



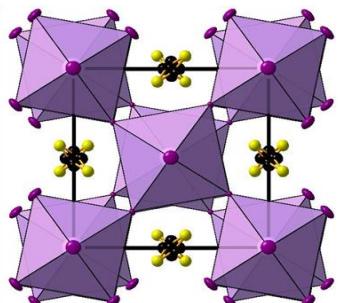
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PHOTOPHYSICS &
OPTO-ELECTRONICS



Colloidal semiconducting Quantum Dots Superlattices: Towards electronic metamaterials

Maria Antonietta Loi



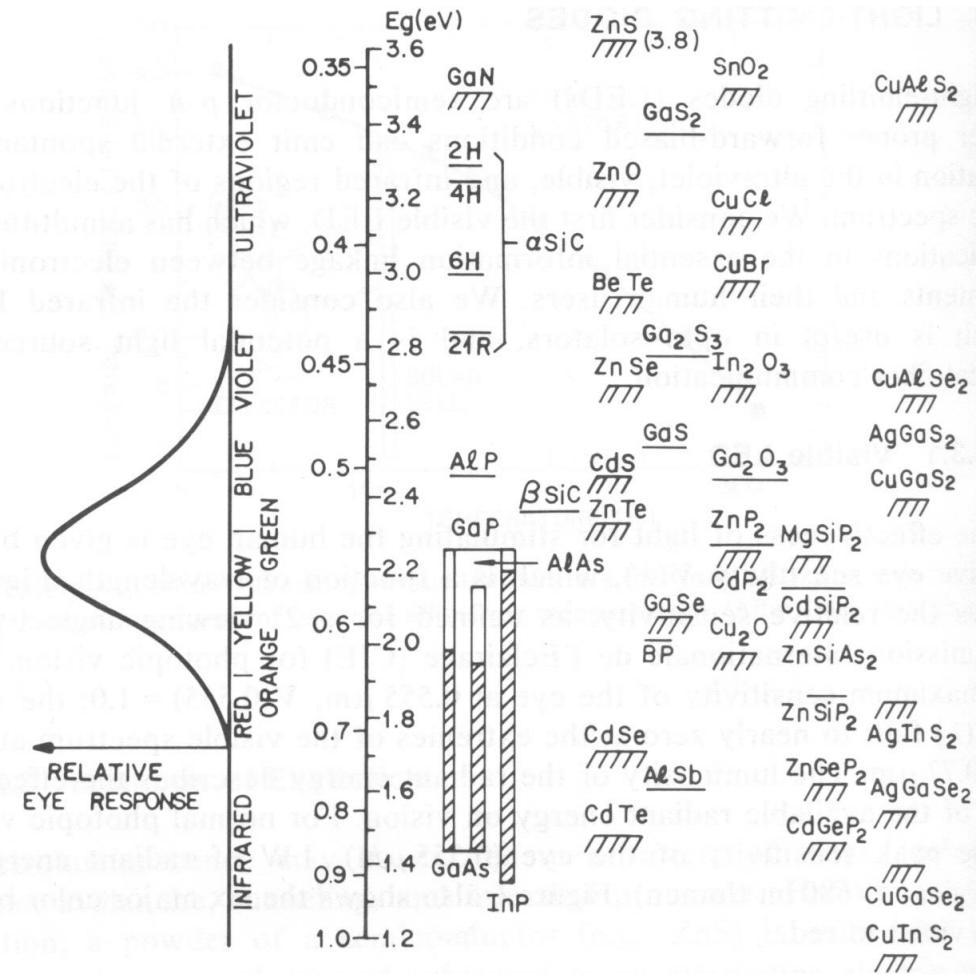
Photophysics & OptoElectronics
Zernike Institute for Advanced Materials
University of Groningen
The Netherlands

M.A.Loi@rug.nl

The optoelectronics problem

| 2

Discrete band gaps



Controlling physical properties

| 3



Very important for optoelectronics....



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Light emission

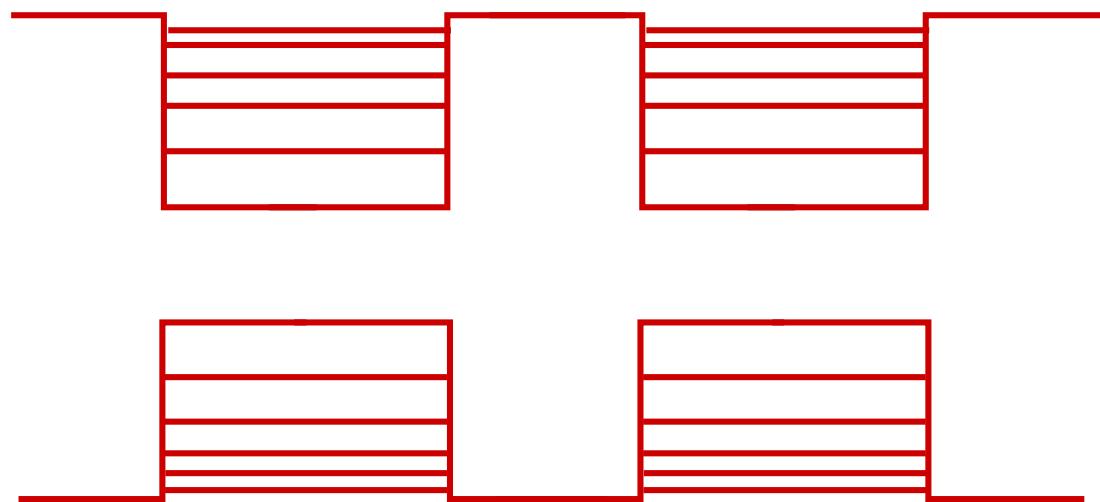
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Electronic devices with QDs?

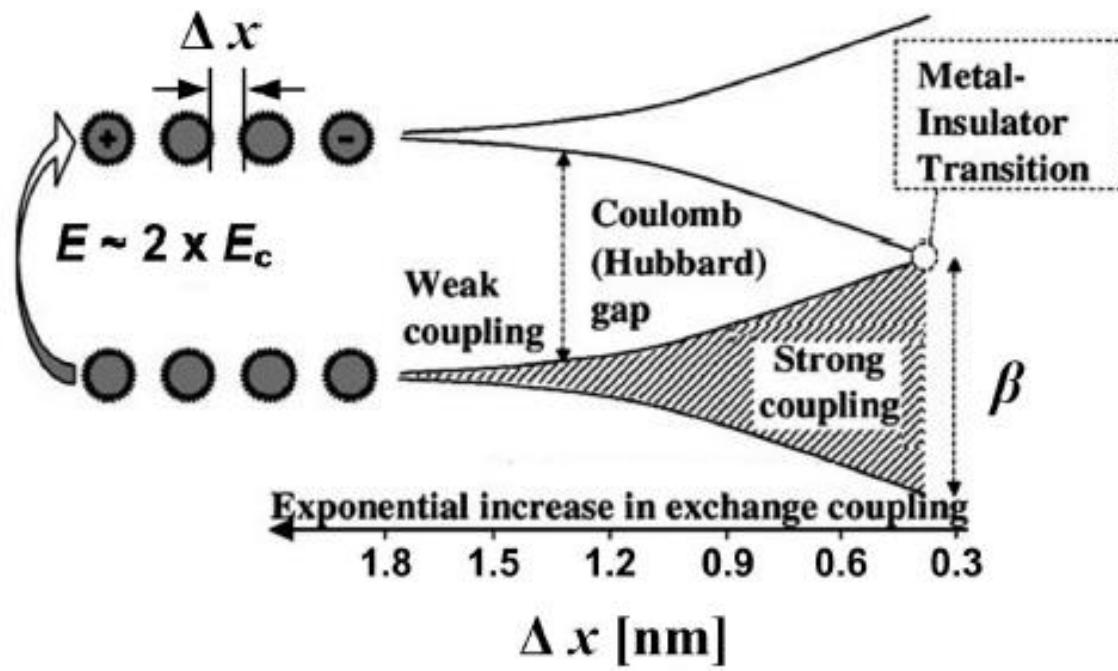


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Coupling of QDs

| 6



At large interparticle distance Δx the QD solid is an insulator.

