Pressure-driven assembly of nanoparticle arrays and nanostructures

SAND2011-5244C

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Outline

I. Introduction - Nanoparticle assembly at ambient pressure

- Synthesis of nanocrystals
- Van der Waals interaction.
- DNA programmable assembly.
- Dipole-dipole interactions and chemical reactions

II. Nanoparticle assembly under pressure

III. Challenges for in-situ high pressure experiments

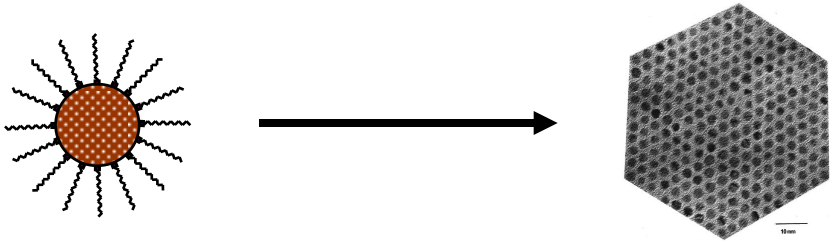
- **X-ray beam**
- **Pressure cell**
- **spectroscopy**

V. Discussion/questions

Applications of Nanocrystals and Nanocrystal Arrays

1. Size-dependent and collective optical, electric, and magnetic properties.

e.g., tuning refractive index for optical coatings, tuning dielectric constant, QD/solar cells, electron transport/conductance, magnetic memory, etc.



Heath, et al *Science*, 1997

2. Chemical and biological sensor & imaging.

e.g., Surface enhanced Raman scattering (**SERS**) based chem-/bio-sensor systems, killing cells using external stimulates such as magnetic field, light etc.

3. Catalyst arrays for orientated growth of nanomaterials films/arrays.

e.g., carbon nanotube arrays/films, nanowire arrays, etc

(CdSe) Semiconductor size increase

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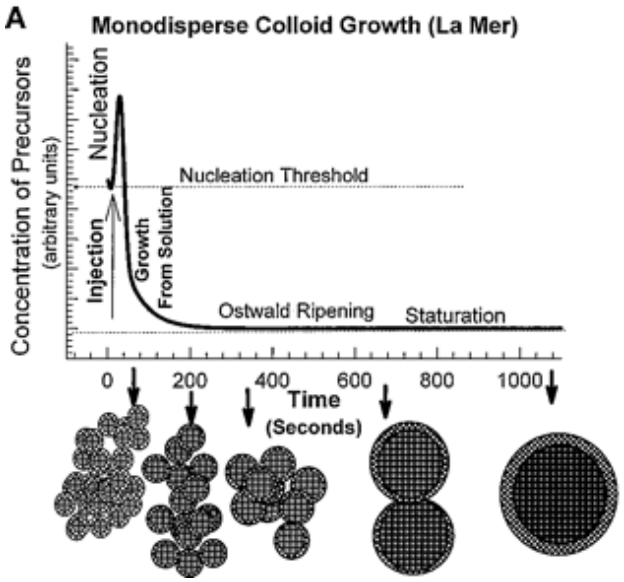
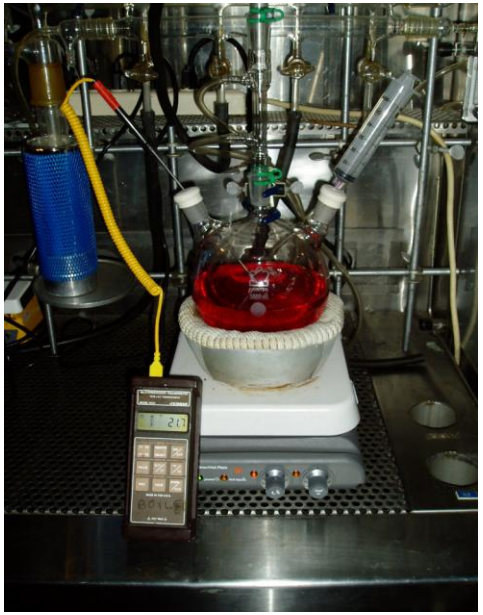
Synthesis of Hydrophobic Nanoparticles Stabilized by Organic Monolayers

(1) Nucleation and growth at high temperature





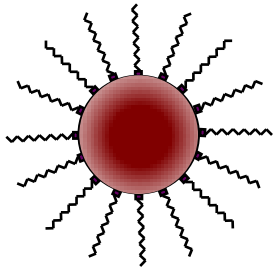
Semiconducting and magnetic nanocrystals
e.g., CdSe, FePt, $FeMnO_4$

Organic ligands:
Trioctylphosphine
Trioctylphosphine oxide
$CH_3(CH_2)_nNH_2$
$CH_3(CH_2)_nCOOH$

Murray, CB *et al*. *Annu. Rev. Mater. Sci*. **2000,** *30,* 545-610.

(2) Synthesis of metal nanocrystals in reverse micelles at room temperature

***$HAuCl_4$**
$CH_3(CH_2)_nSH$
$(CH_3(CH_2)_7)_4N^+Br^-$
$NaBH_4$



Metal nanocrystals
e.g., gold, silver, etc.

* Brust, M., *et al*. *J. Chem. Soc.-Chem. Comm*. 7, 801 - 802 (1994).

