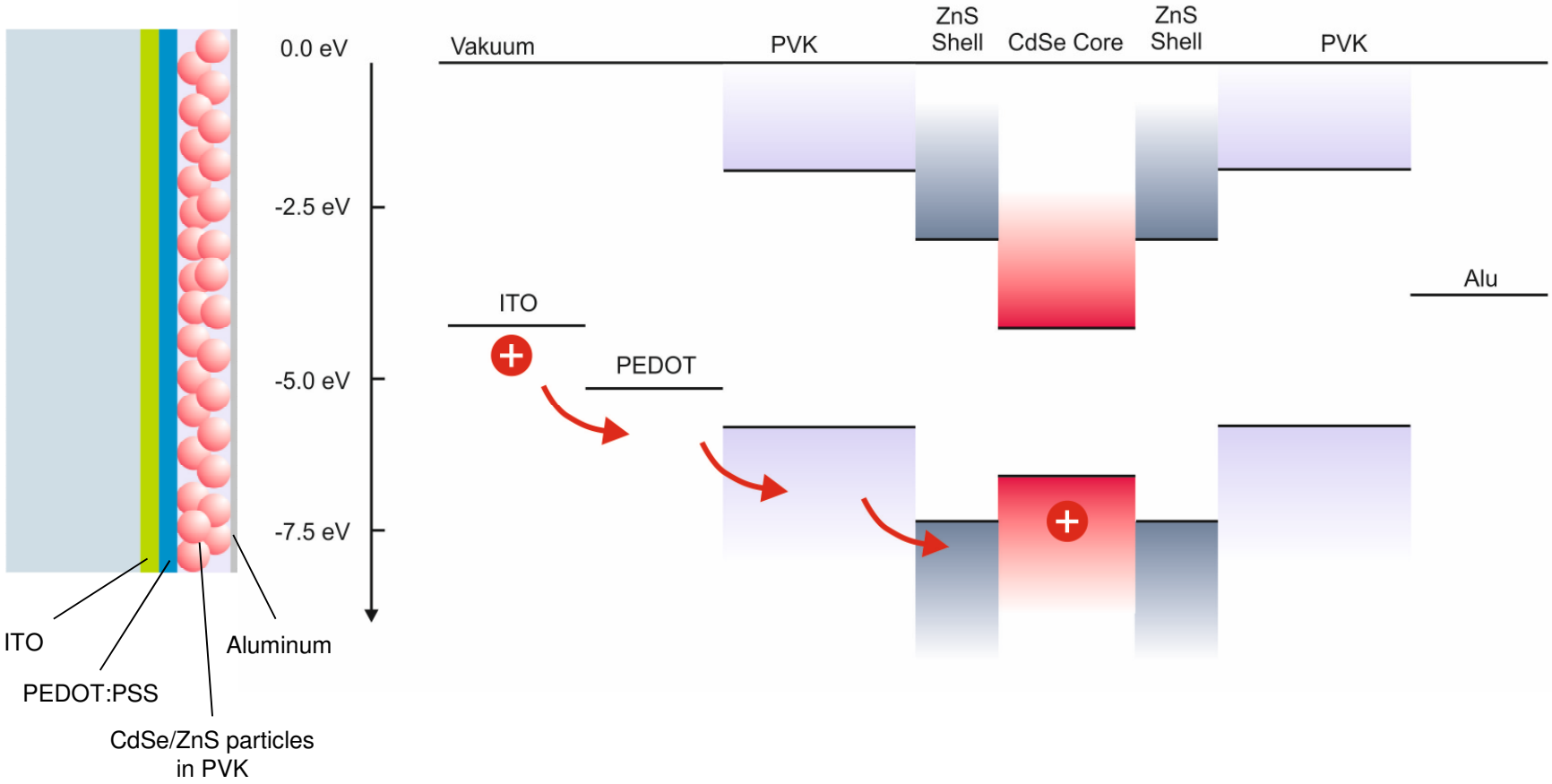
Load detection sensor

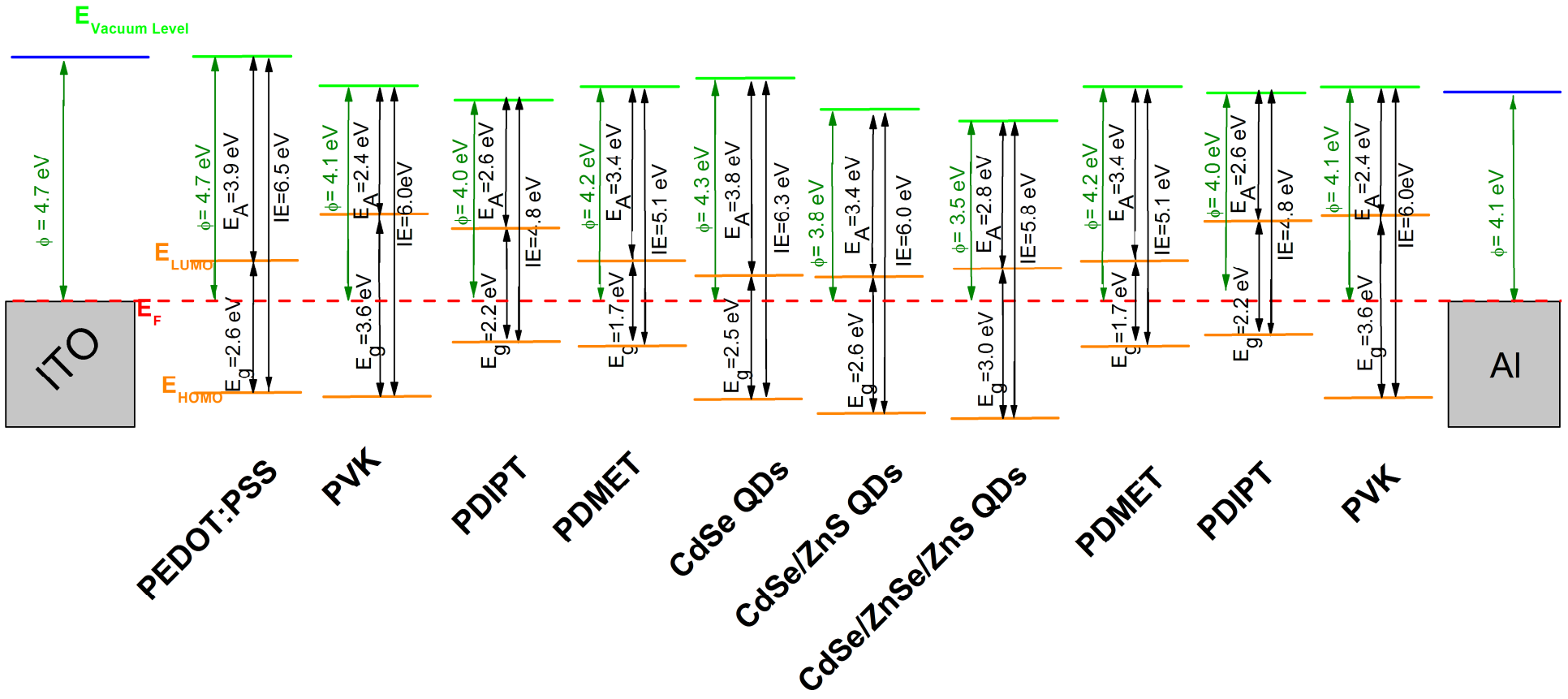


Important material parameters = charge mobility and band level alignment

Load detection sensor

Band level alignment

… determined by UV and inverse photoemission spectroscopy



Goal = Use of matrix material with lowest possible HOMO level.