As the interparticle distance decreases, the electronic wave functions of the individual QD spread out over multiple particles.

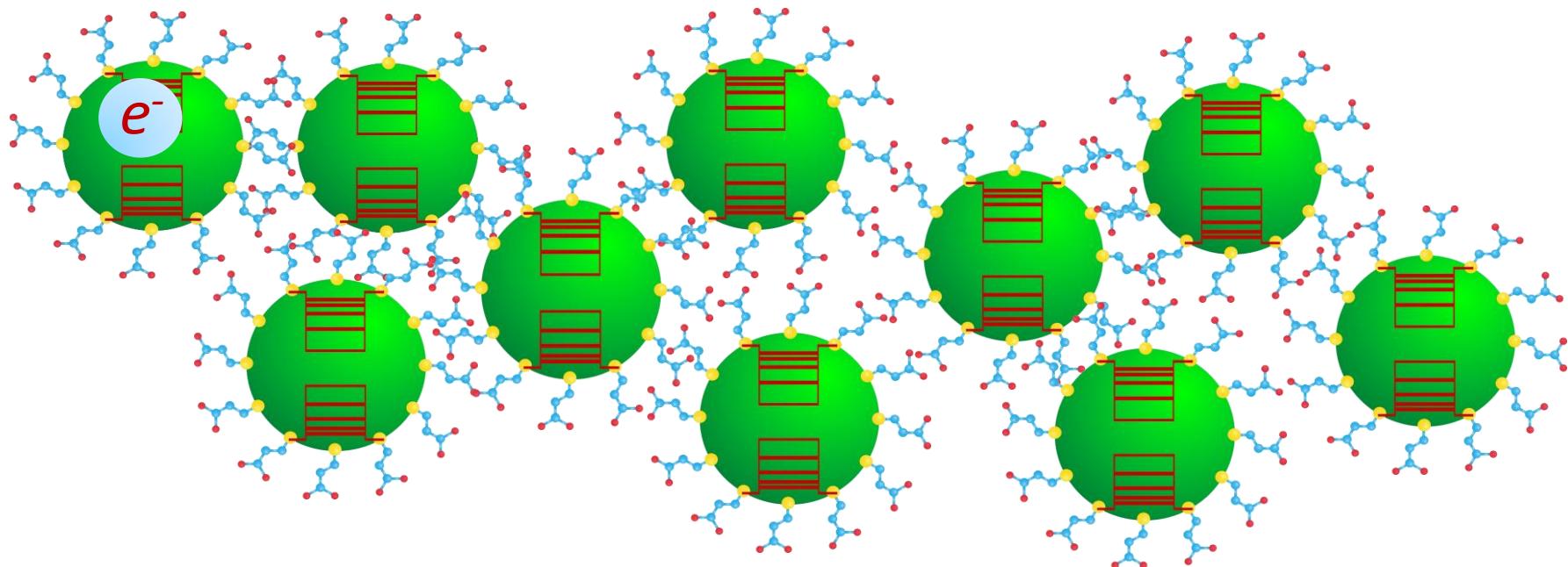


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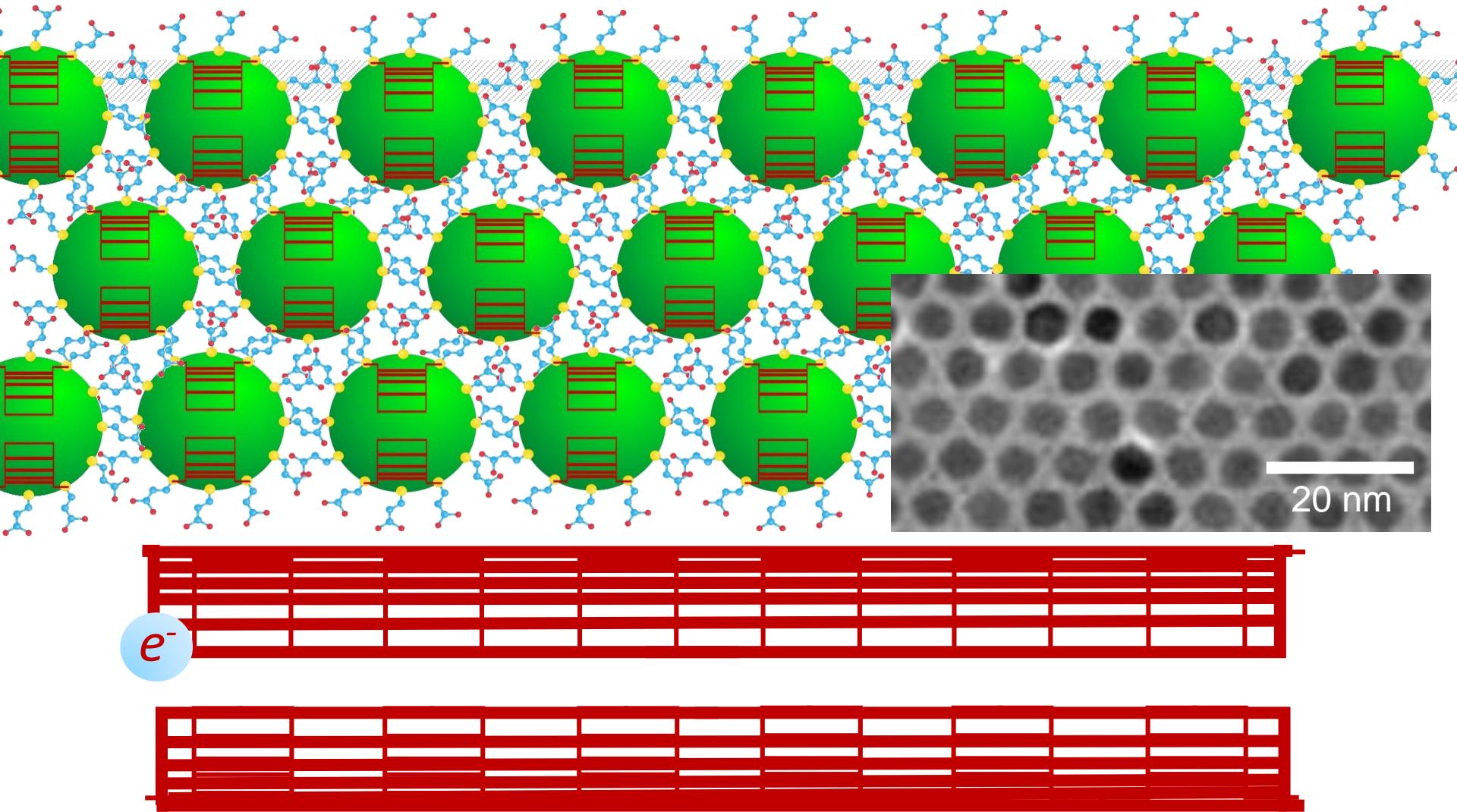
Murray, C. B.; Kagan, C. R.; Bawendi, M. G.
Annu. Rev. Mater. Sci., 30, 545 (2000).