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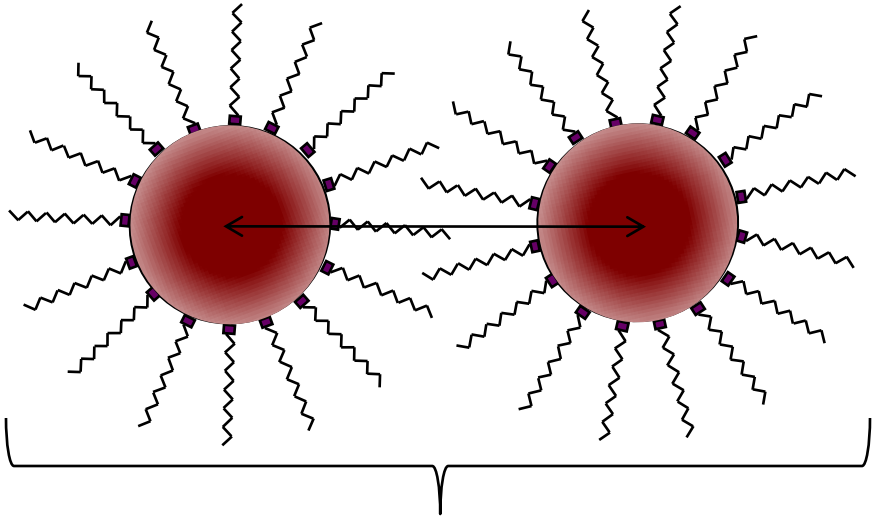
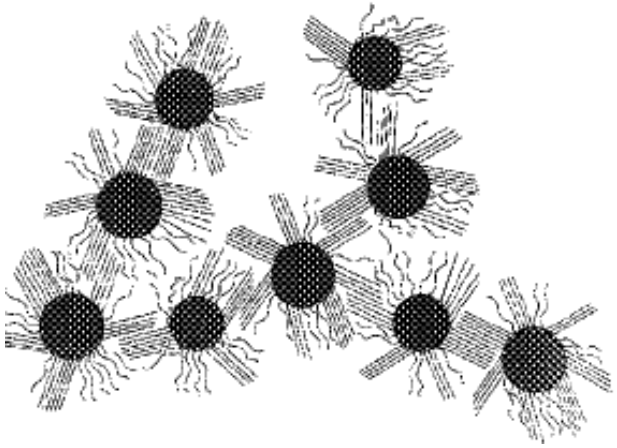
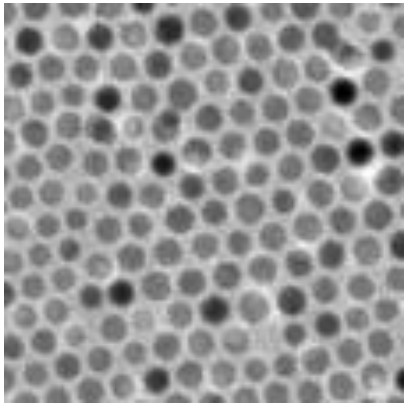
Nanoparticle Assembly at Ambient Pressure:
1. Balanced Interparticle Interactions



Balanced interparticle interactions





Lennox, R.B. *et al. Chem. Eur. J.* 1996, Vol. 2, 359-363.

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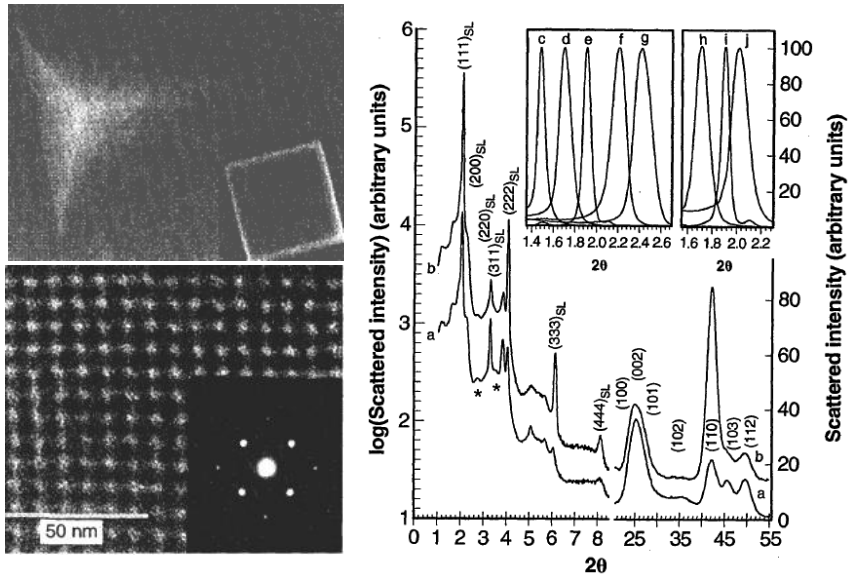
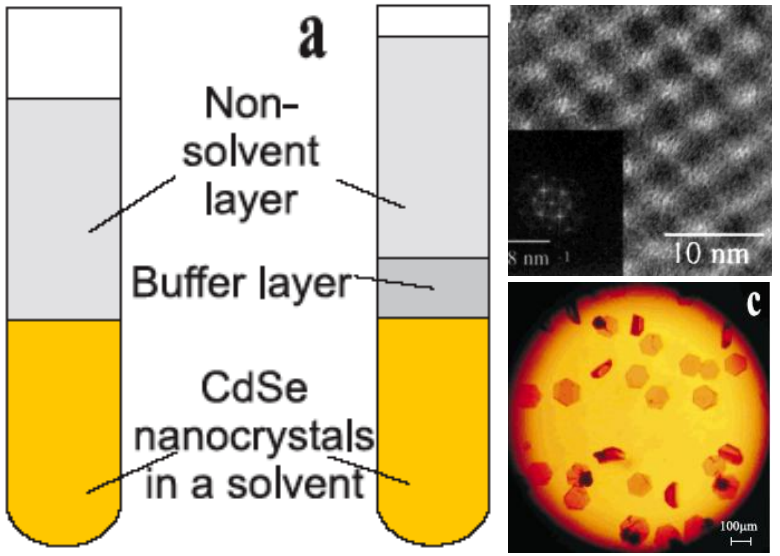
Nanoparticle Assembly at Ambient Pressure:
1. Balanced Interparticle Interactions