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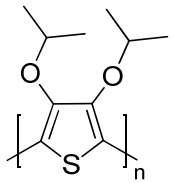
Synthesis and characterization of Polythiophenes

Polythiophenes with different side chains

PDIPT

Polydiisopropoxythiophene

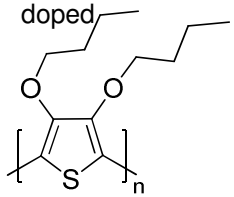
doped



PDBT

Polydibutoxythiophene

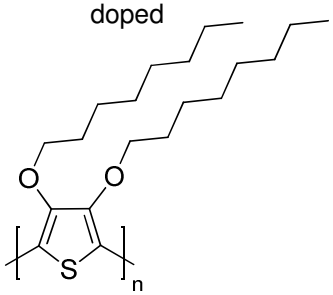
doped



PDOT

Polydioctoxythiophene

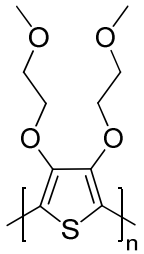
doped

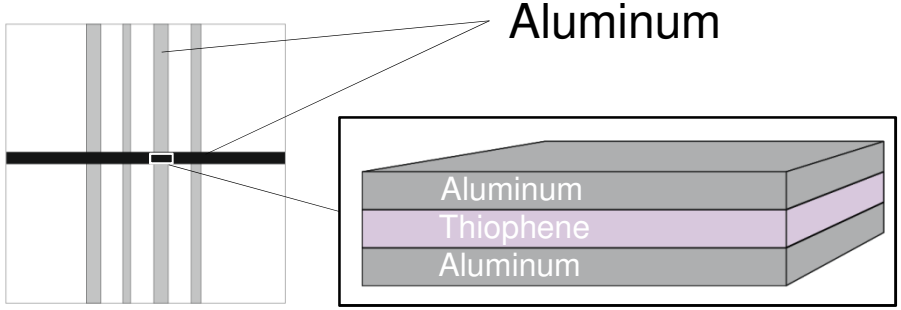


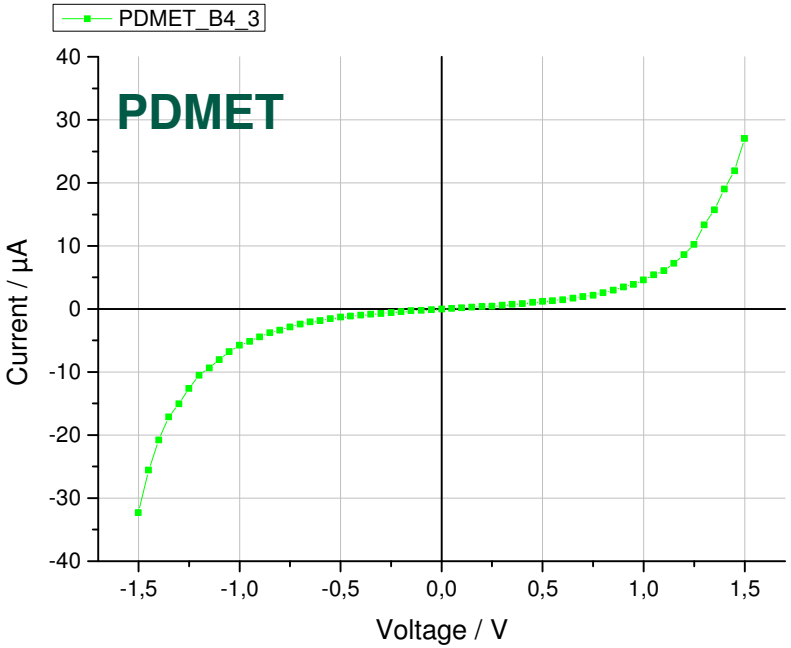
PDMET

Polydimethoxyethoxythiophene

doped







- typical non-linear behavior
