

# *Self-Assembly and Directed Assembly of Gold Nanorods*

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# Nanotechnology

“Development of research and technology at atomic, molecular or macromolecular levels, in a scale of approximately 1-100 nm, to obtain a fundamental comprehension of phenomena and materials in such nanometric scale and to create and use structures, devices and systems possessing new properties and functions due to their size...”



# Nanoparticle Assembly



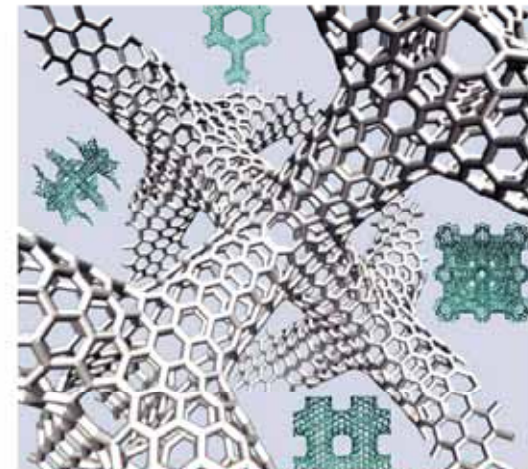
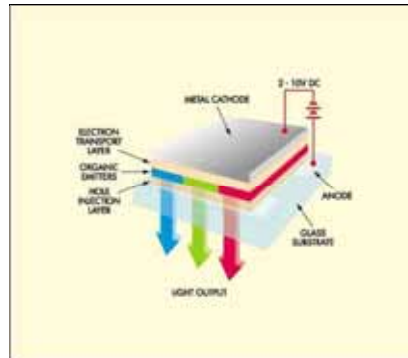
Control of the detailed structure of matter on the finest possible scale is a major goal of chemistry, materials science and nanotechnology. This goal may be approached in two steps: first, the construction of individual molecules through synthetic chemistry; and second, the arrangement of molecular building blocks into larger structures.

**Erik Winfree<sup>\*</sup>, Furong Liu<sup>†</sup>, Lisa A. Wenzler<sup>†</sup> & Nadrian C. Seeman<sup>†</sup>**

NATURE | VOL 394 | 6 AUGUST 1998

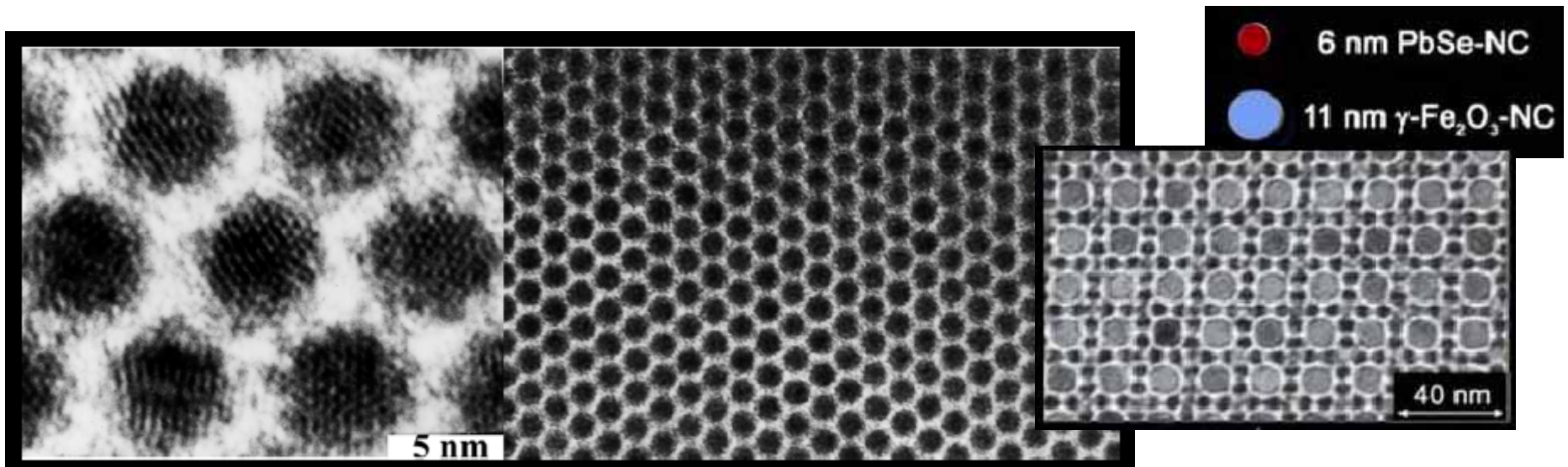
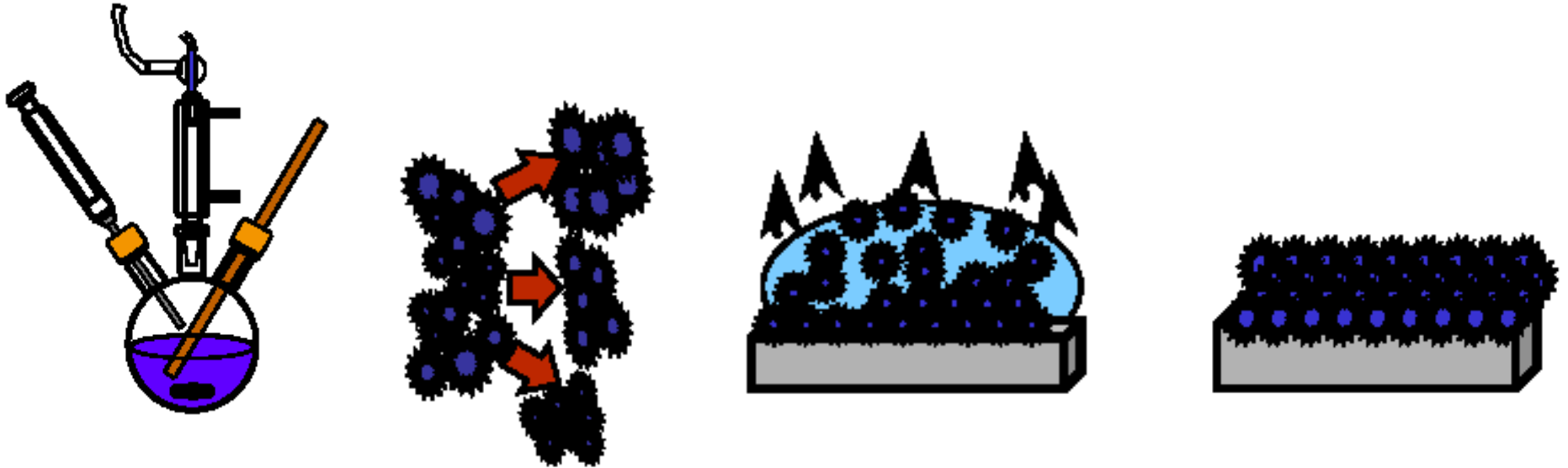


