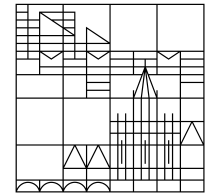


Synthesis of Semiconductor Nanoparticles with Heterojunctions

B.Sc. Samuel Monter
Jülich, 09.02.2021

Universität
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Synthesis and Structure Control of Nanorods with Axial Heterojunctions

Bachelor Thesis

submitted by Samuel Monter
at the University Konstanz



cm CHEMISTRY OF MATERIALS
regioselective Growth Mechanism of Single Semiconductor Tips on
Fluorinated Surfaces
Florian Enders, Sebastian Sutter, Deniz Fackl, Rebecca Köster, Samuel Monter, Simon Cardinal, and Klaus Höfner

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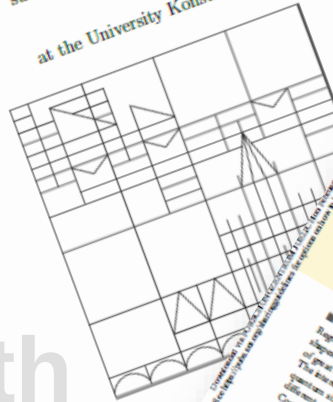
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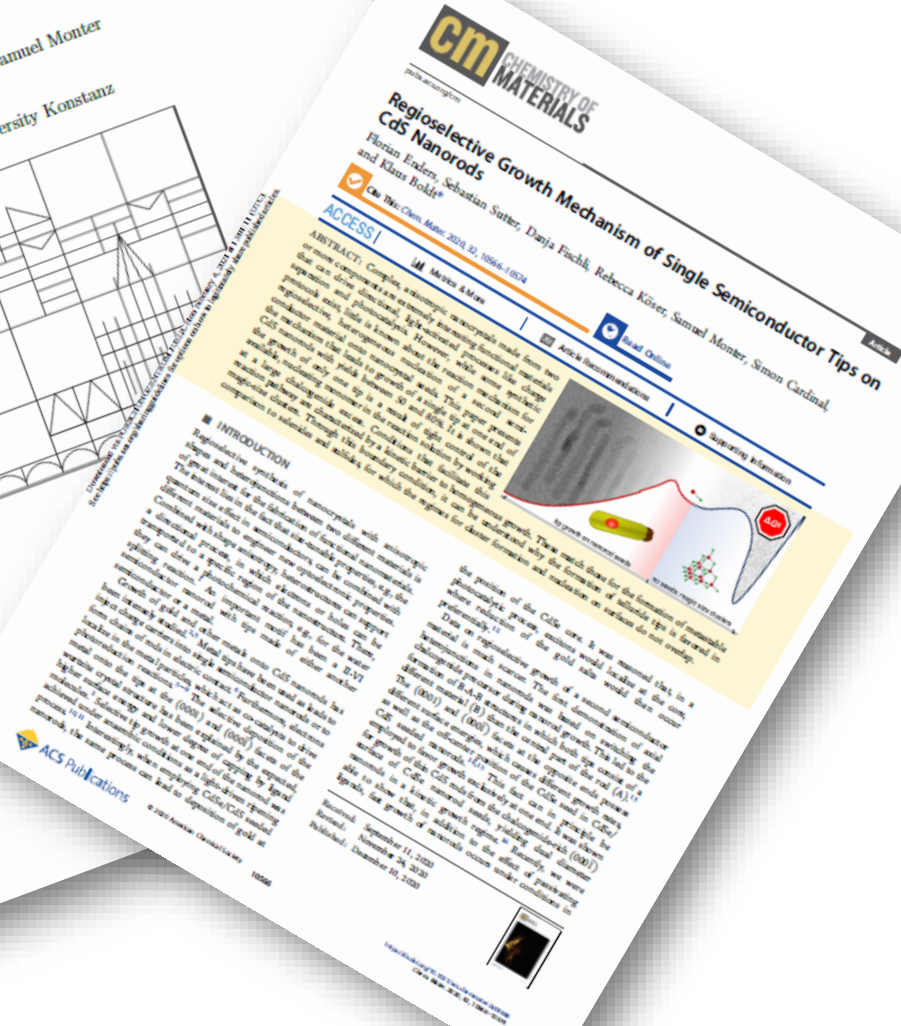
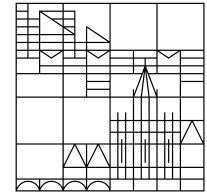
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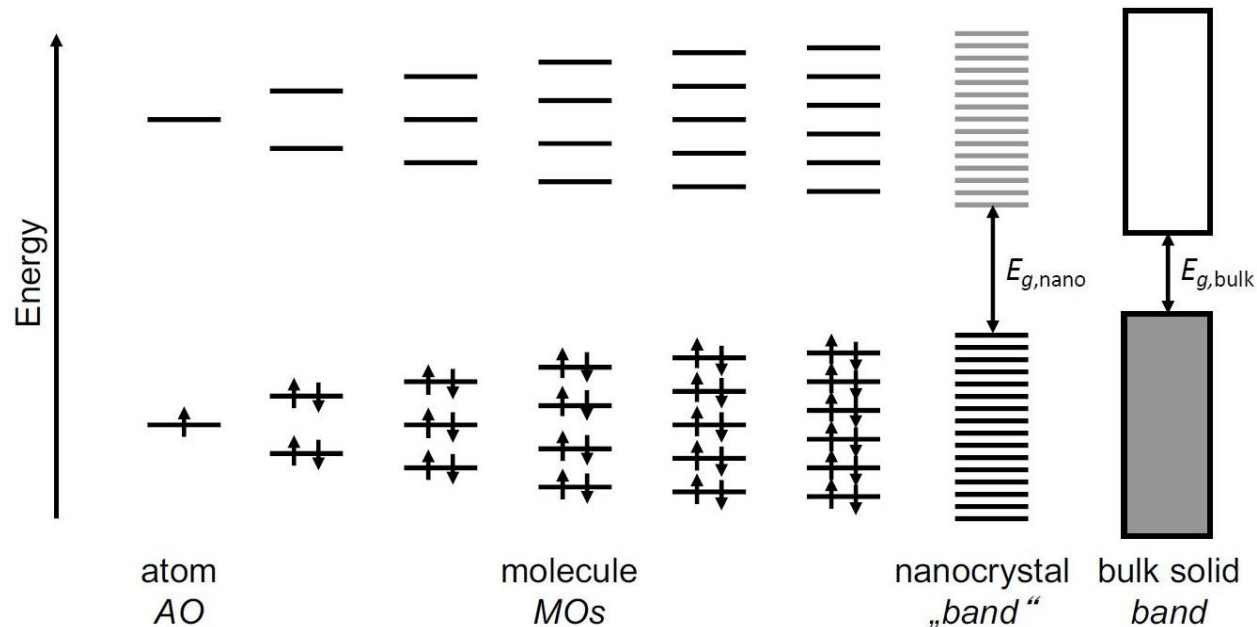