- conductivity comparable to PVK

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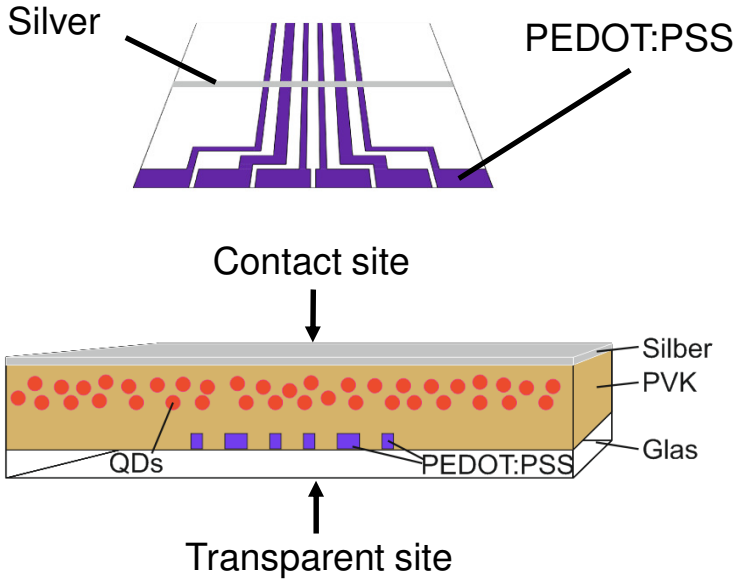
Load detection sensor

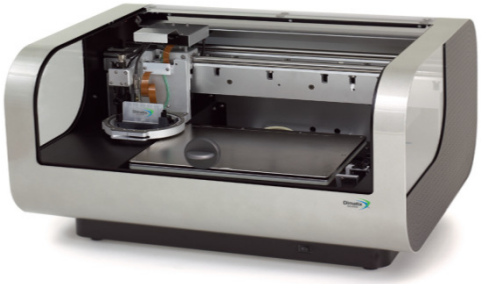
Ink-jet printing

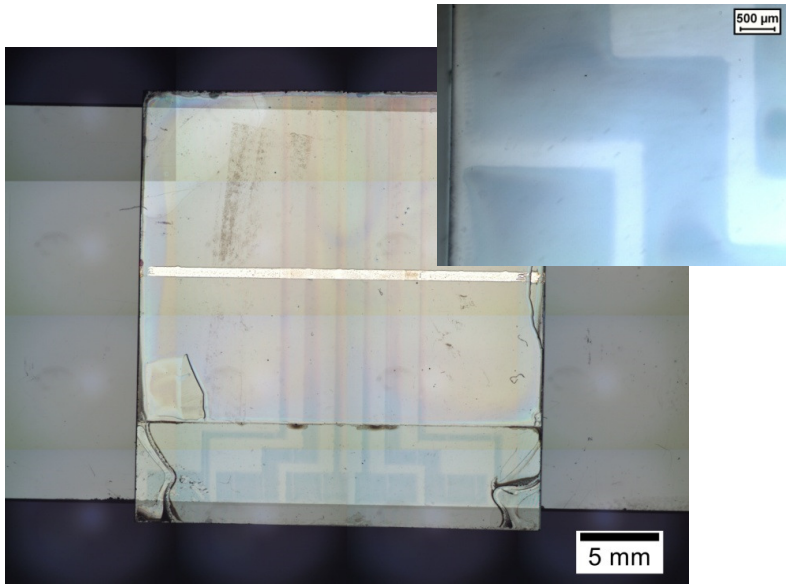
Option without ITO



- investigations on influence of drop-space, pre-treatment (e.g. ozone plasma) and sintering
- optical and electrical characterization
- compromise between transparency and conductivity

Sheet fed inkjet printer DMP2831 *(Fujifilm Dimatix)*





Sample stack with printed electrodes
(closed silver and PEDOT structures)