NATURE | Vol 451 | 31 January 2008



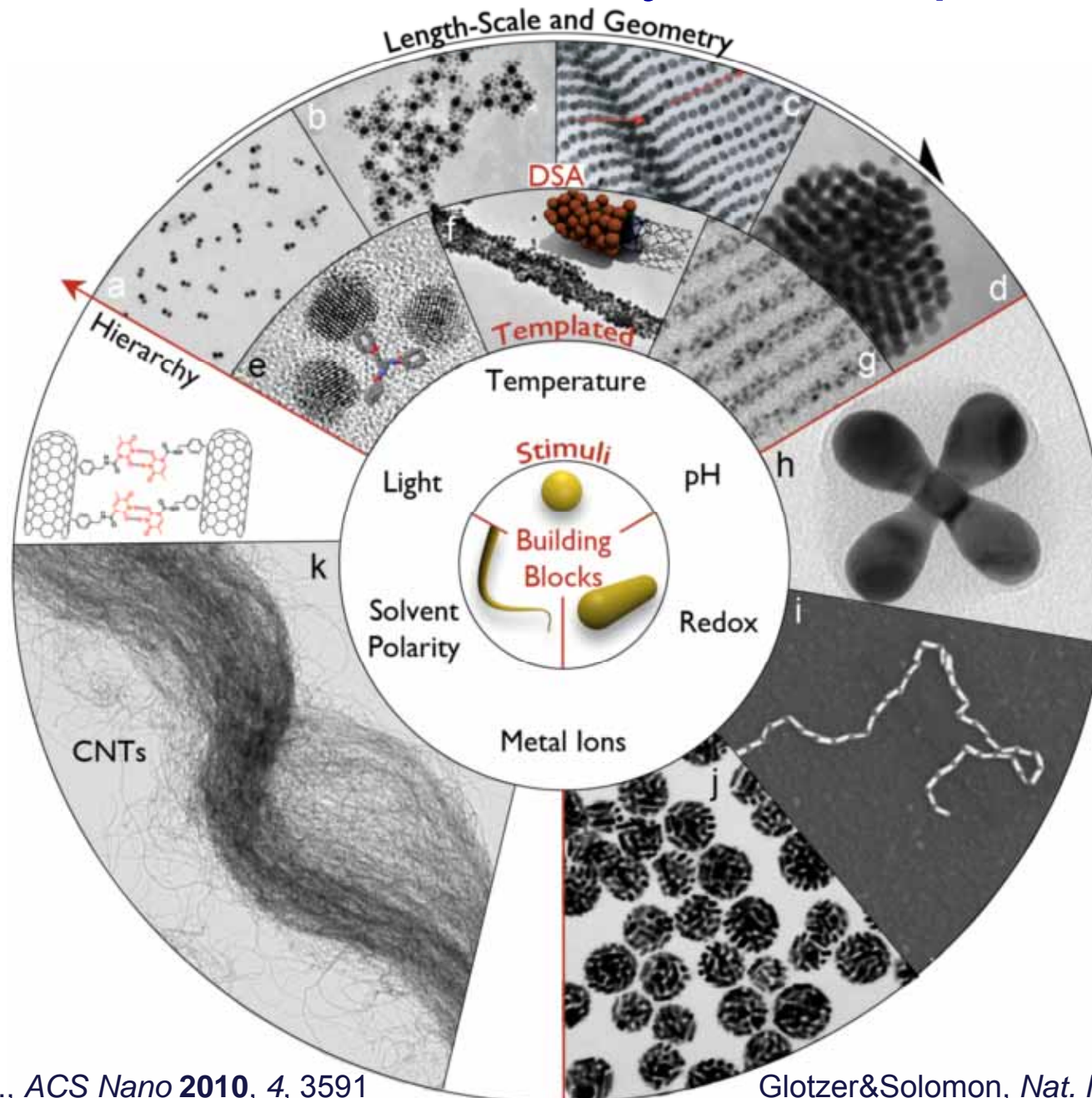
Ordered Networks Based on Carbon Nanotubes