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Semiconductor Nanoparticles

- Nanoparticle size: 1nm – 1000nm
- Material Properties become size dependent below a certain size
- Electronic structure:
 - Molecules → discrete energy levels
 - Bulk solids → continuous energy bands
 - Nanoparticles → size dependent electronic structure
 - Quantum Size Effect





Synthesis of Semiconductor Nanoparticles with Heterojunctions

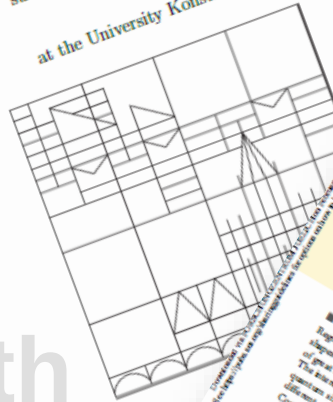
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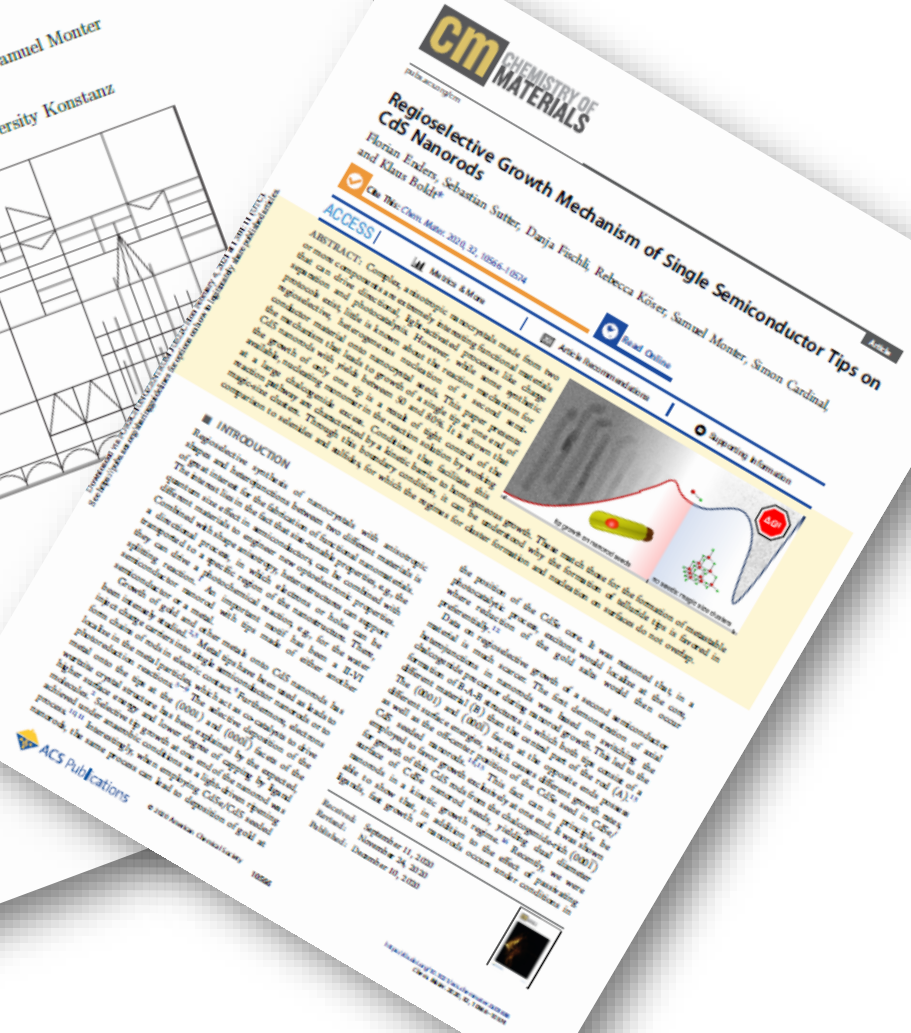
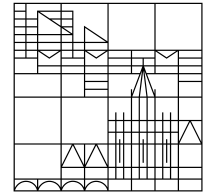
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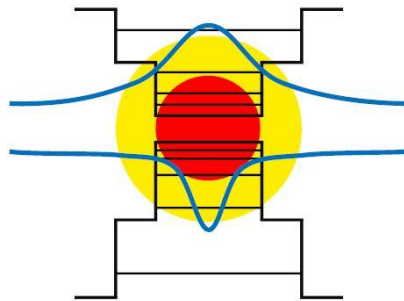