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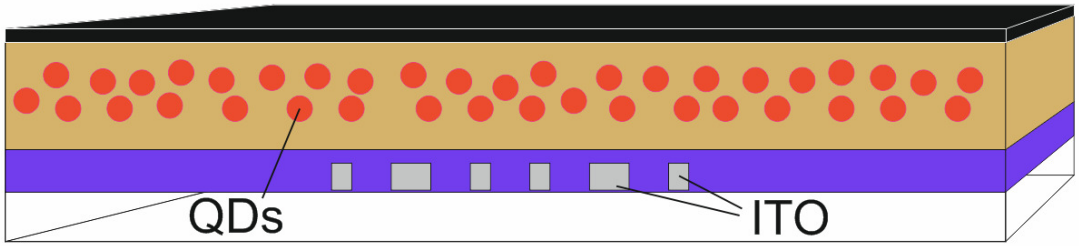
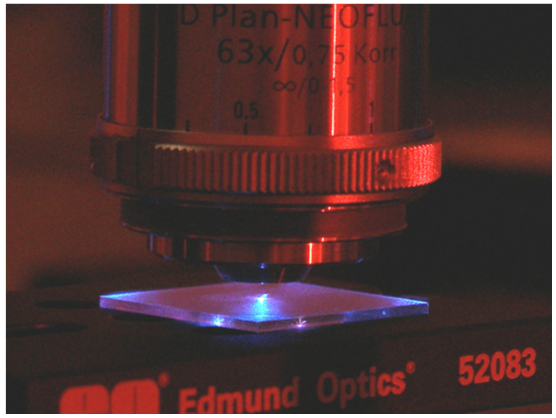
Load detection sensor

PL Quenching

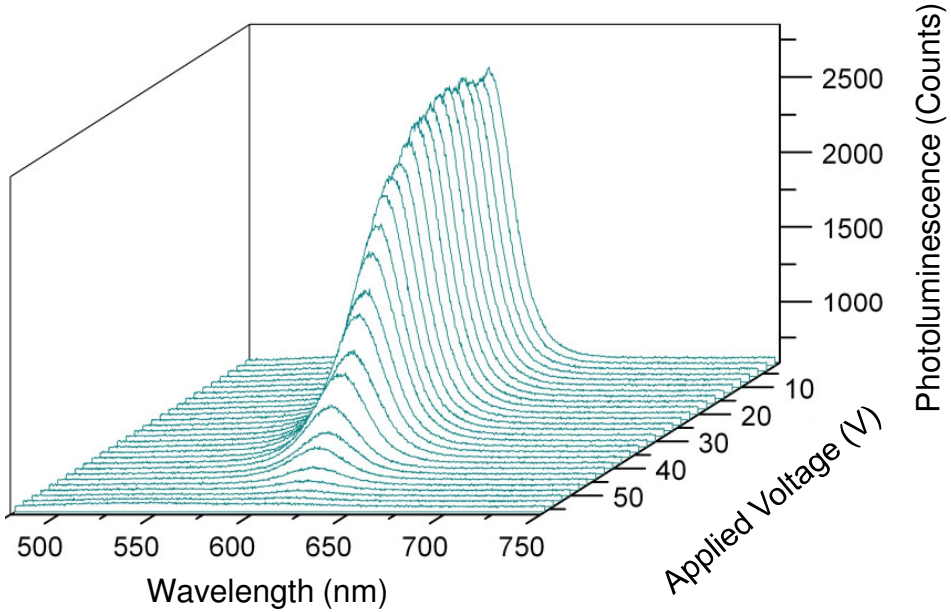
Characterization via confocal micro-spectroscopy