# Self-Assembly

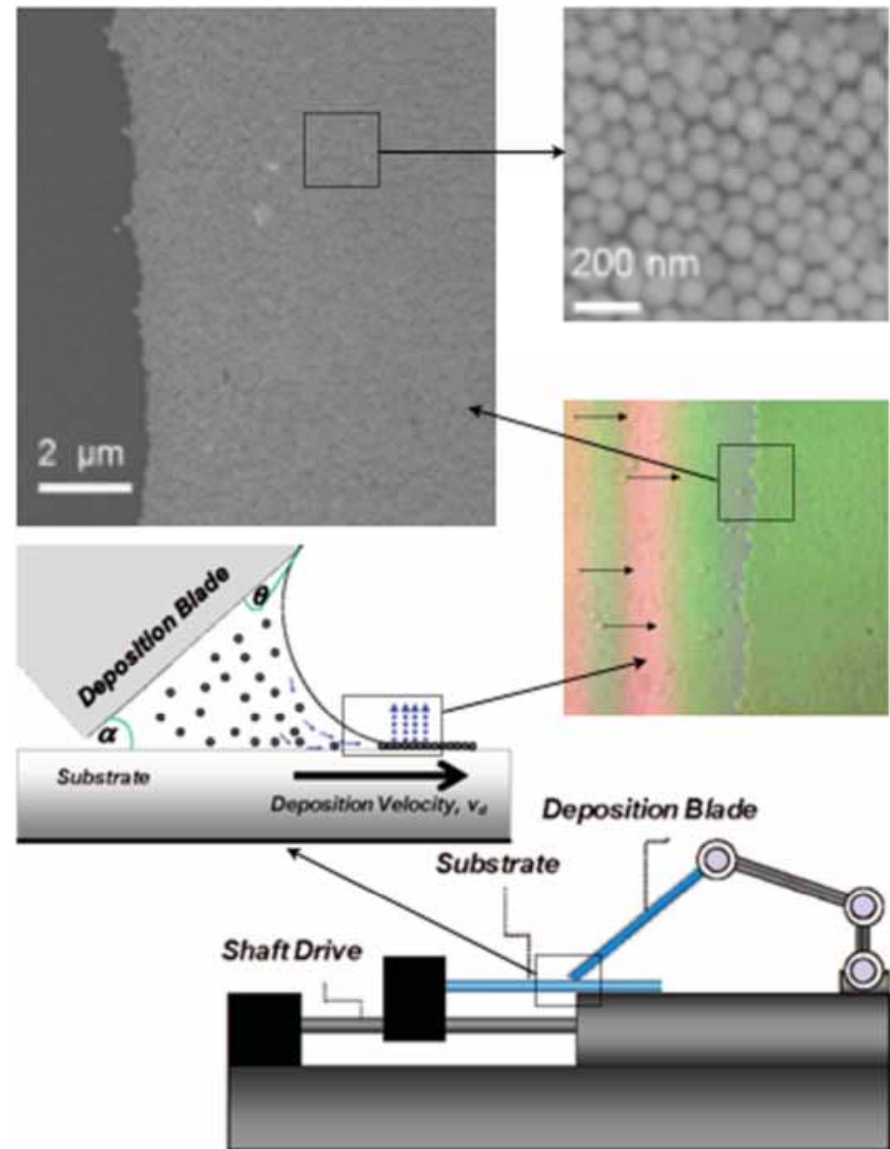
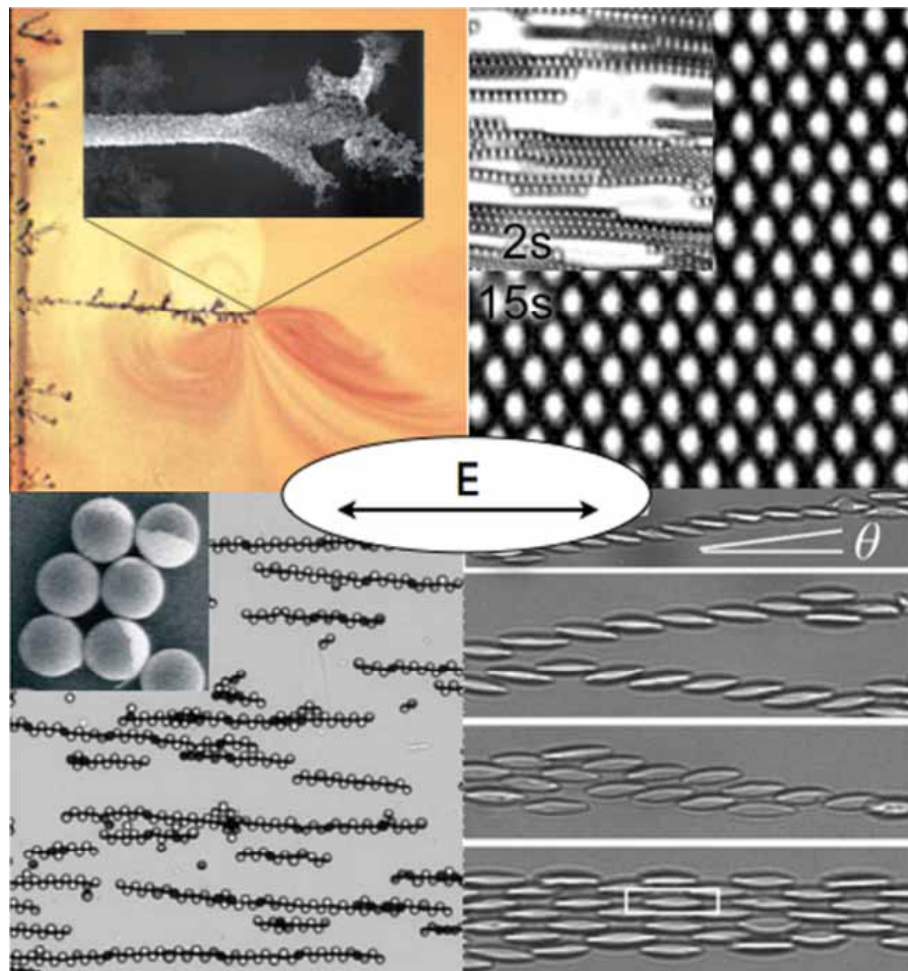