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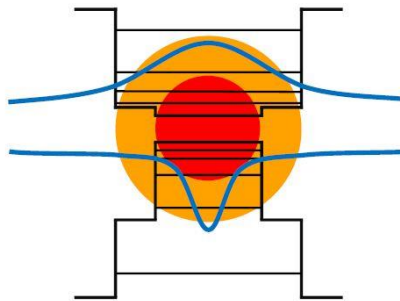


Semiconductor Heterojunctions

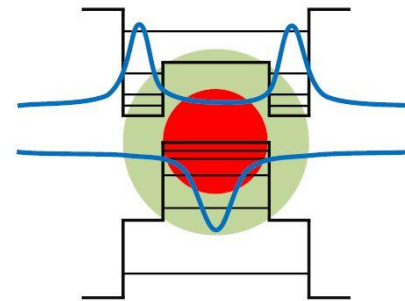
- **Combination of different materials** → **complex band structure in single particle**
 - Charge separation → catalysis, solar cells
 - Charge protection → high fluorescence quantum yields



Type-I



Quasi Type-II



Type-II

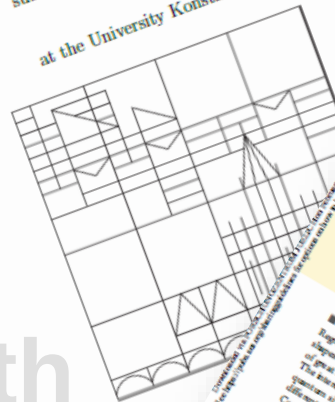