Hopping vs Band-like Transport



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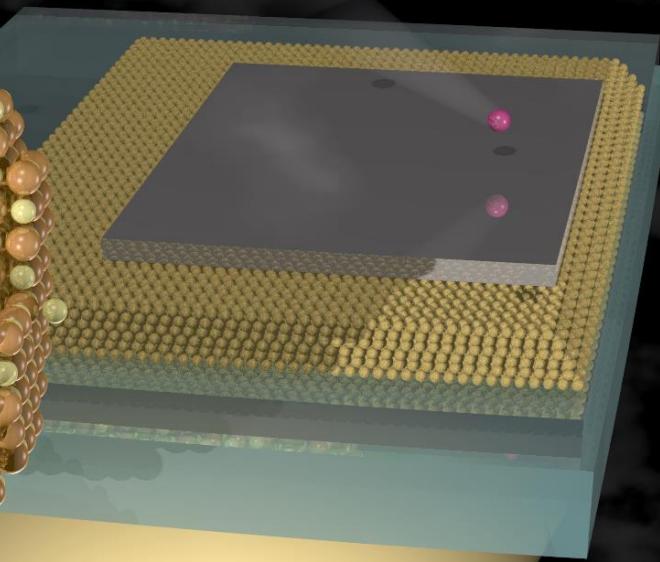
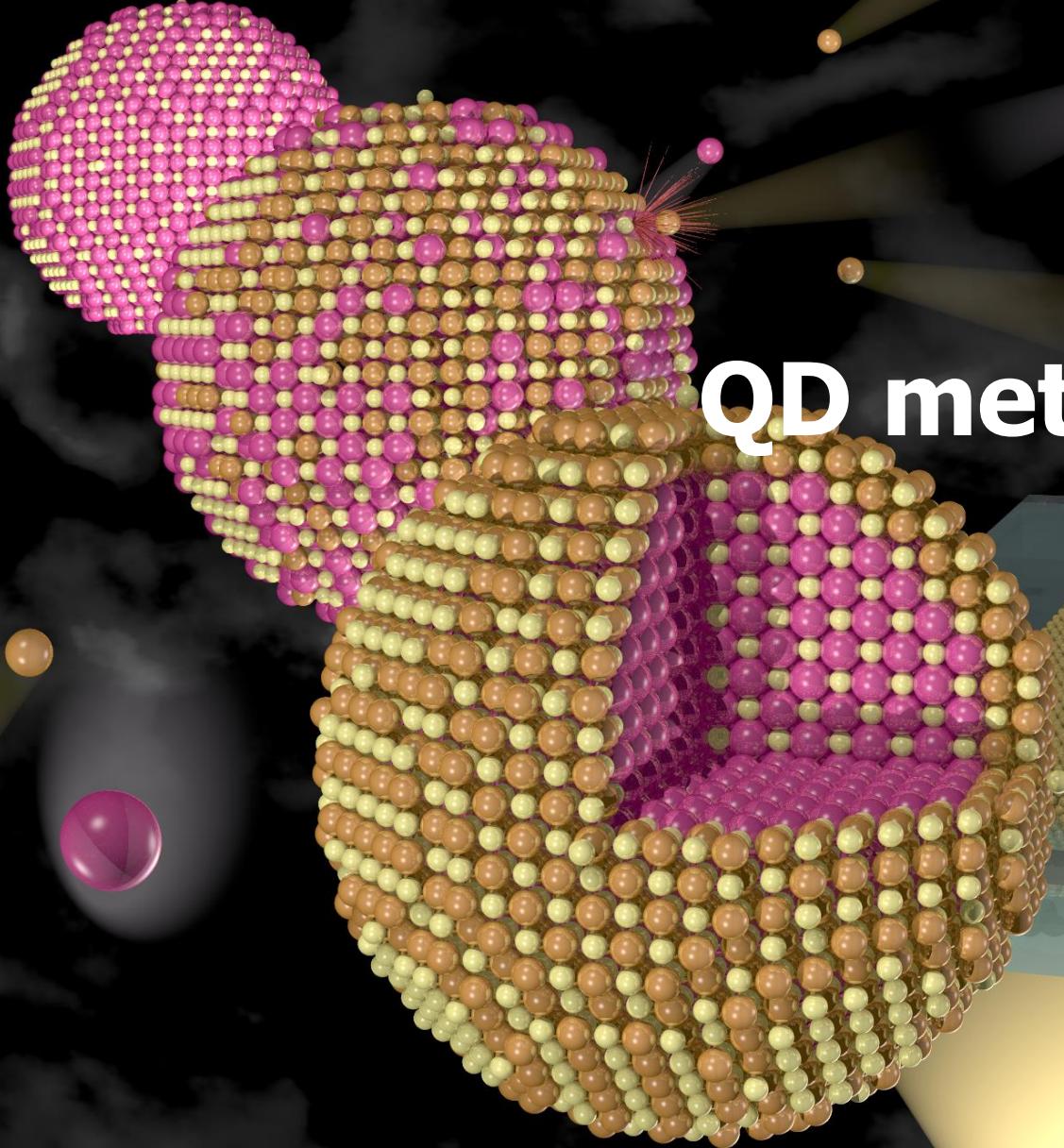
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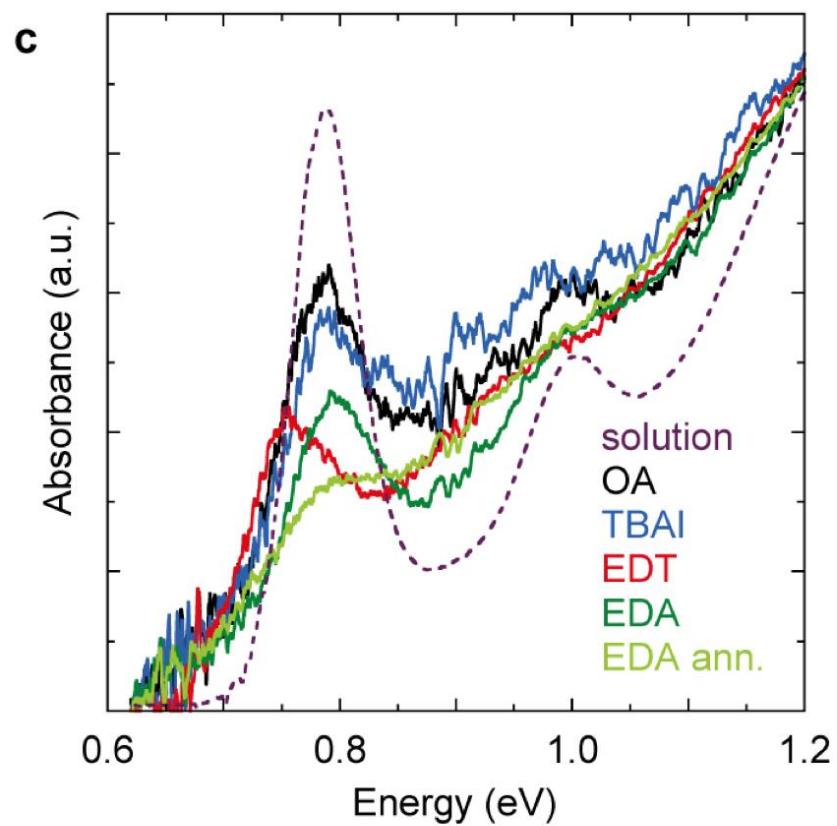
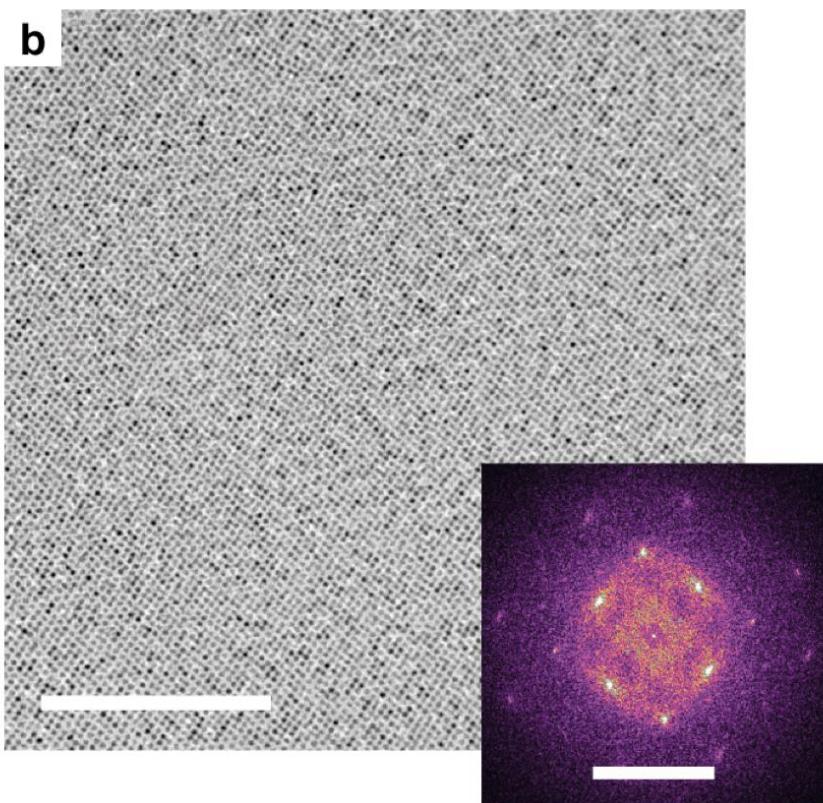
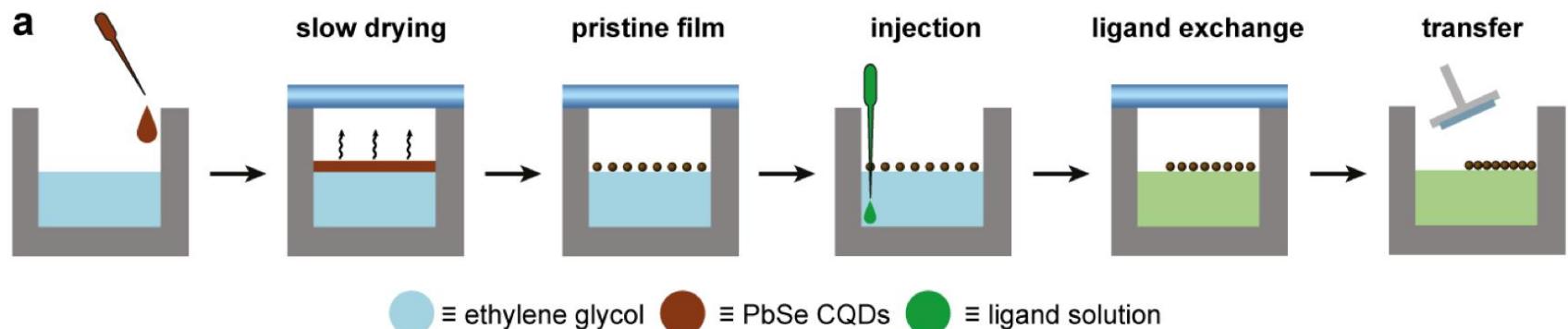