C.B. Murray, IBM, U. Penn

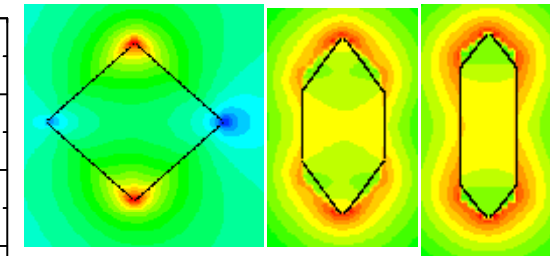
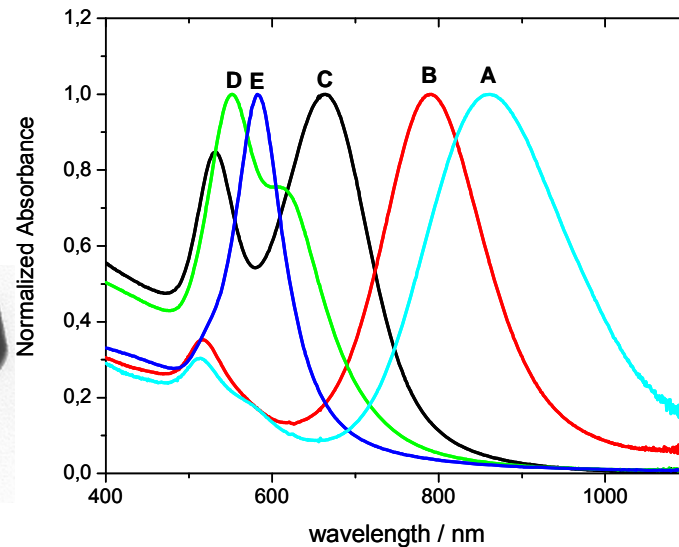
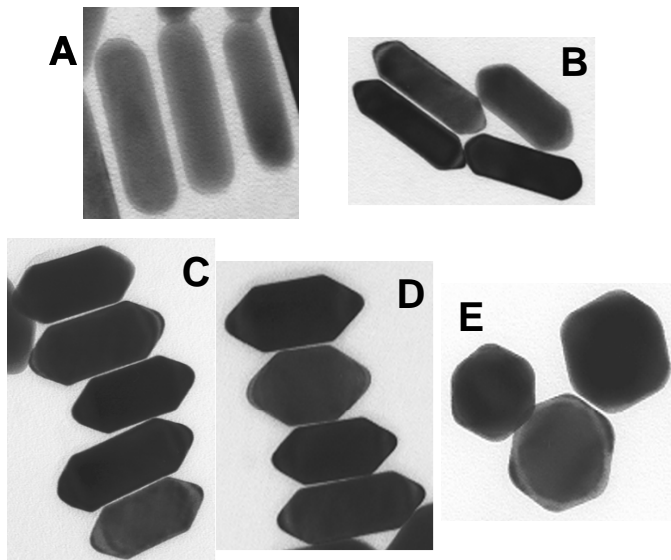
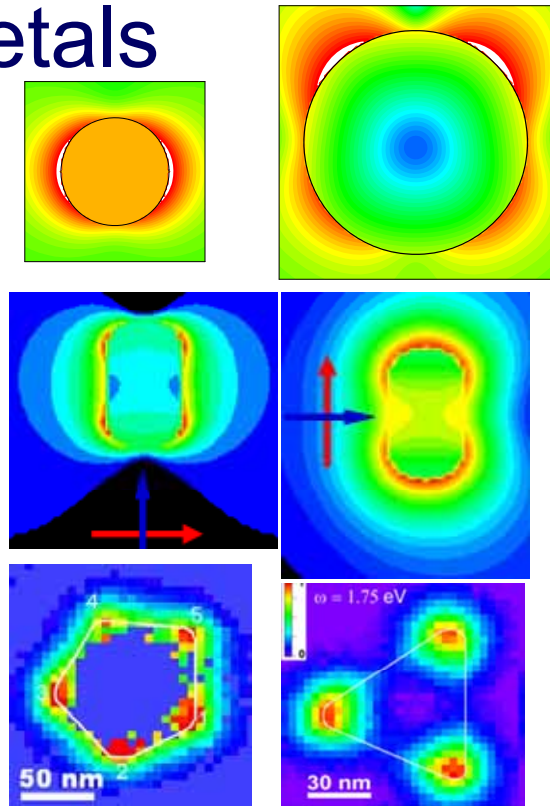
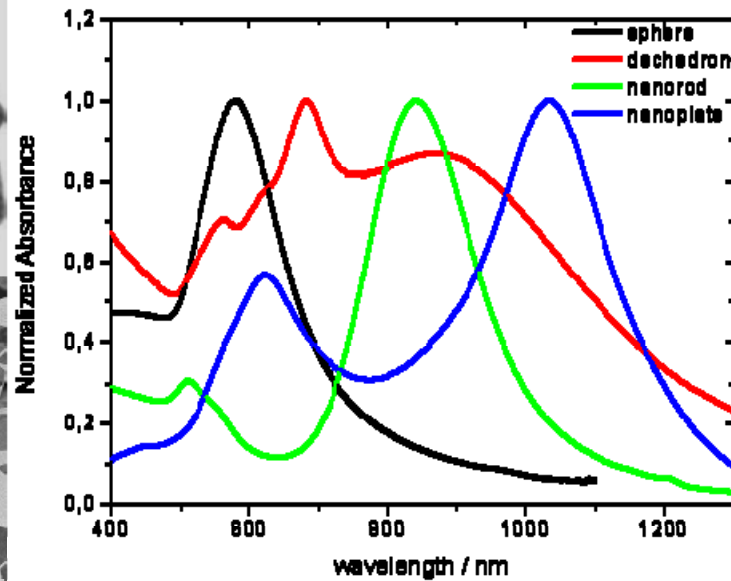
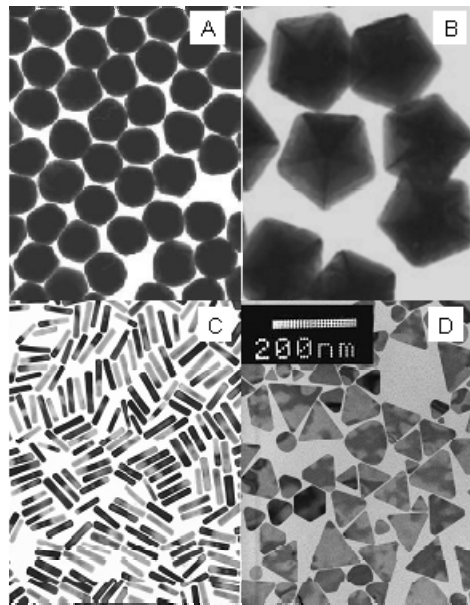
# Directed self-assembly of nanoparticles