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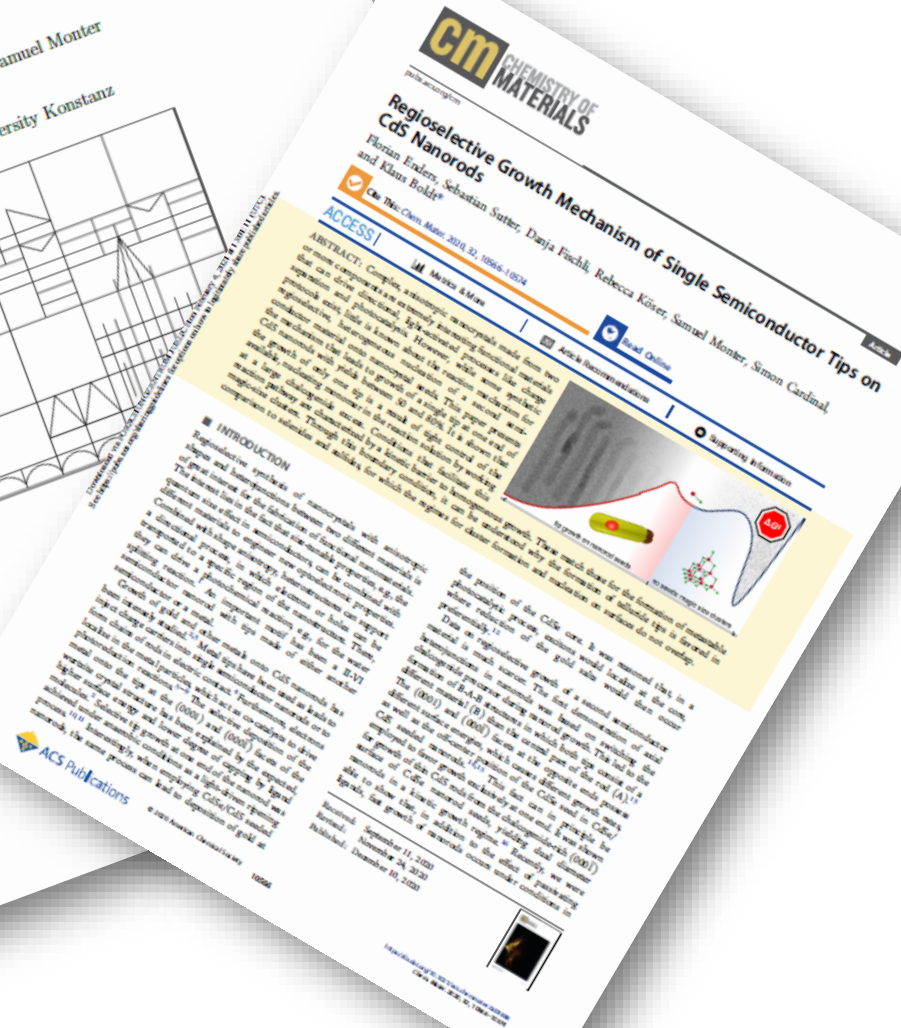
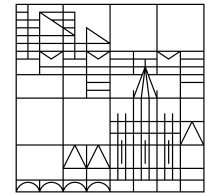
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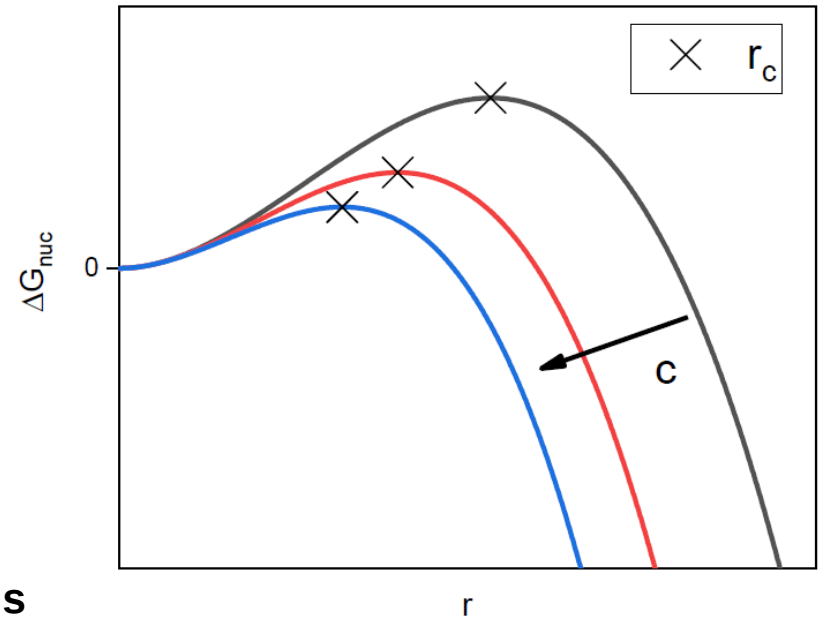
Synthesis of Nanoparticles

- **Bottom-Up Approach**
- **Classical Nucleation Theory**

$$\Delta G = \frac{4}{3}\pi r^3 \Delta G_V + 4\pi r^2 \gamma$$

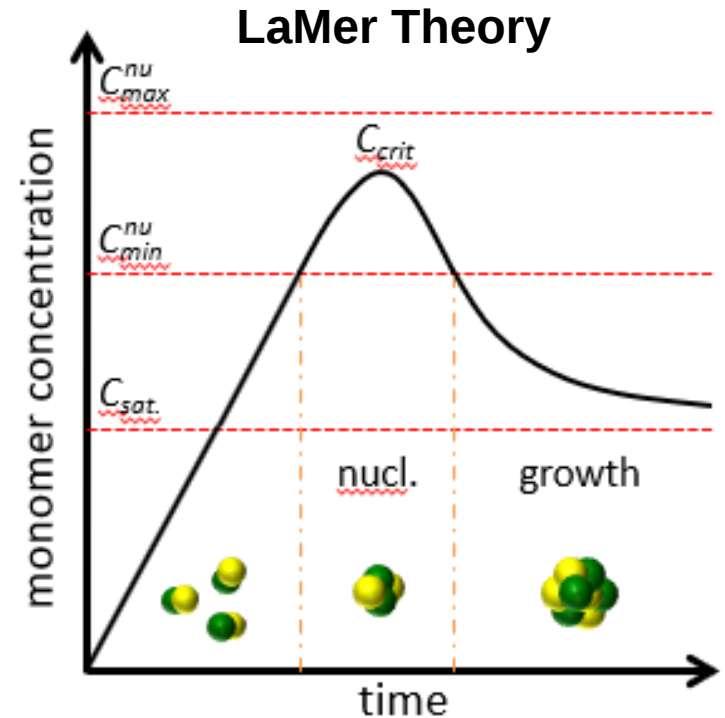
$$\Delta G_V \propto \ln\left(\frac{c_{sat}}{c}\right)$$