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QD metamaterials





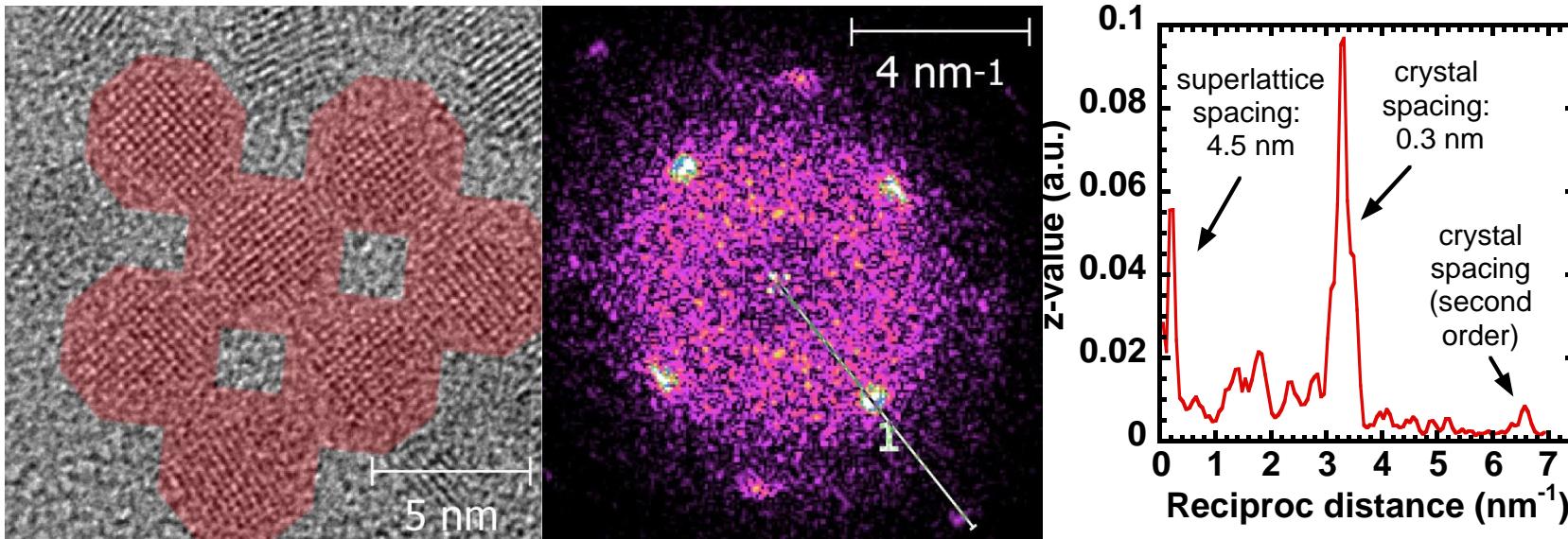
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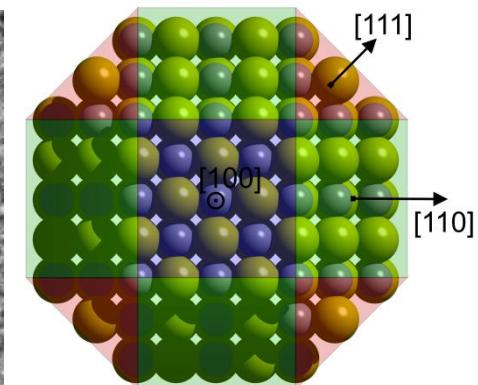
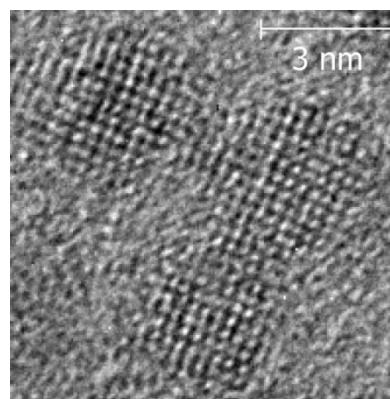
D.M. Balasz, MAL, Adv. Mater., 30
1802265 (2018)