1. Slow solvent evaporation



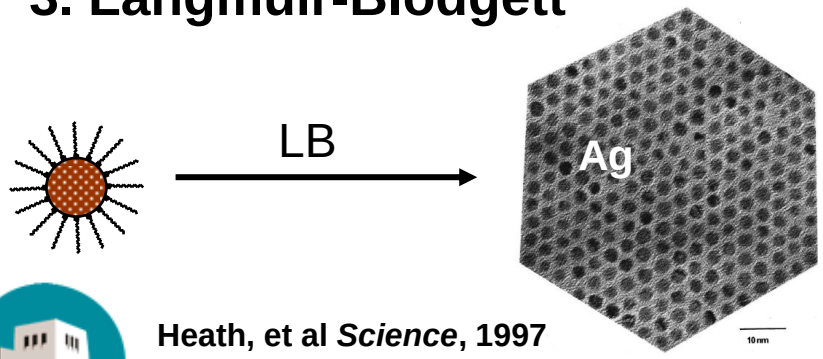
Murray, et al., *Science*, 1995

2. Heterogeneous nucleation



Talapin, et al., *Adv. Mater*. 2001

3. Langmuir-Blodgett



Heath, et al *Science*, 1997

4. Others:

- **Break figure:**

Han YC *et al*.
Russell, T *et al*.
Korgel B. *et al.*

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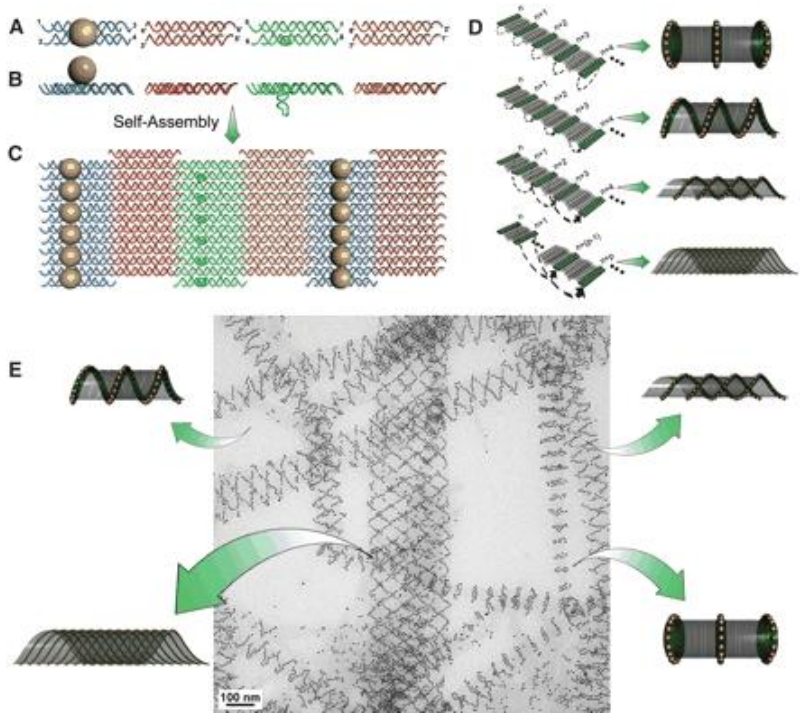
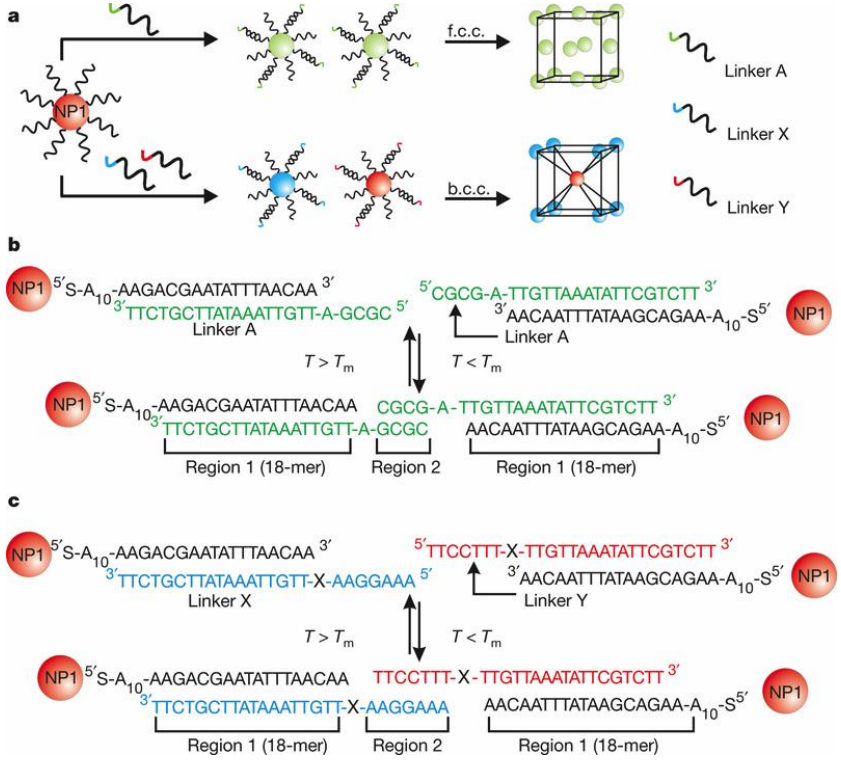
Nanoparticle Assembly at Ambient Pressure: 2. DNA-Programmable Nanoparticle Crystallization





Jaswinder Sharma, *et al*., *Science* 323, 112-116, 2009; Sung Yong Park, et al., *Nature* 451, 530-556, 2008; Dmytro Nykypanchk, *et al*., *Nature* 451, 549, 2008.

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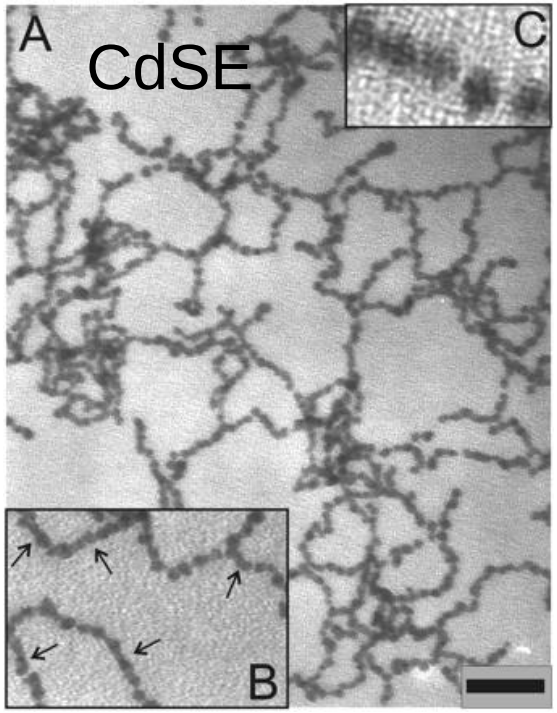
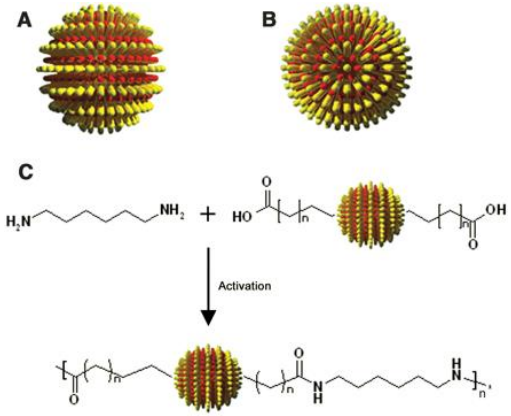
Nanoparticle Assembly at Ambient Pressure: 3. Dipole-Dipole Interaction and Chemical Reactions