- **Nucleation is hindered by surface energy**
- **Nucleation if $\Delta G^\ddagger < kT$**
- **Homogeneous Nucleation**
 - New particle in solution
- **Heterogeneous Nucleation**
 - Lower/higher interfacial tension
 - Lower/higher activation barrier
 - New particle on existing surface
- **Competition between Homo- & Heterogeneous Nucleation**



Synthesis of Nanoparticles

- **LaMer Theory [1]**
 - A short nucleation period yields a narrow particle size distribution
- **Hot injection synthesis for II-VI-semiconductors**
 - Prepare a hot metal precursor solution
 - Quickly inject chalcogenide precursor
 - Stop reaction through rapid cooling
- **Seeded growth synthesis**
 - Add seed particles to metal precursor solution
 - Build hetero structures through heterogeneous nucleation

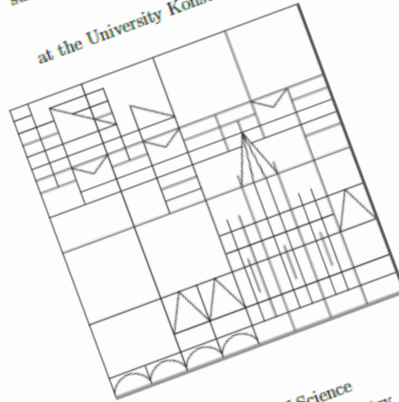


[1] LaMer et al. Theory, production and mechanism of formation of monodispersed hydrosols. Journal of the American Chemical Society 1950

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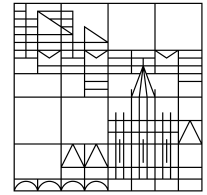
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Faculty of Science
Departement of Chemistry

Referee: Dr. Klaus Boldt

Universität
Konstanz



SELECTIVE GROWTH MECHANISM OF SINGLE SEMICONDUCTOR TIPS ON NANORODS

Sebastian Sutter, Danja Fischl, Rebecca Köster, Samuel Morier, Simon Gähle, Michael H. Engelke

Arxiv.org

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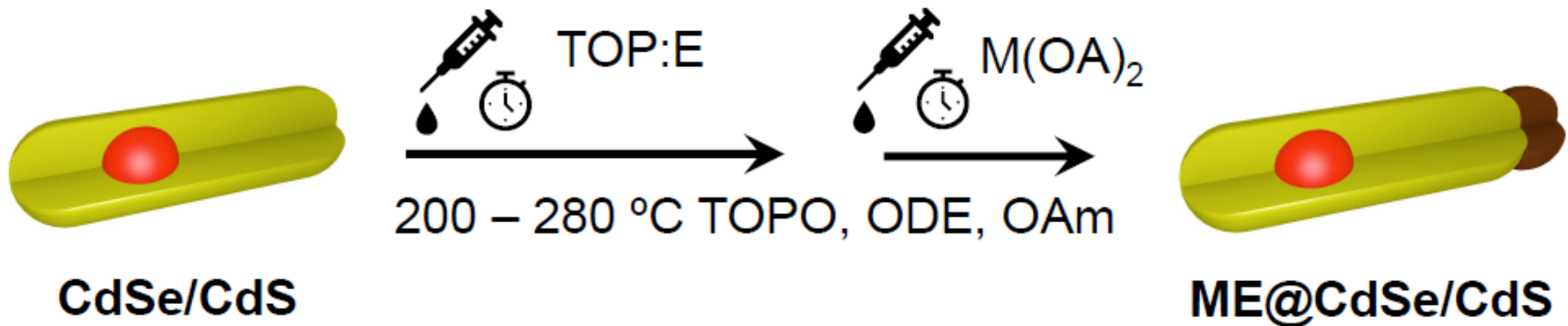
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Aim of my Bachelor Thesis