Oriented attachment on substrates

| 11



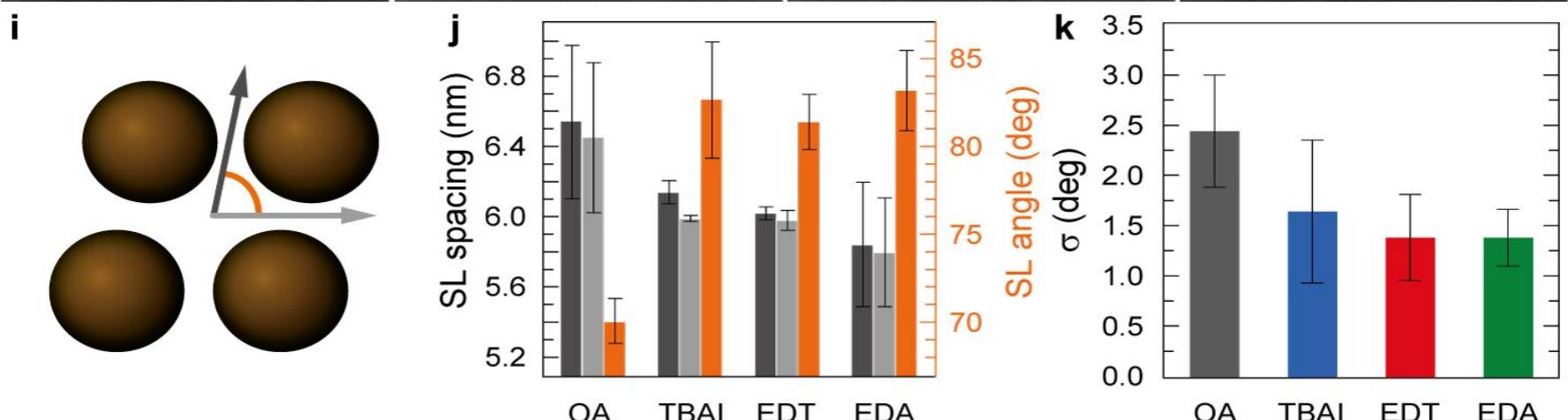
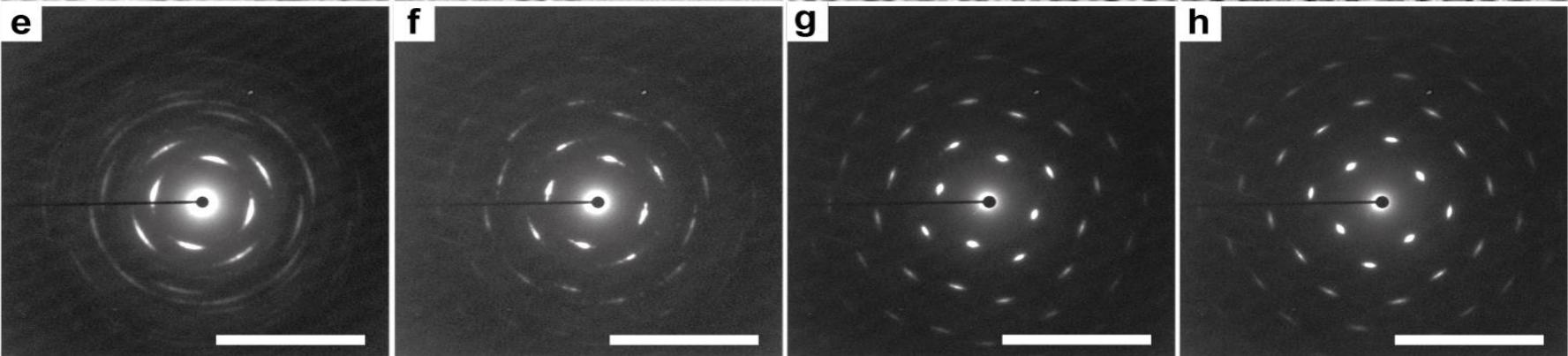
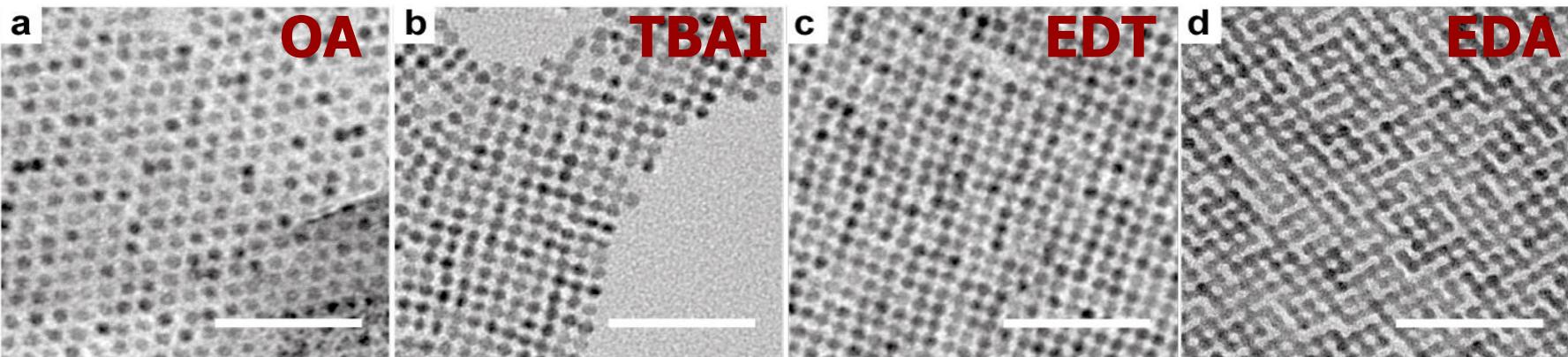
- > Superlattice and atomic lattice vectors coincide
- > Epitaxial fusion of $\{100\}$ facets
- > Larger QD spacing due to neck formation



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D.M. Balasz, MAL, ACS Nano 9 , 11951 (2015)

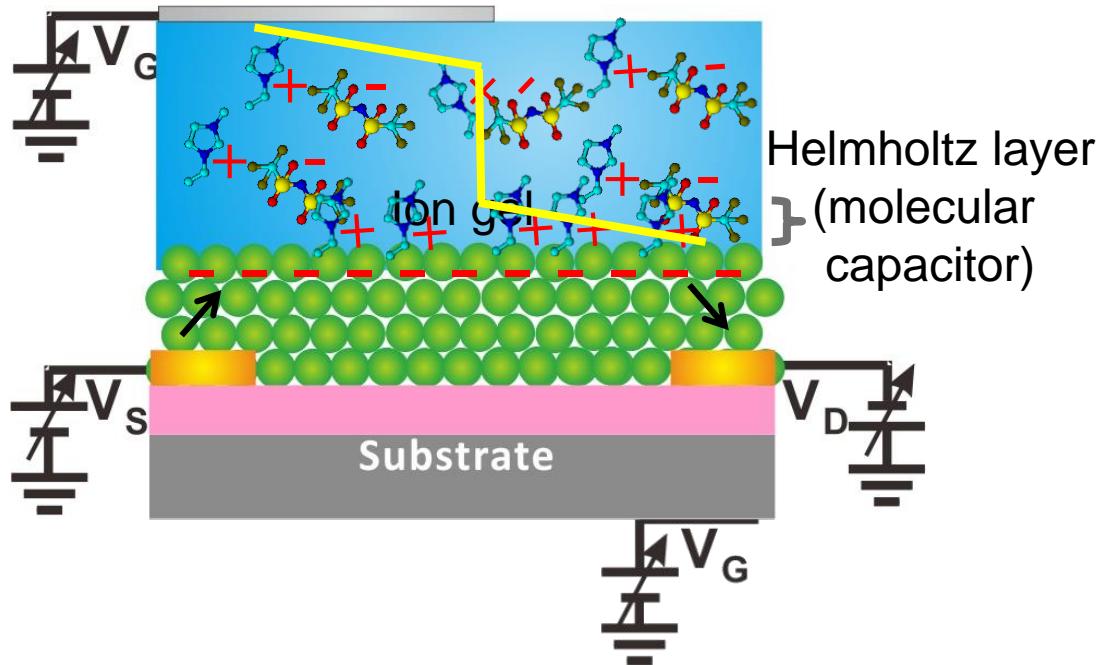


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D.M. Balasz, MAL, Adv. Mater., 30
1802265 (2018)