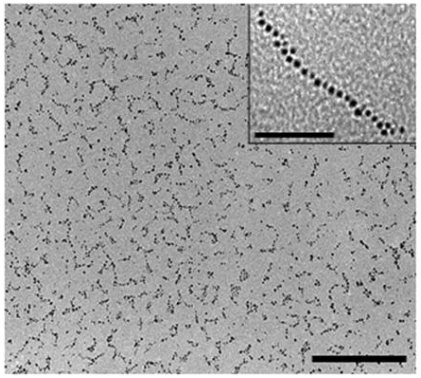
Dipole-Dipole Interaction



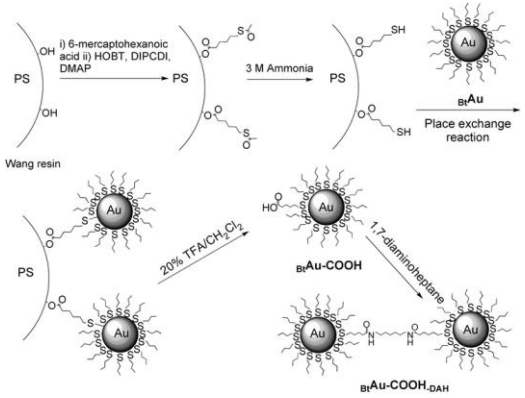
Z. Y. Tang, *et al., Science* 2002, 297, 237.

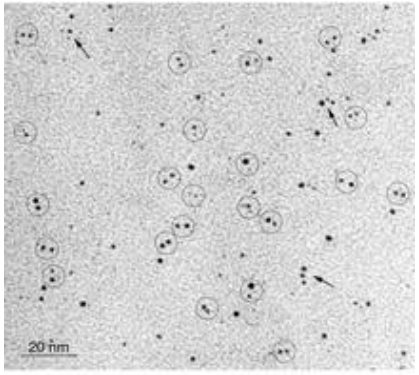
Chemical Reactions





G. A. DeVries, *et al., Science* 2007, 315, 358.





J. G. Worden, *et al., Chem. Comm*. 2004, 518.

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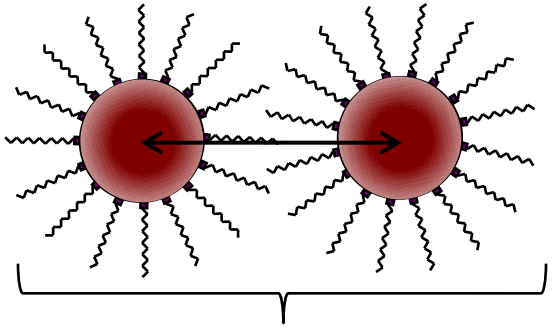
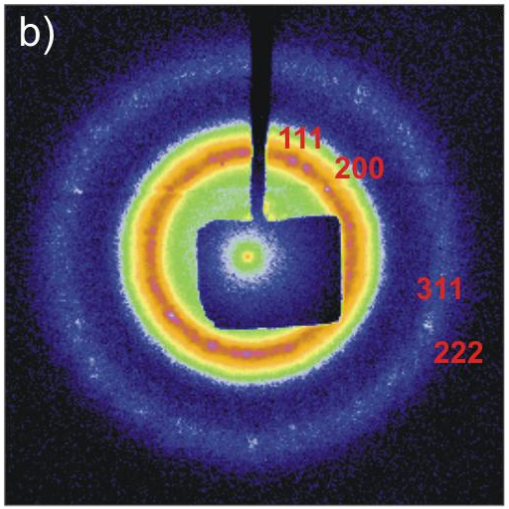
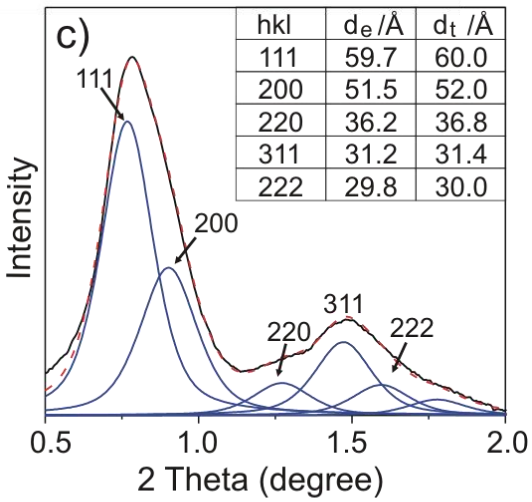
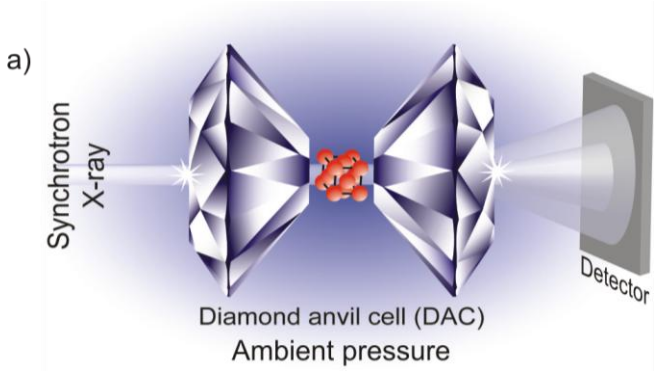
II. Nanoparticle Assembly under Pressure:

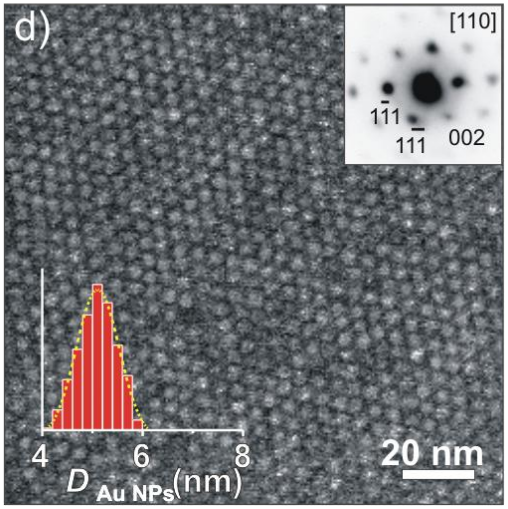


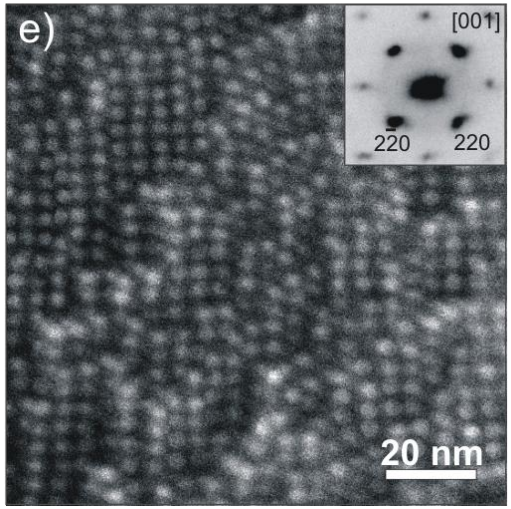
Balanced interparticle interactions











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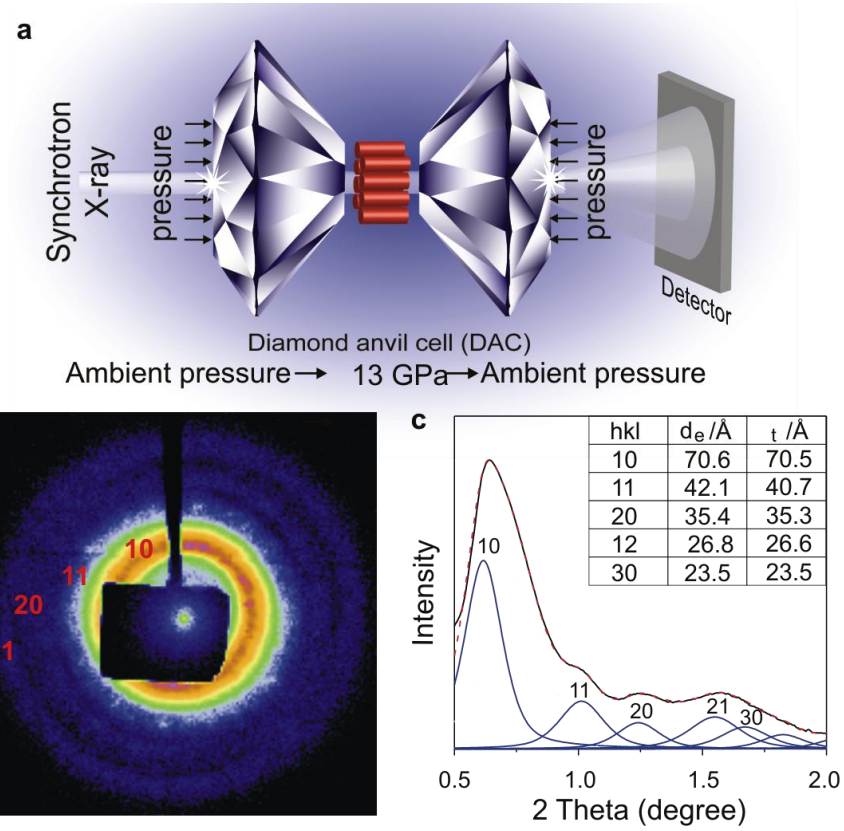
High Pressure Driven Formation of 1D Nanowires



Angwandte Chemie Int. Edit., accepted.