LASER

Photoluminescence



- application of external voltage
- spacial- and time-resolved records

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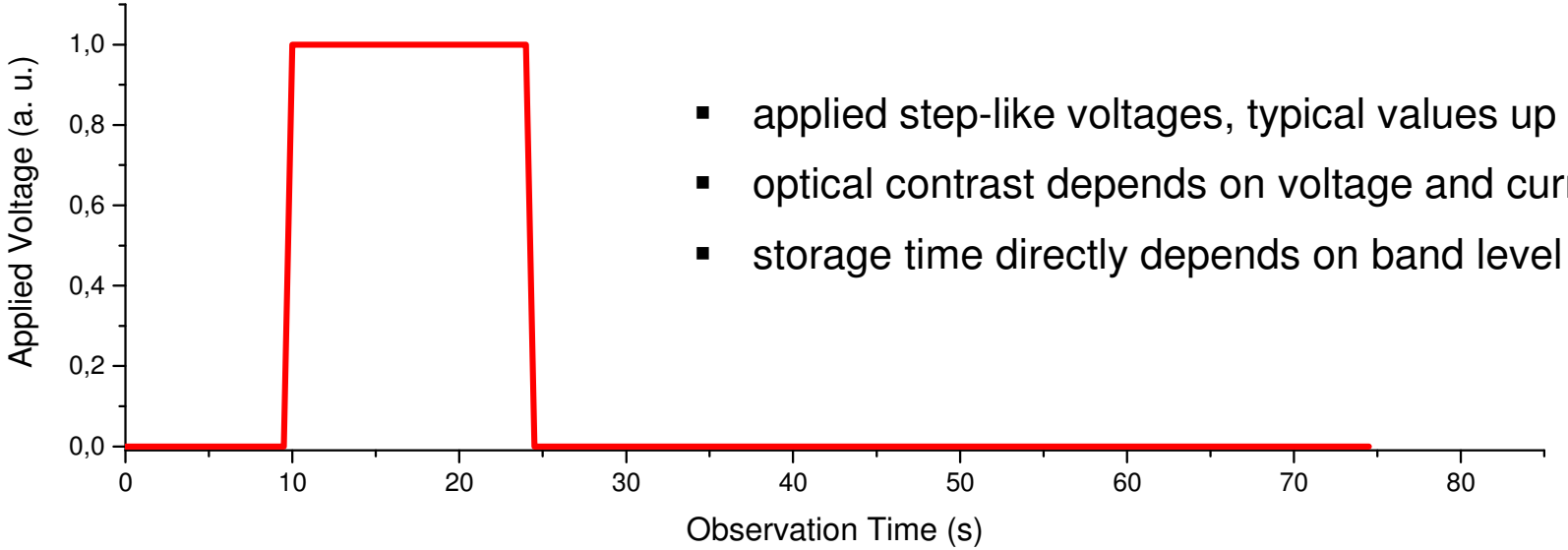
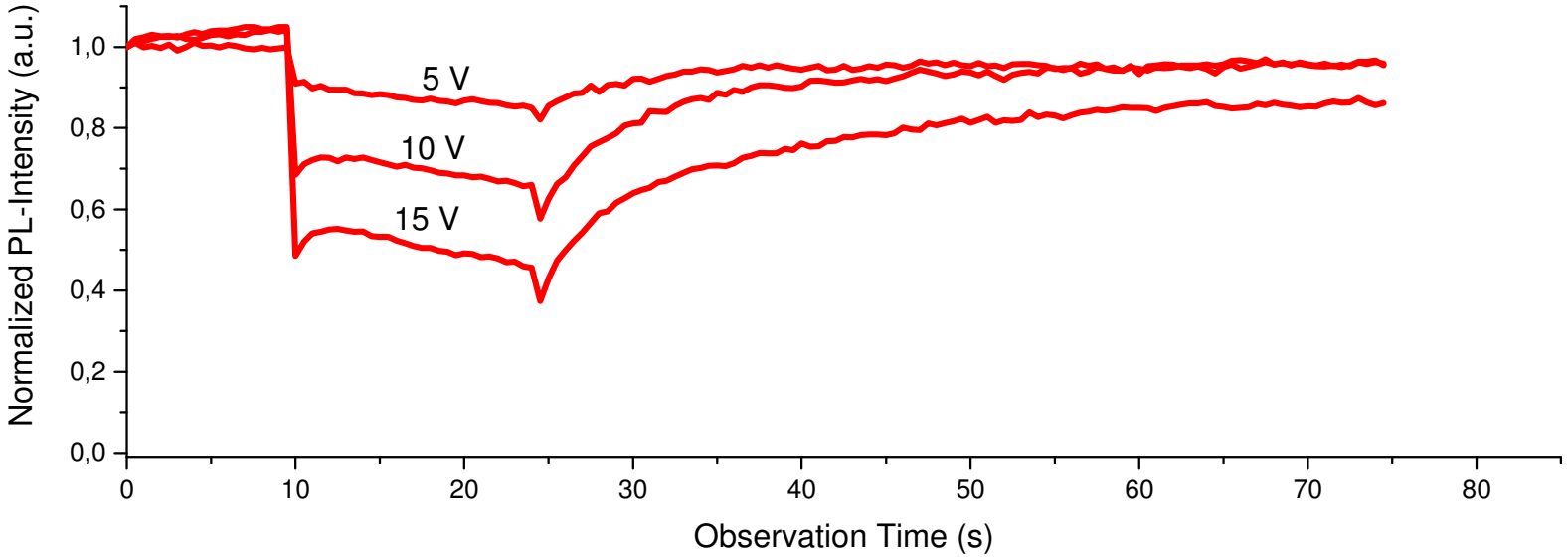
Load detection sensor