Ion Gel Gated Transistors



[EMIM] [TFSI]
in
PS-PMMA-PS block copolymer

*Thin Capacitor

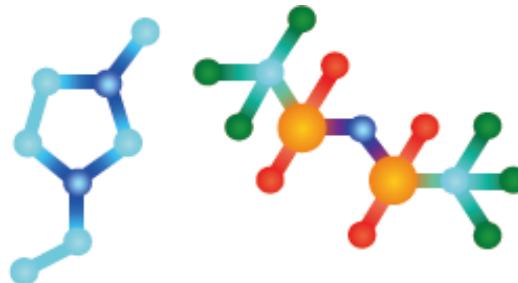
$\approx 1 \text{ nm}$

*High Carrier Density

$\sim \times 10^{14} \text{ cm}^{-2}$

*Large Capacitance

$\sim 10 \mu\text{F cm}^{-2}$



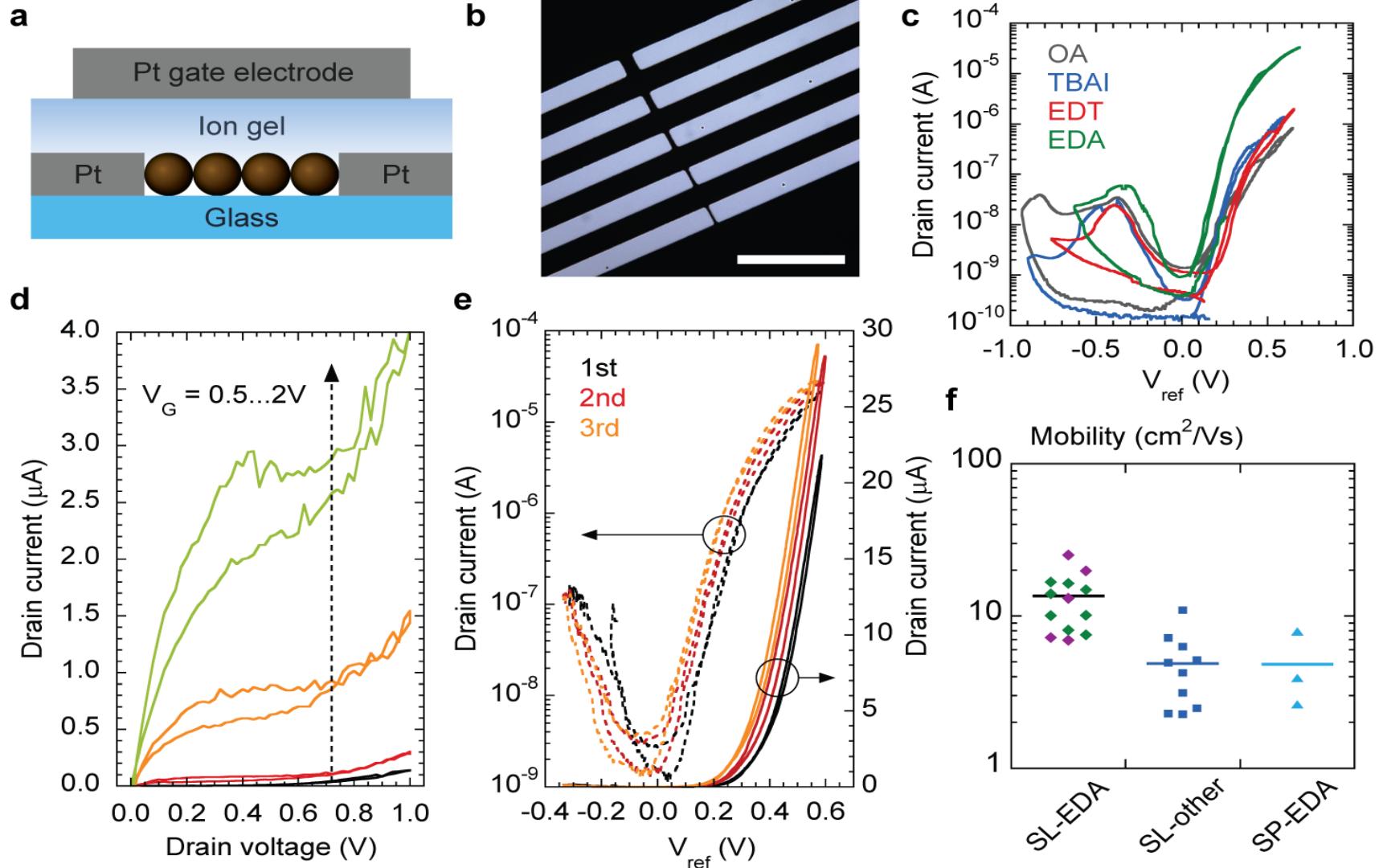
H. Hwang, Y. Iwasa, M. Kawasaki, Y. Tokura,
Nature (2012).
(review on ionic-liquid gating)



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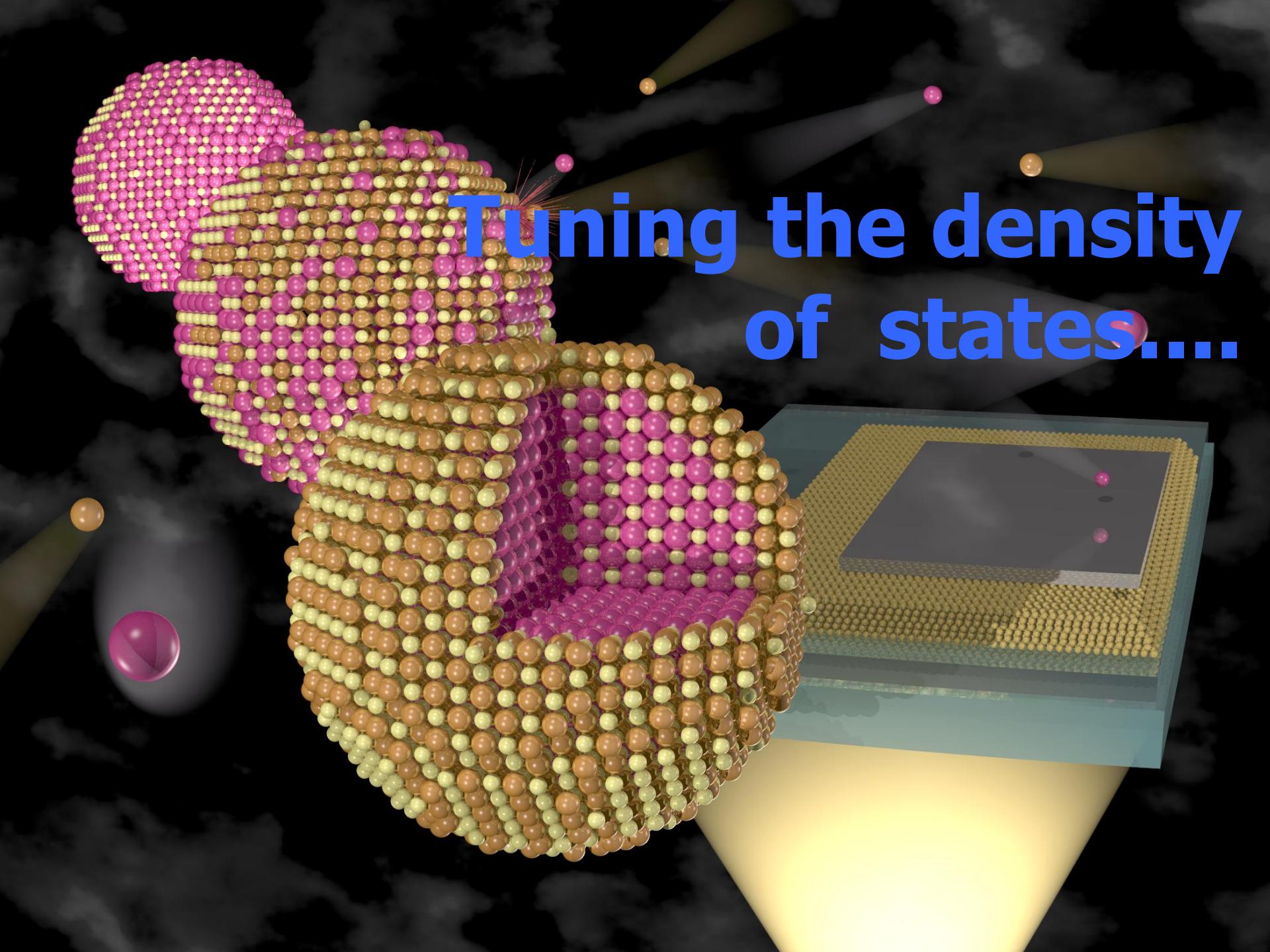
Superlattice transistors