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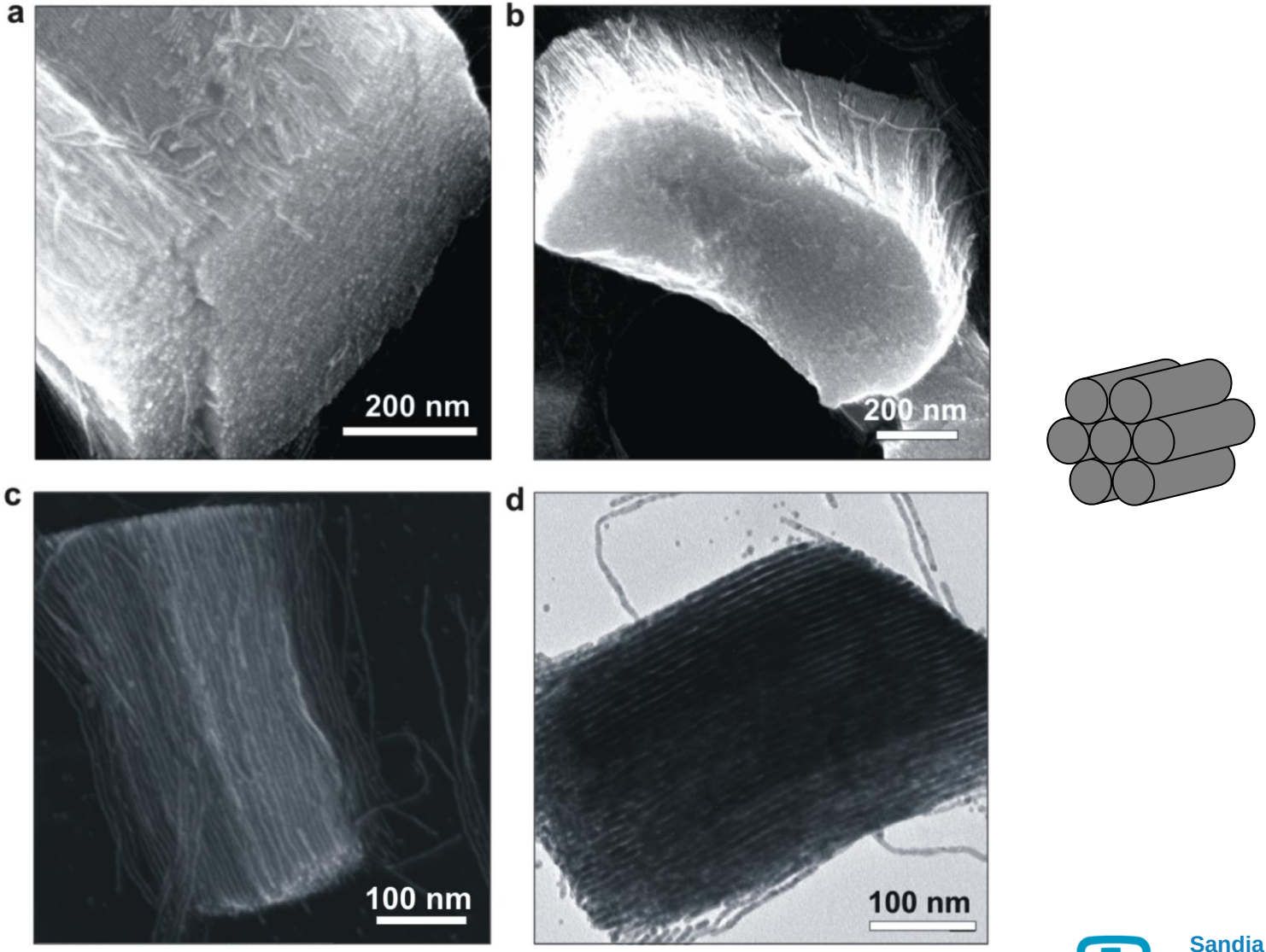
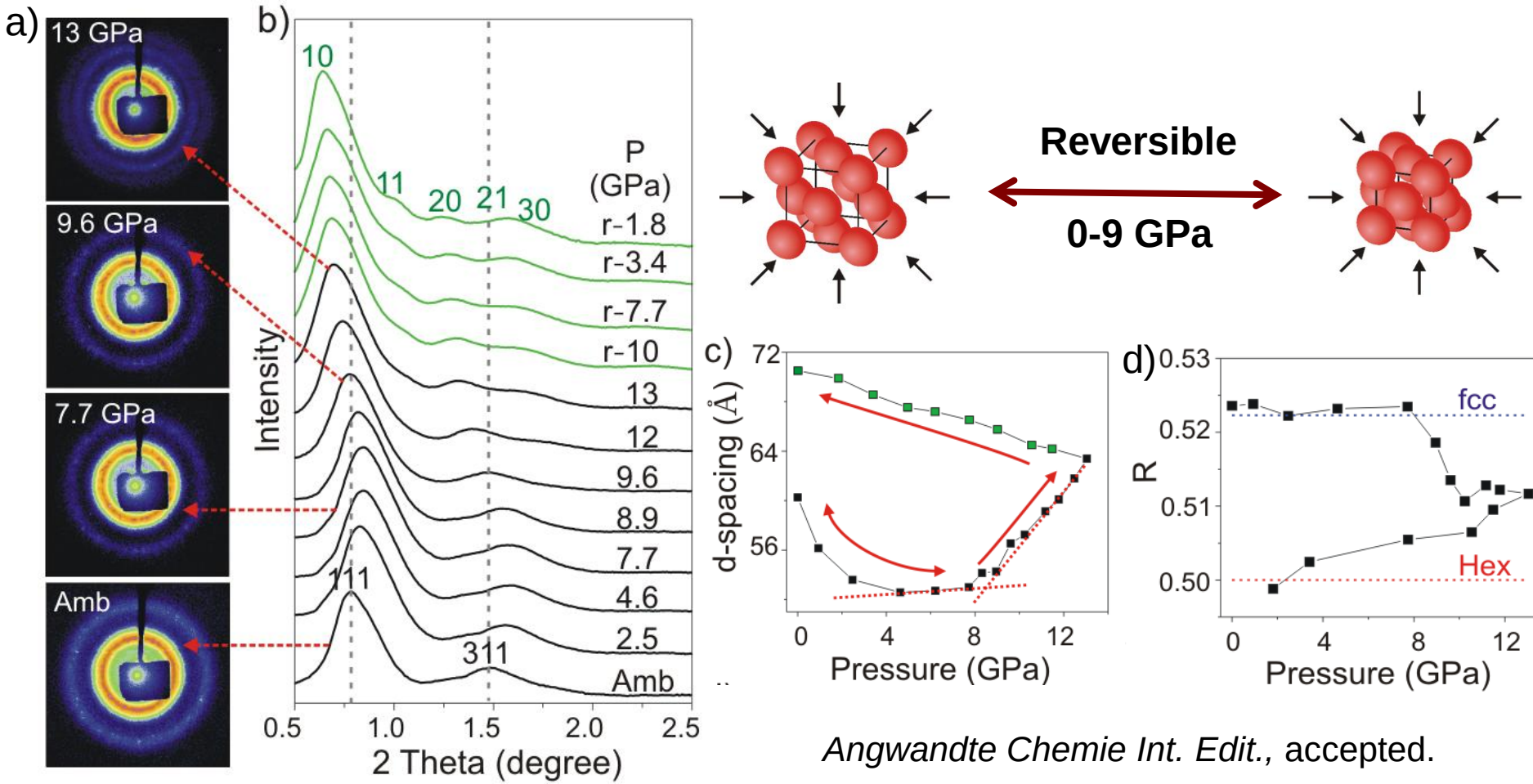
1D nanostructure arrays