# Directed self-assembly by external fields

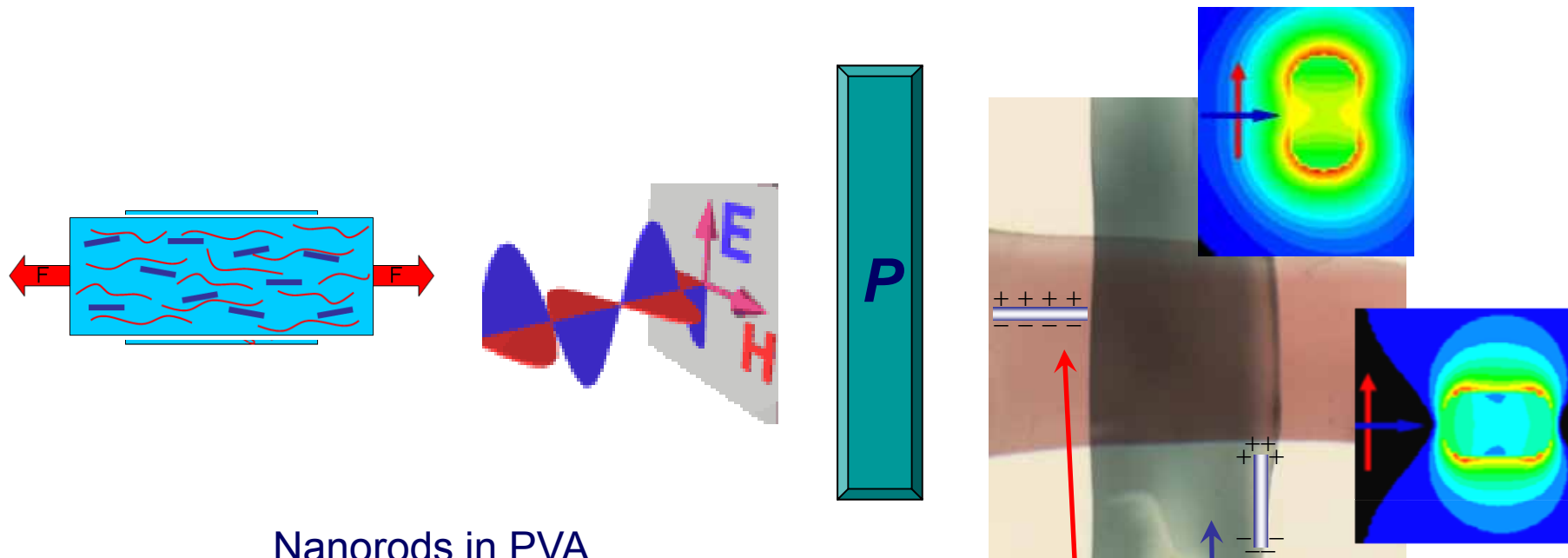


# Surface plasmon modes in nanometals

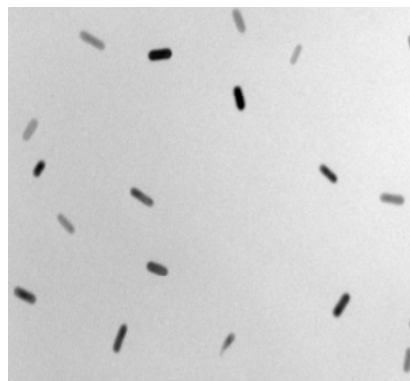


*Coord. Chem. Rev.* **2005**, 249, 1870  
*Langmuir* **2006**, 22, 32  
*Langmuir* **2006**, 22, 7007  
*Adv. Mater.* **2006**, 18, 2529  
*Nature Phys.* **2007**, 3, 348  
*Angew. Chem. Int.* **2007**, 46, 8983  
*Chem. Soc. Rev.* **2008**, 37, 1792

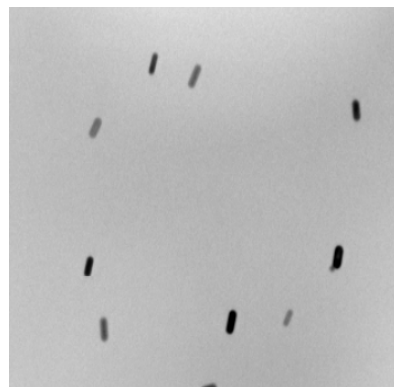
# The *anisotropic* optical response of Au rods



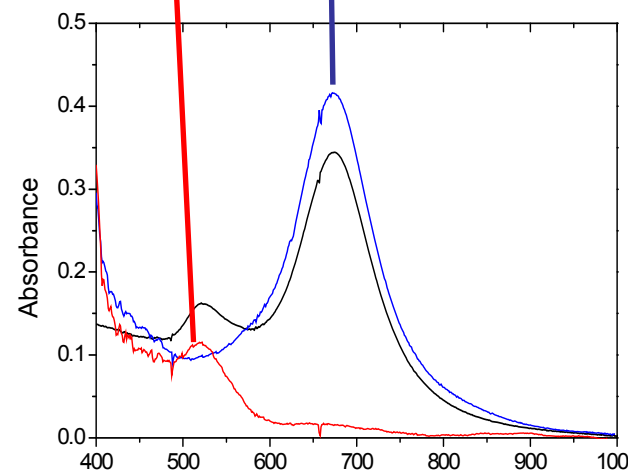
Nanorods in PVA



non.-stretched



stretched



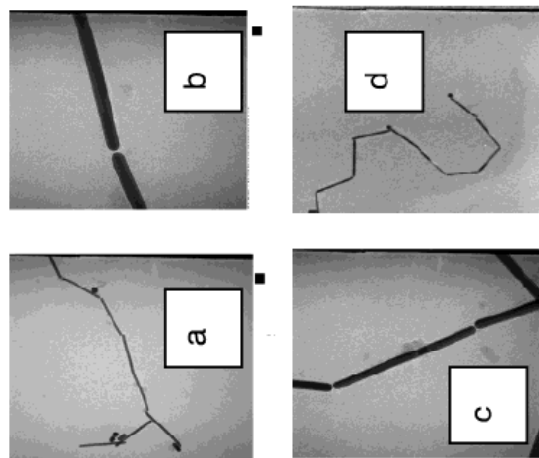
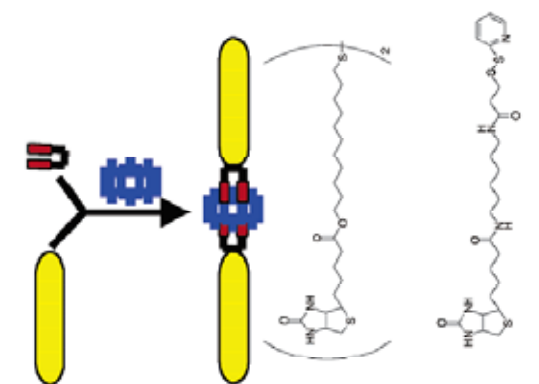