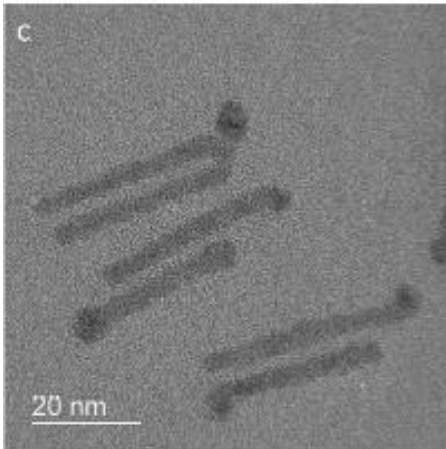


- Existing synthesis for ZnTe tips
- Adapt protocol for ZnSe, CdTe, CdSe tips
- Gain insight into the reaction mechanism

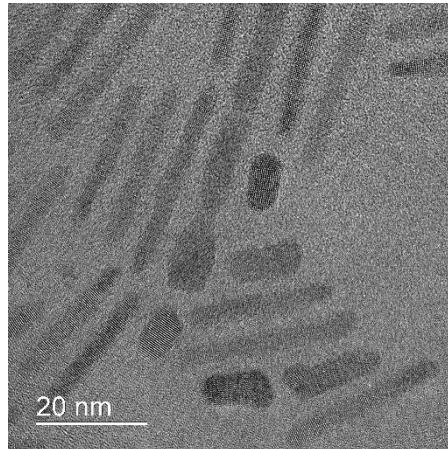
[2] Carbone et al. Synthesis and micrometer-scale assembly of colloidal CdSe/CdS nanorods prepared by a seeded growth approach
[3] Deutsch et al. Luminescence upconversion in colloidal double quantum dots. Nat Nanotechnol 2013
[4] Boldt et al. Switchable Dissociation of Excitons bound at Strained CdTe/CdS Interfaces. Nanoscale 2018

Variation of Reaction Parameters

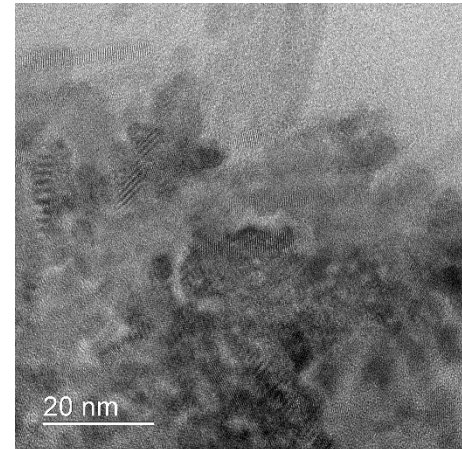
- Variation of chalcogenide precursor showed no success