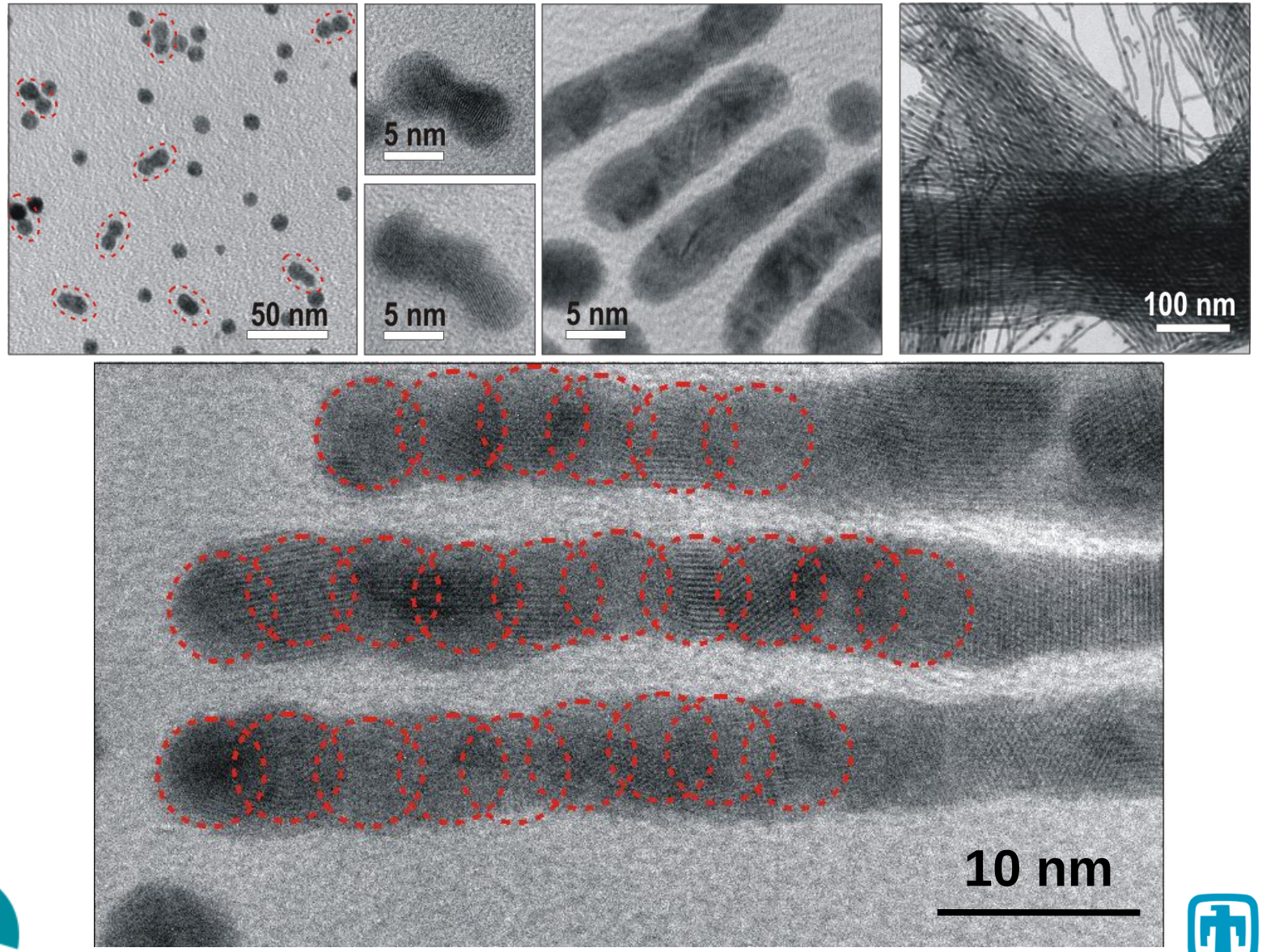
High Pressure GISAXS Studies of Nanoparticle Assembly under Pressure

An external pressure can be utilized to engineer nanoparticle assembly, allowing fine-tuning of lattice structure and interparticle separation distance and to fabricate new nanoparticle architectures without relying on these specific interactions.



Angwandte Chemie Int. Edit., accepted.

High Pressure Driven Nanoparticle Sintering and Formation of New Chemically and Mechanically Stable 1D Nanostructures



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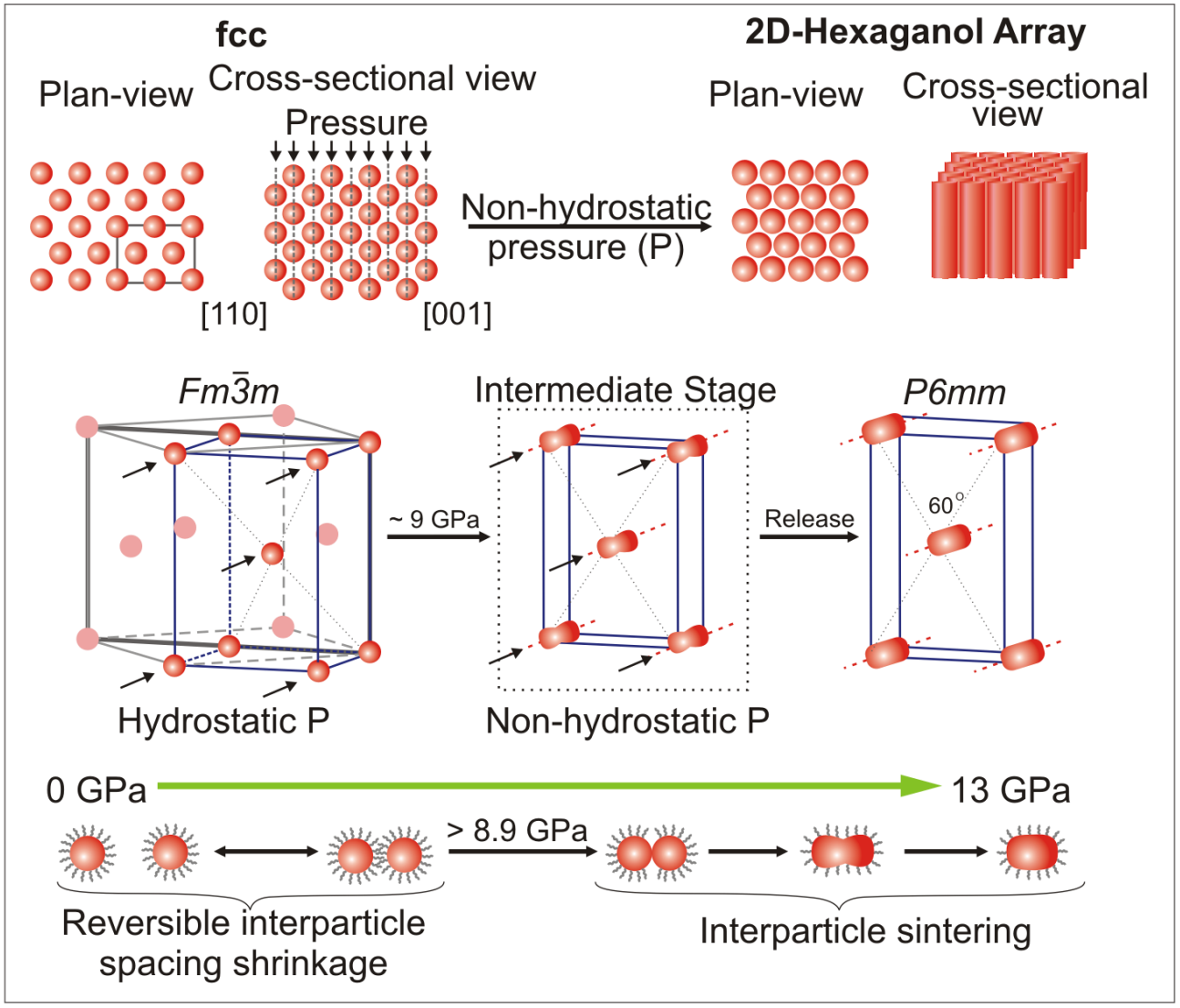
Proposed Processes for High Pressure Driven Nanoparticle Sintering and Formation of 1D Nanostructures



Angwandte Chemie Int. Edit., accepted.