# Chemistry as a “Directing Agent” for nanorod assembly

## Preferential End-to-End Assembly of Gold Nanorods by Biotin–Streptavidin Connectors

K. K. Caswell, James N. Wilson,<sup>†</sup> Uwe H. F. Bunz,<sup>\*,†</sup> and Catherine J. Murphy<sup>\*</sup>

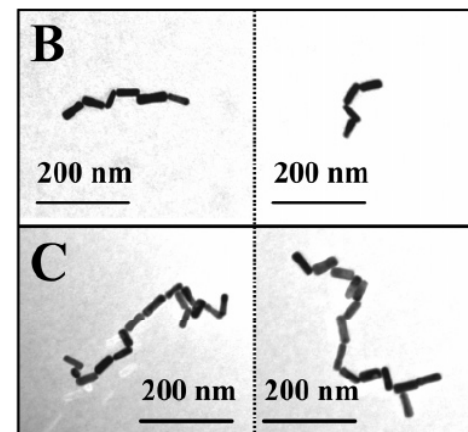
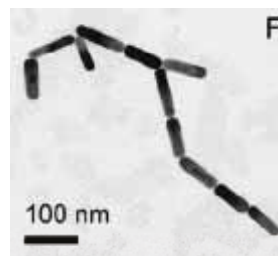
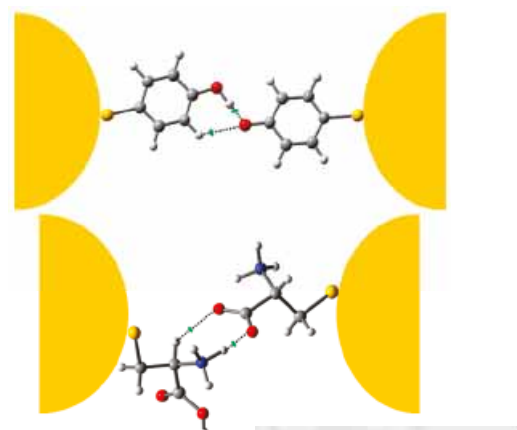
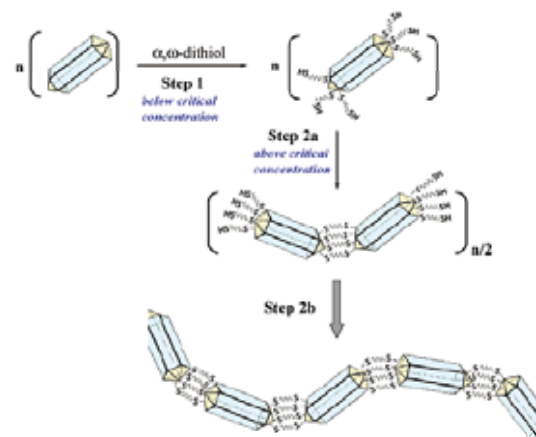
*J. AM. CHEM. SOC.* 2003, 125, 13914–13915