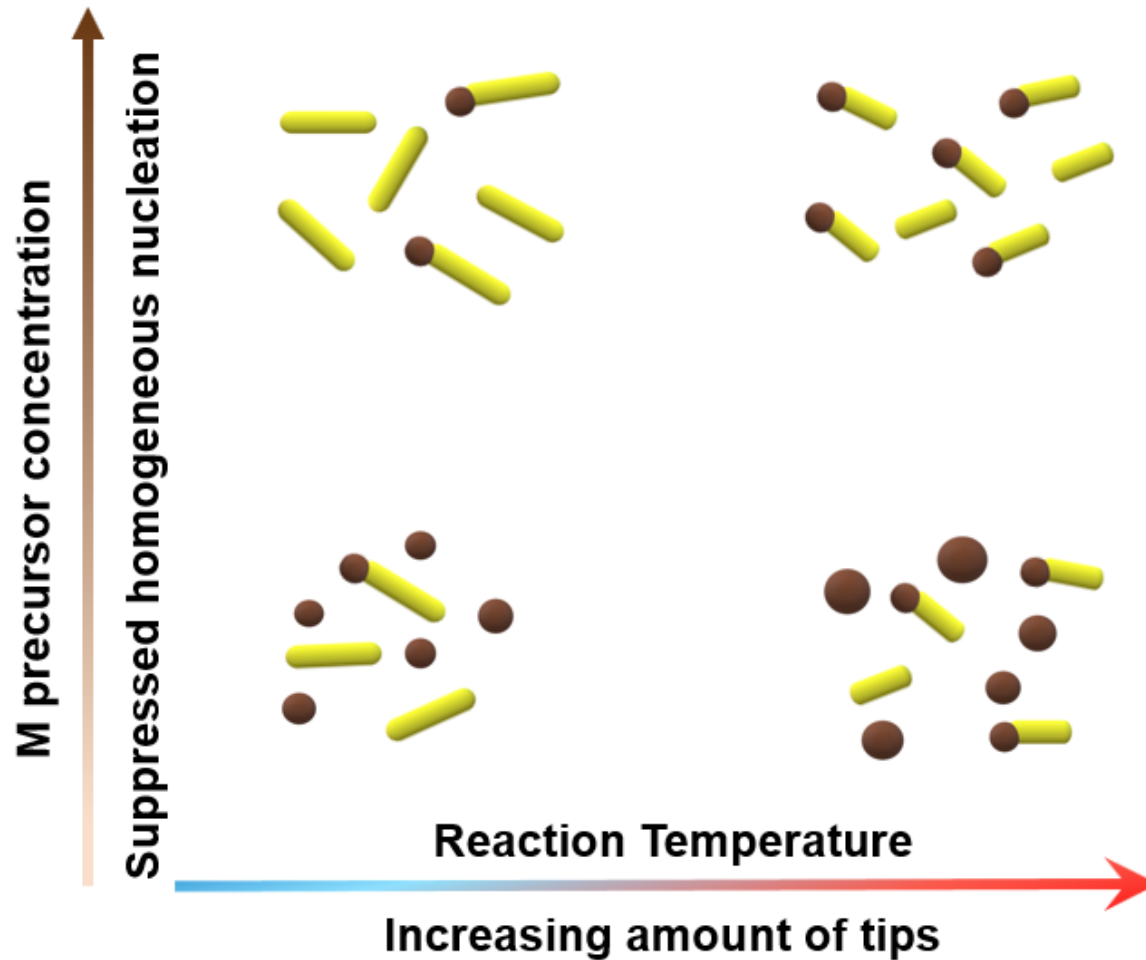
successful synthesis of
ZnTe tips



unsuccessful synthesis
if ZnSe tips



Variation of Reaction Parameters



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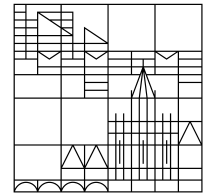
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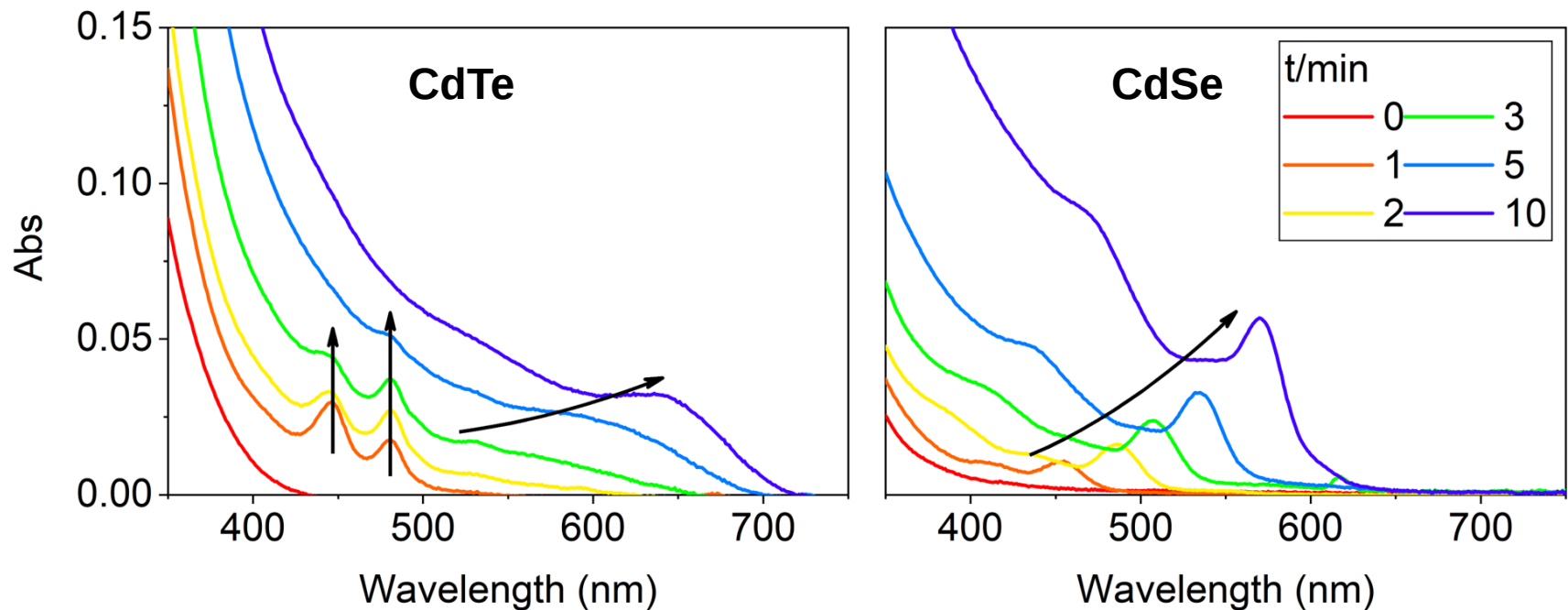