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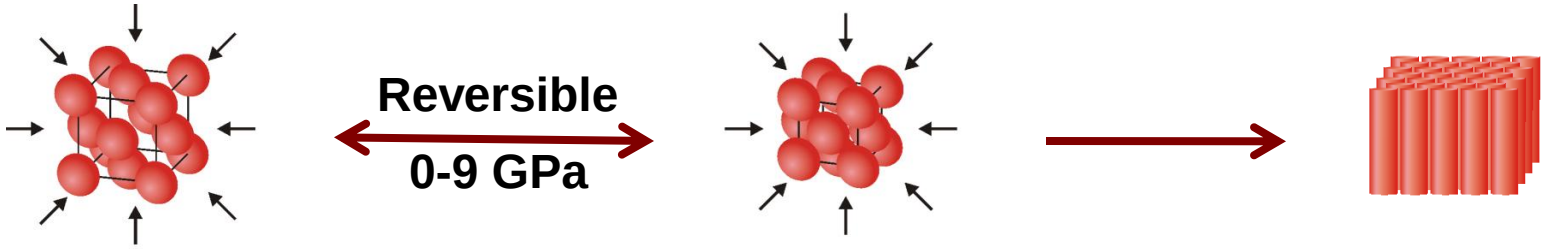
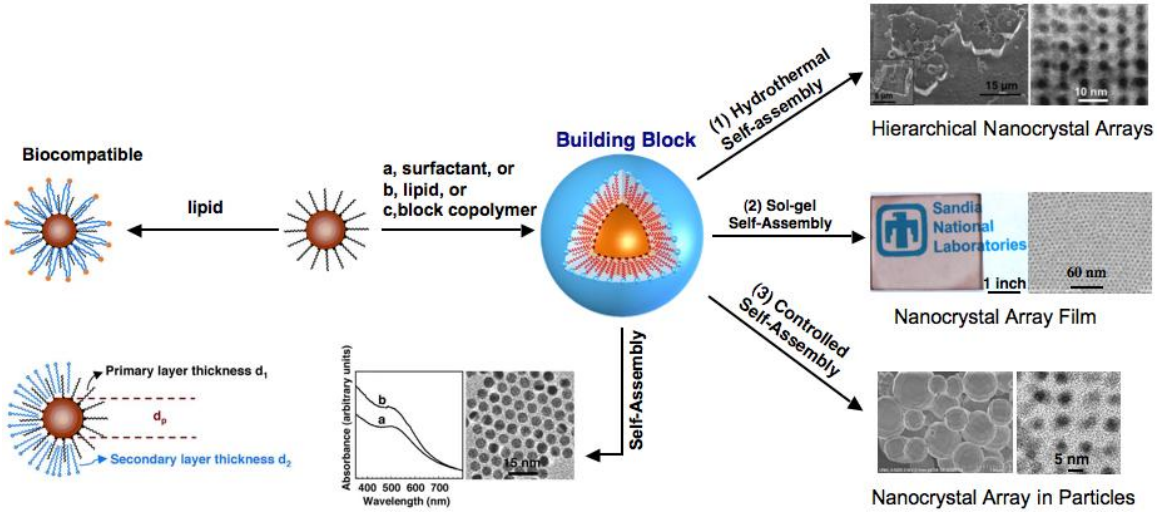
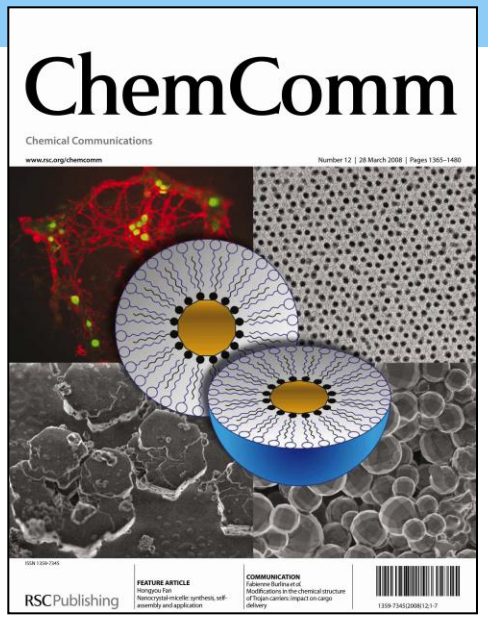
Summary

I. An external pressure can be utilized to engineer nanoparticle assembly, allowing fine-tuning of lattice structure and interparticle separation distance and to fabricate new nanoparticle architectures without relying on these specific interactions.



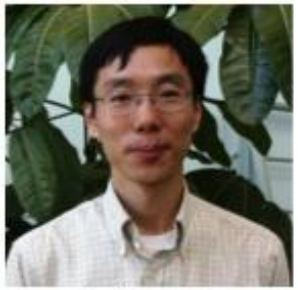
II. We have developed a simple, flexible method to functionalize nanoparticles and simple, economic coating processes for nanoparticle coatings with robotic structure, property (e.g., optical, electrical, and magnetic), and improved uniformity and enhanced stability.





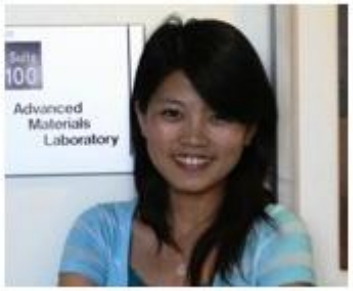
Fan H.
Chem. Comm., 2 , 259-261,2008, Feature article and Cover.

Acknowledgements:



Dr. Zaicheng Sun
UNM postdoc

Dr. Feng Bai
UNM postdoc



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UNM student

Adam Wright
UNM student

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UNM student

Samantha Schmitt
UNM student

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Davidson College
Sabbatical, 2008-2009

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