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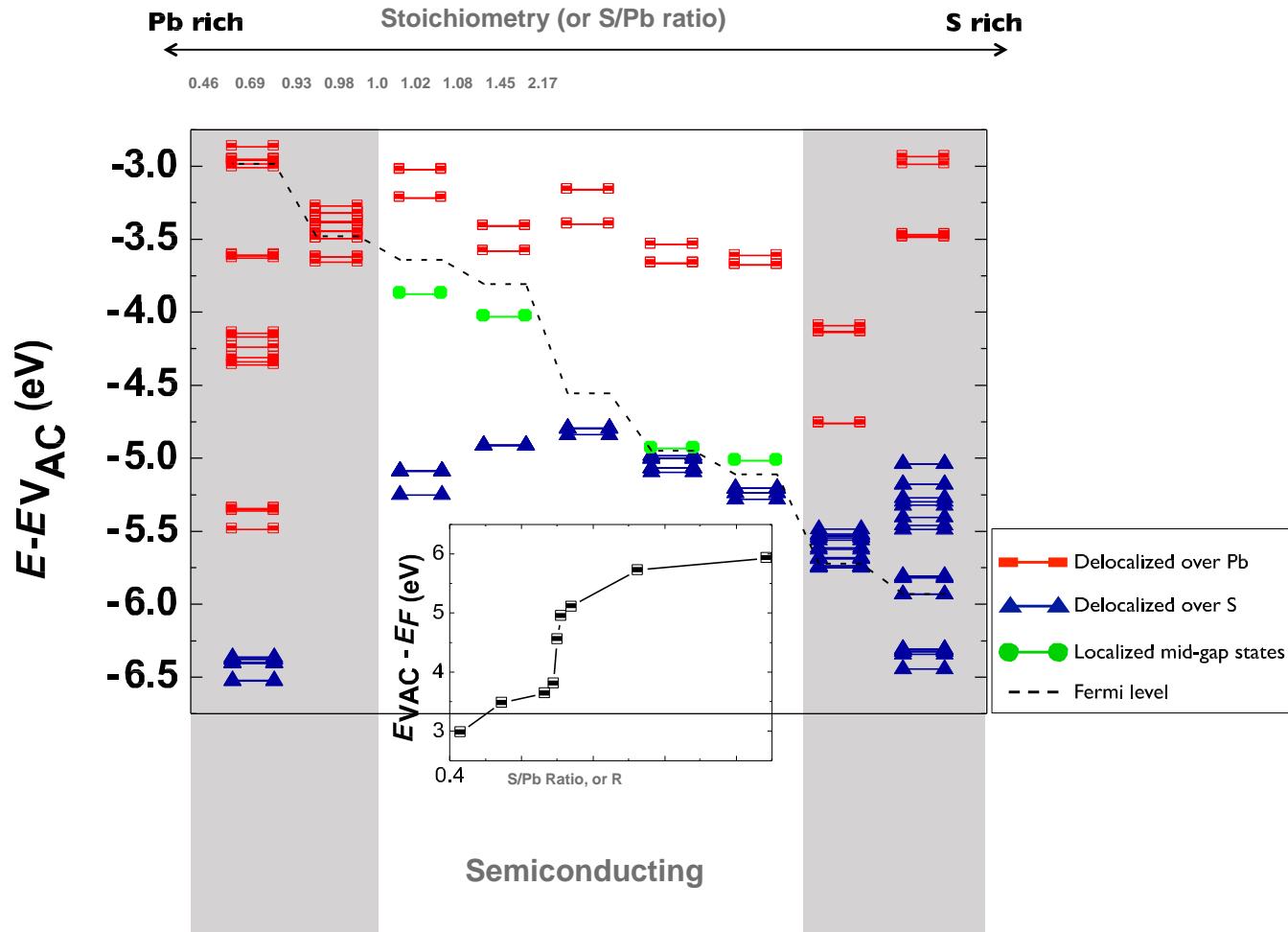
D.M. Balasz, MAL, Adv. Mater., 30
1802265 (2018)



Tuning the density of states....

The problem...

| 16



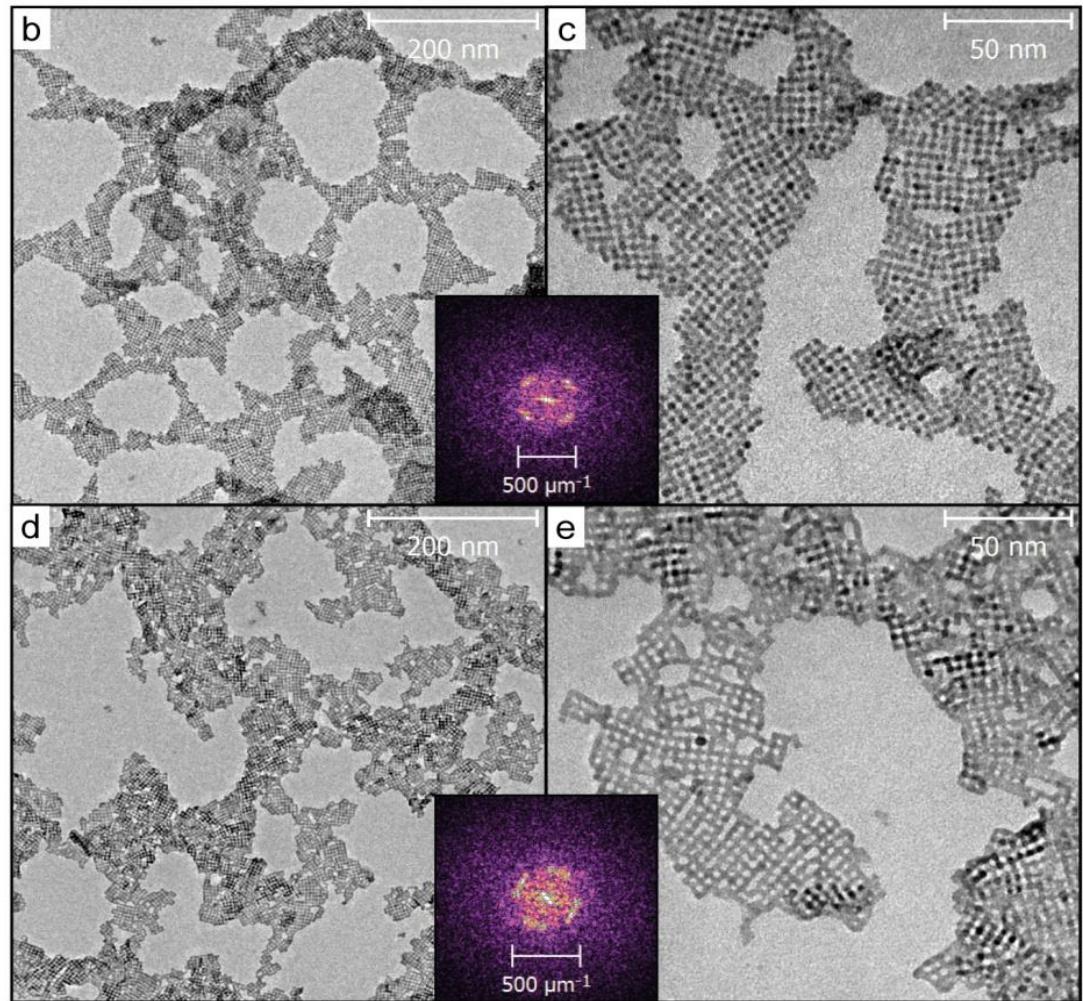
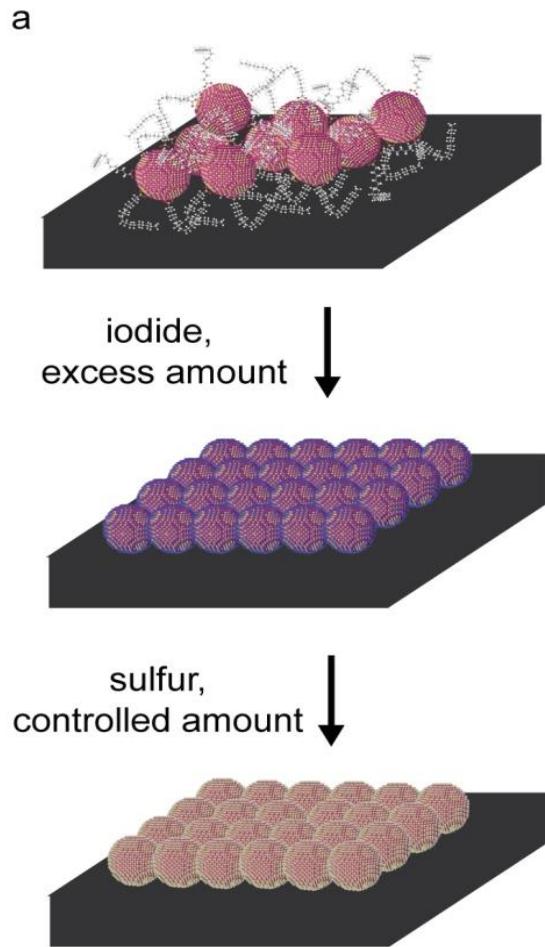
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D. Kim , and , J. C. Grossman,
Phys. Rev. Lett. 110, #196802 (2013).