## Gold Nanorods to Nanochains: Mechanistic Investigations on Their Longitudinal Assembly Using $\alpha,\omega$ -Alkanedithiols and Interplasmon Coupling

S. T. Shibu Joseph, Binil Itty Ipe, P. Pramod, and K. George Thomas<sup>\*</sup>

*Photosciences and Photonics, Regional Research Laboratory (CSIR), Trivandrum 695 019, India*

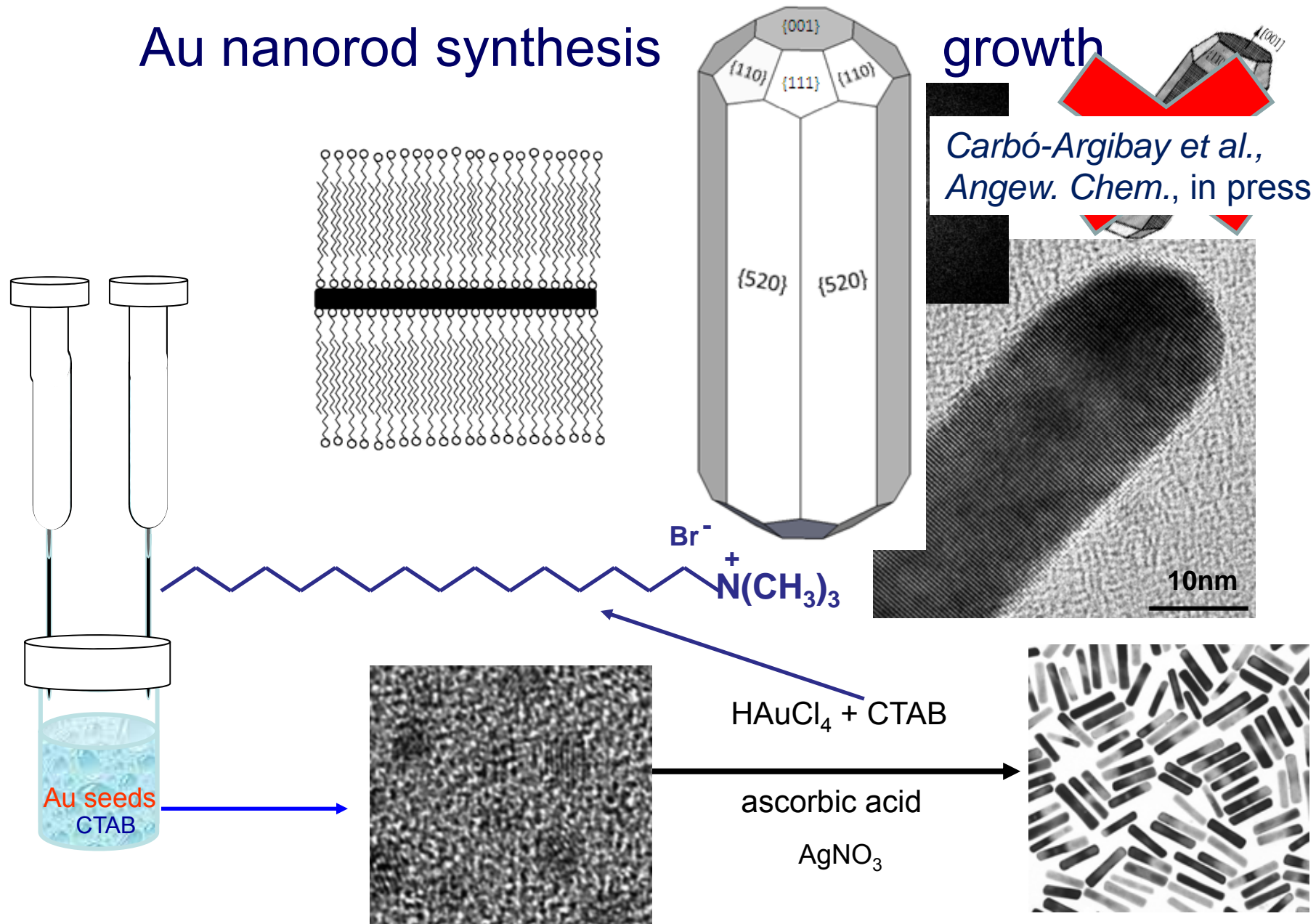


*THE JOURNAL OF PHYSICAL CHEMISTRY Letters* J. Phys. Chem. Lett. 2010, 1, 1181–1185