PL Quenching



- applied step-like voltages, typical values up to 30 V
- optical contrast depends on voltage and current
- storage time directly depends on band level alignment



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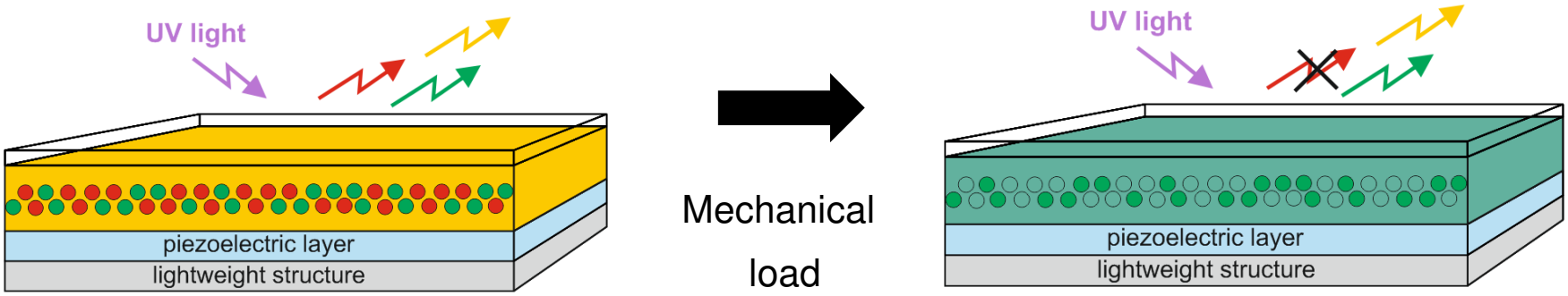
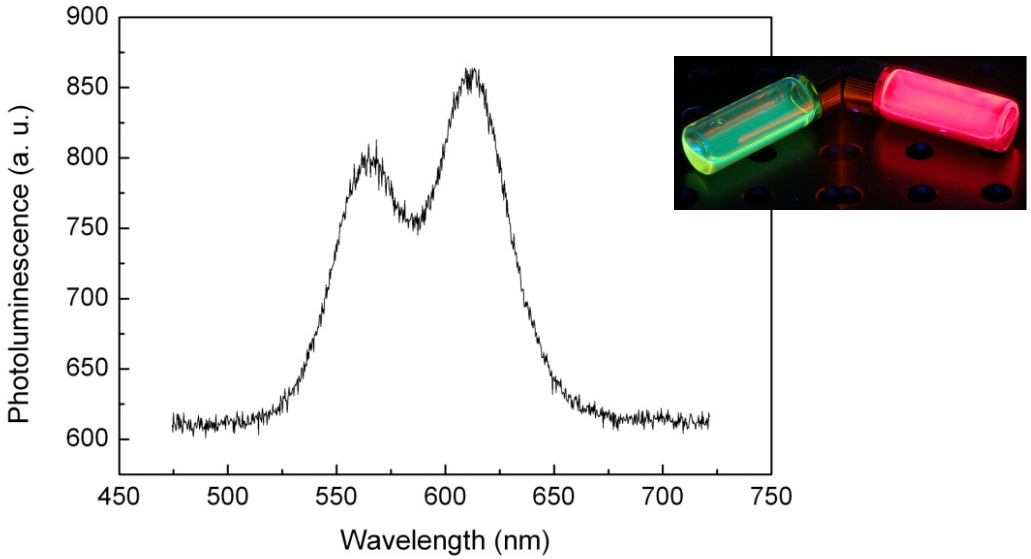
Summary and Outlook