NaHS ligand – two step process

| 17



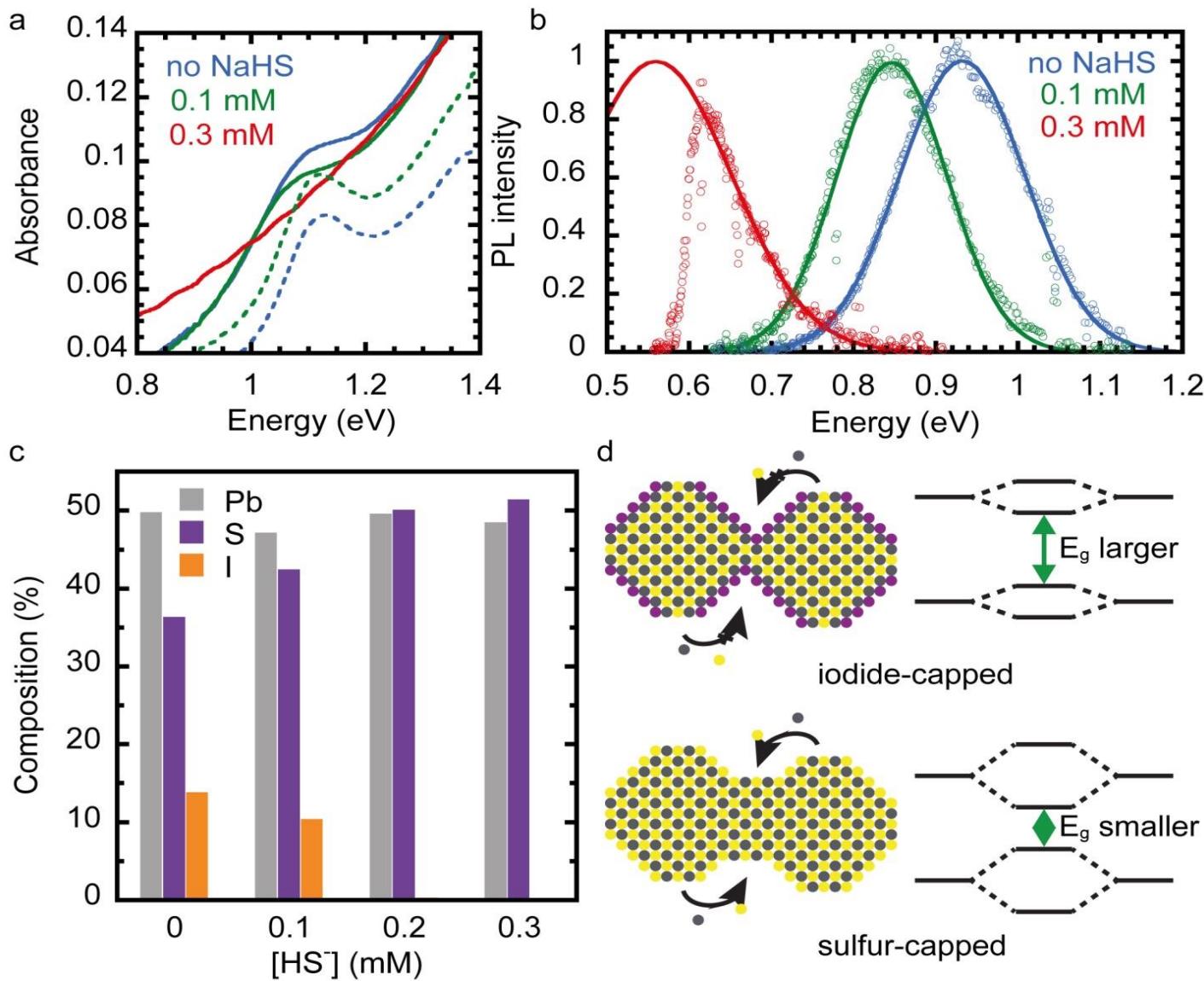
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D.M. Balazs...and MAL, *Science Advances* 3,
eaao1558 (2017).

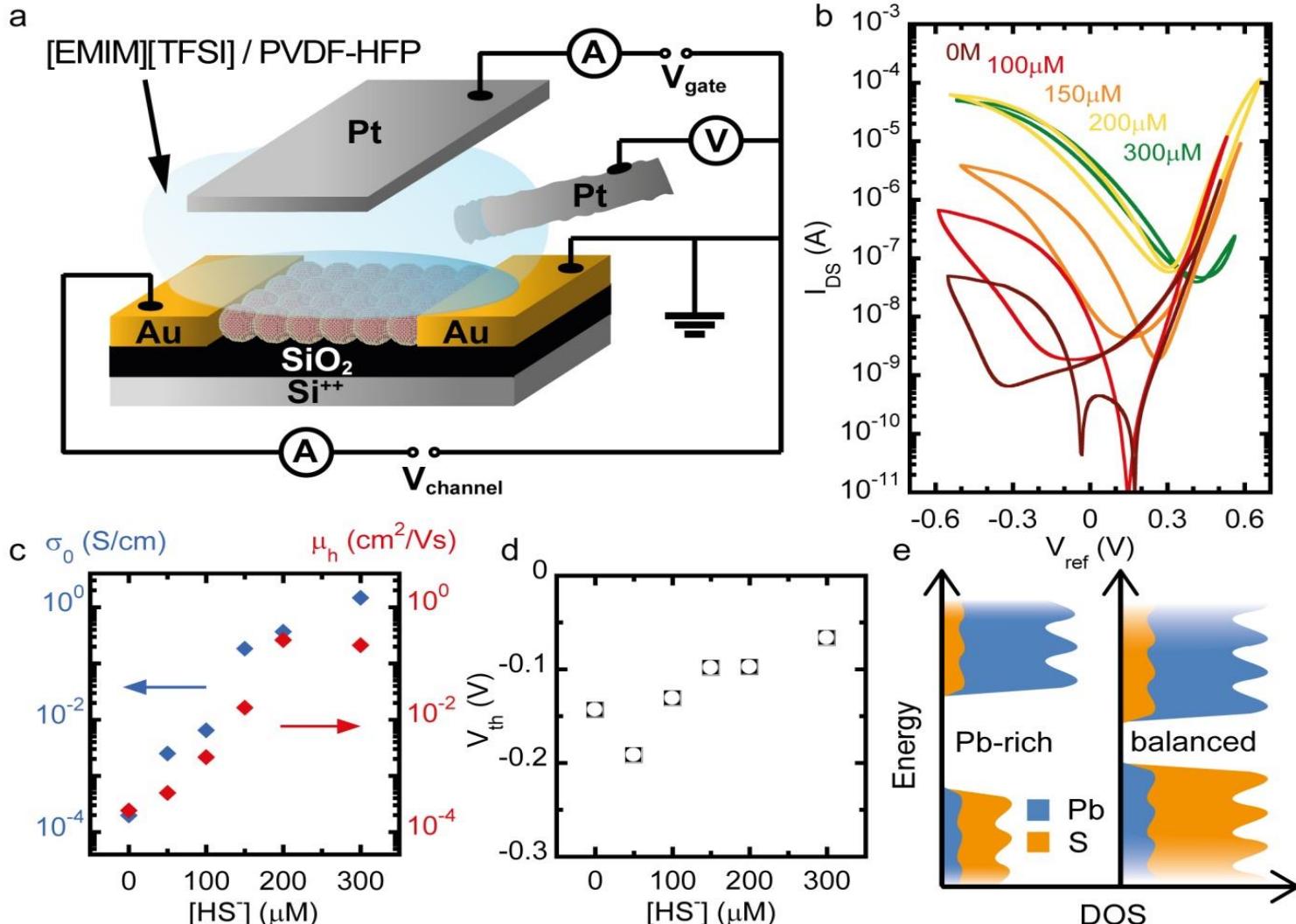
Fine tuning of the stoichiometry

| 18



Manipulation of the DOS

19



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D.M. Balazs...and MAL, Science Advances 3,
eaao1558 (2017).

Summary

| 20

- Colloidal QDs can solve the problem of optoelectronic devices
- Transport properties can be tuned by arranging the QDs in superlattices
- QDs can be ordered in with ordered domains in the hundreds of nanometer range.
- By using their large surface we can tune their electronic properties.....QD metamaterials
- 3D superlattices can be obtain...with mobilities above $100 \text{ cm}^2/\text{Vs}$



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2014 | 400 years