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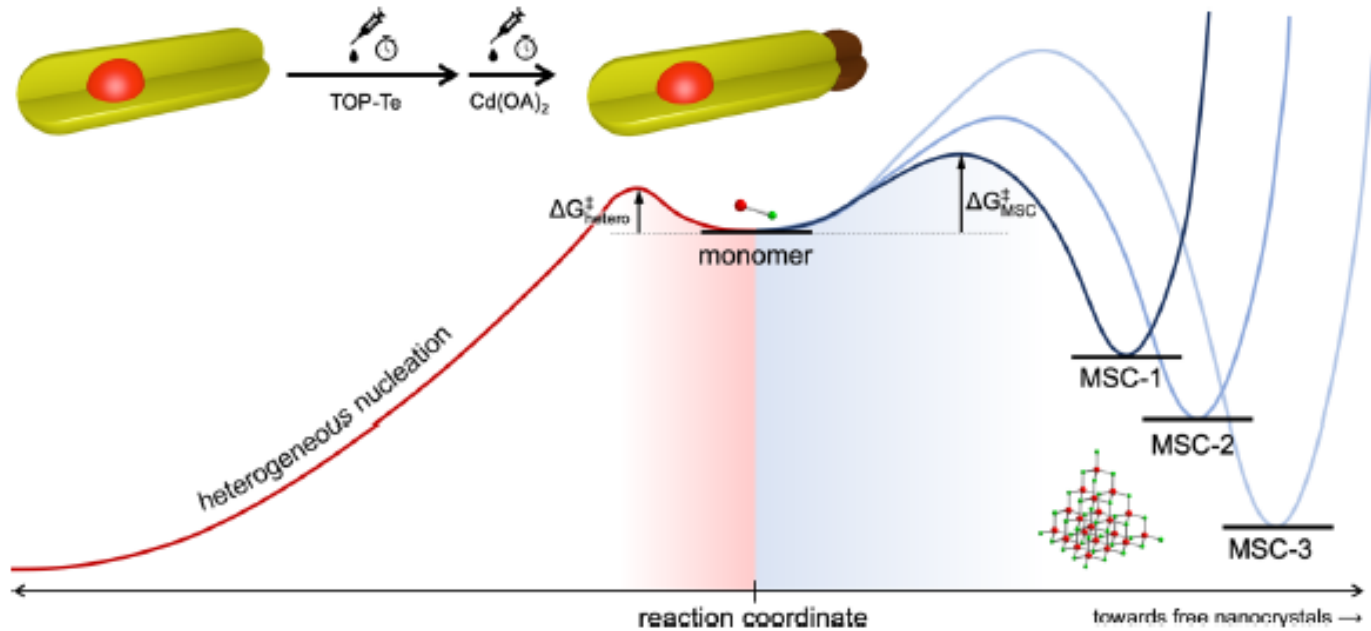


Magic Sized Clusters as Intermediates

- **UVVIS spectroscopy of reaction process**
 - CdSe: Continuous shift of absorption onset
 - Continuous growth of nanoparticles
 - CdTe: additional stable absorption peaks
 - Formation of magic sized clusters



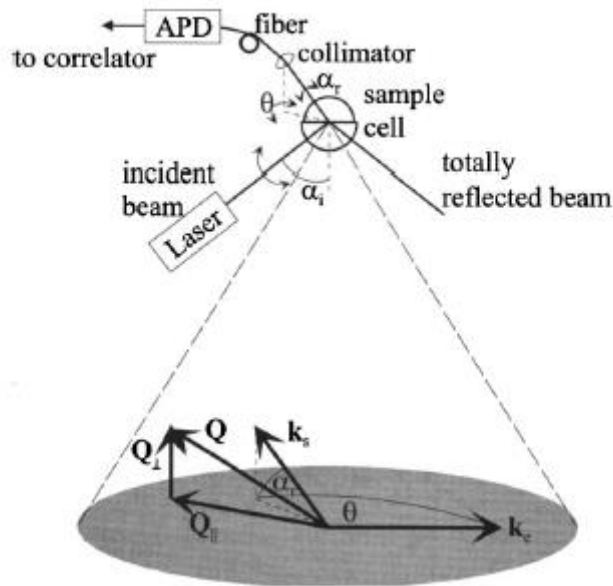
Final reaction mechanism



[5] Boldt et al. Regioselective Growth Mechanism of Single Semiconductor Tips on CdS Nanorods. Chemistry of Materials 2020

Coming up in Jülich....

- **EWDLS measurements at liquid-liquid-interfaces**
 - Cell alignment procedure
 - Proof of principle experiment design



[6] Lang et al. Colloidal dynamics near a wall studied by evanescent wave light scattering: Experimental and theoretical improvements and methodological limitations. The Journal of Chemical Physics 2007

Thank you for your kind attention!

Let's discuss!

Thanks to Klaus Boldt and his group for
the shared materials



How it is done



Semiconductors

- Electronic structure

- Continuous energy bands
- Fully occupied valence band
- Unoccupied conduction band
- Excitation creates mobile charge carriers: electron and hole