Selective switching of different types of quantum dots





- first experiments indicate possibility of color change
- reason: different tunneling probabilities

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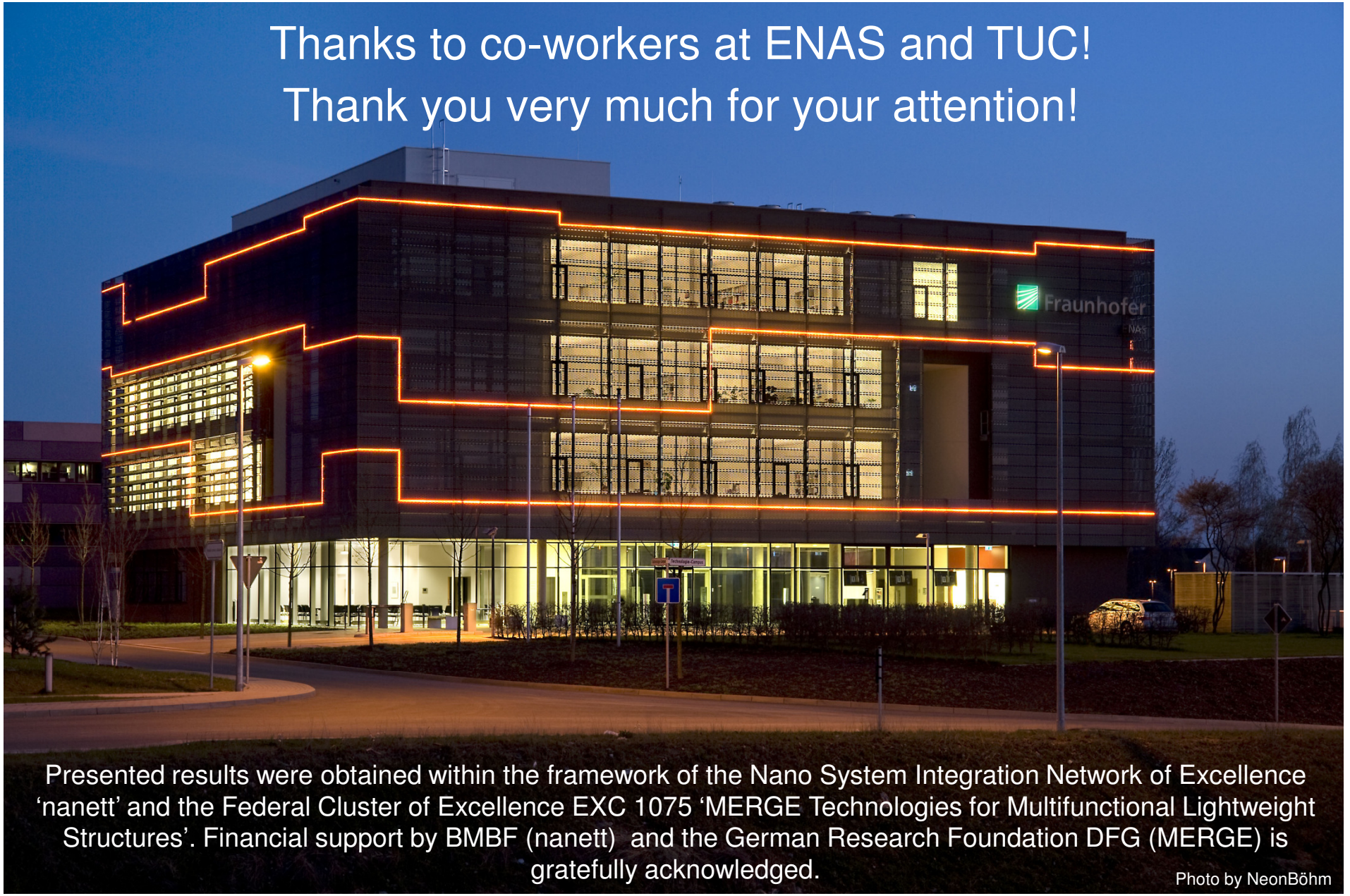

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Photo by NeonBöhm

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