## Evidence for Hydrogen-Bonding-Directed Assembly of Gold Nanorods in Aqueous Solution

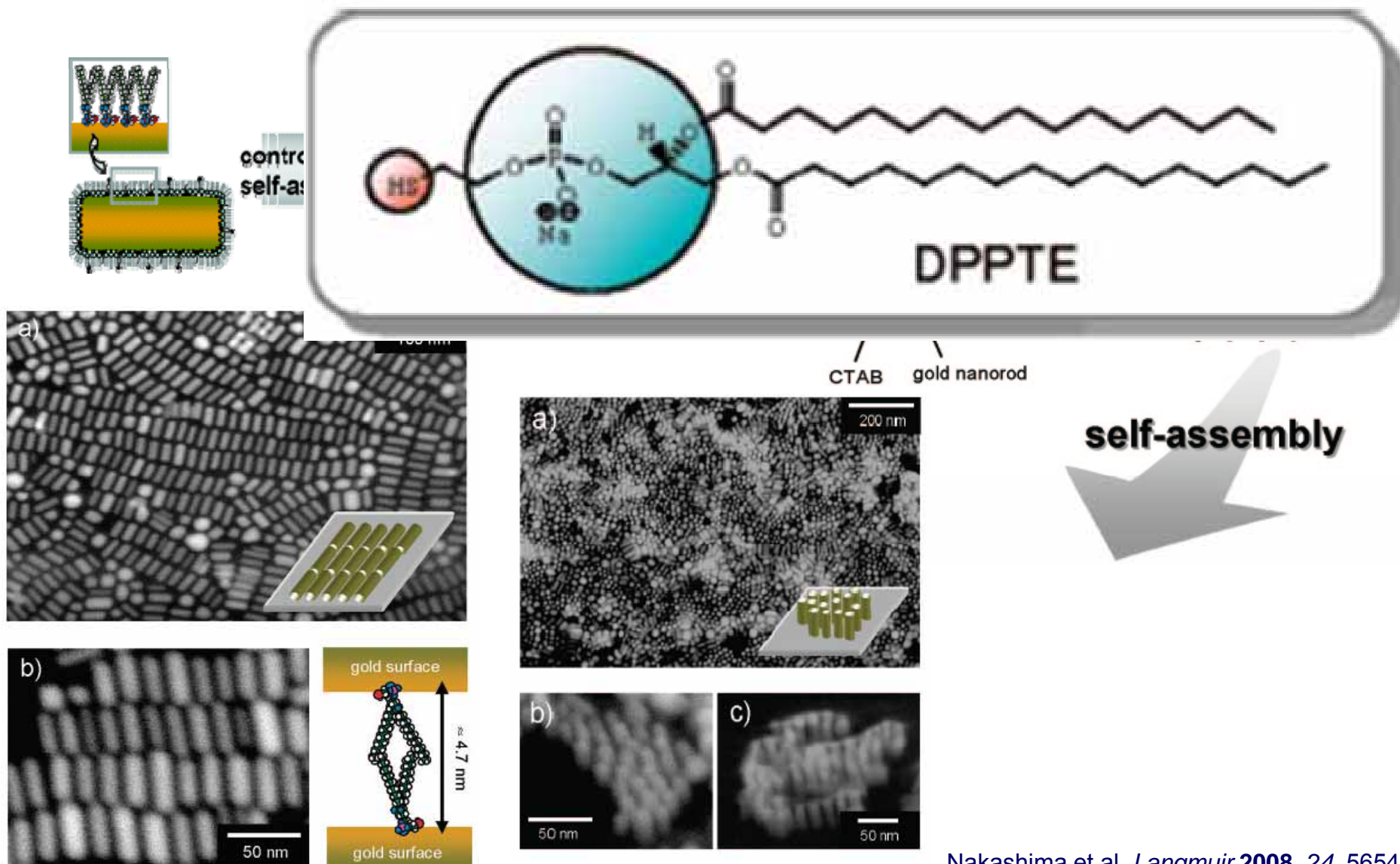
Weihai Ni,<sup>\*</sup> Ricardo A. Mosquera, Jorge Pérez-Juste, and Luis M. Liz-Marzán<sup>\*</sup>

# Au nanorod synthesis




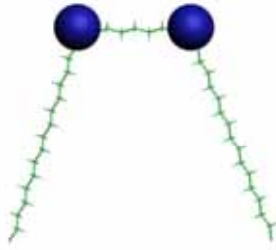
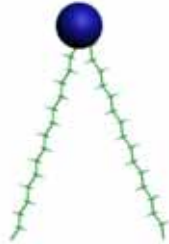
## Self-Assembly of Gold Nanorods Induced by Intermolecular Interactions of Surface-Anchored Lipids

Hiroshi Nakashima,\* Kazuaki Furukawa, Yoshiaki Kashimura, and Keiichi Torimitsu



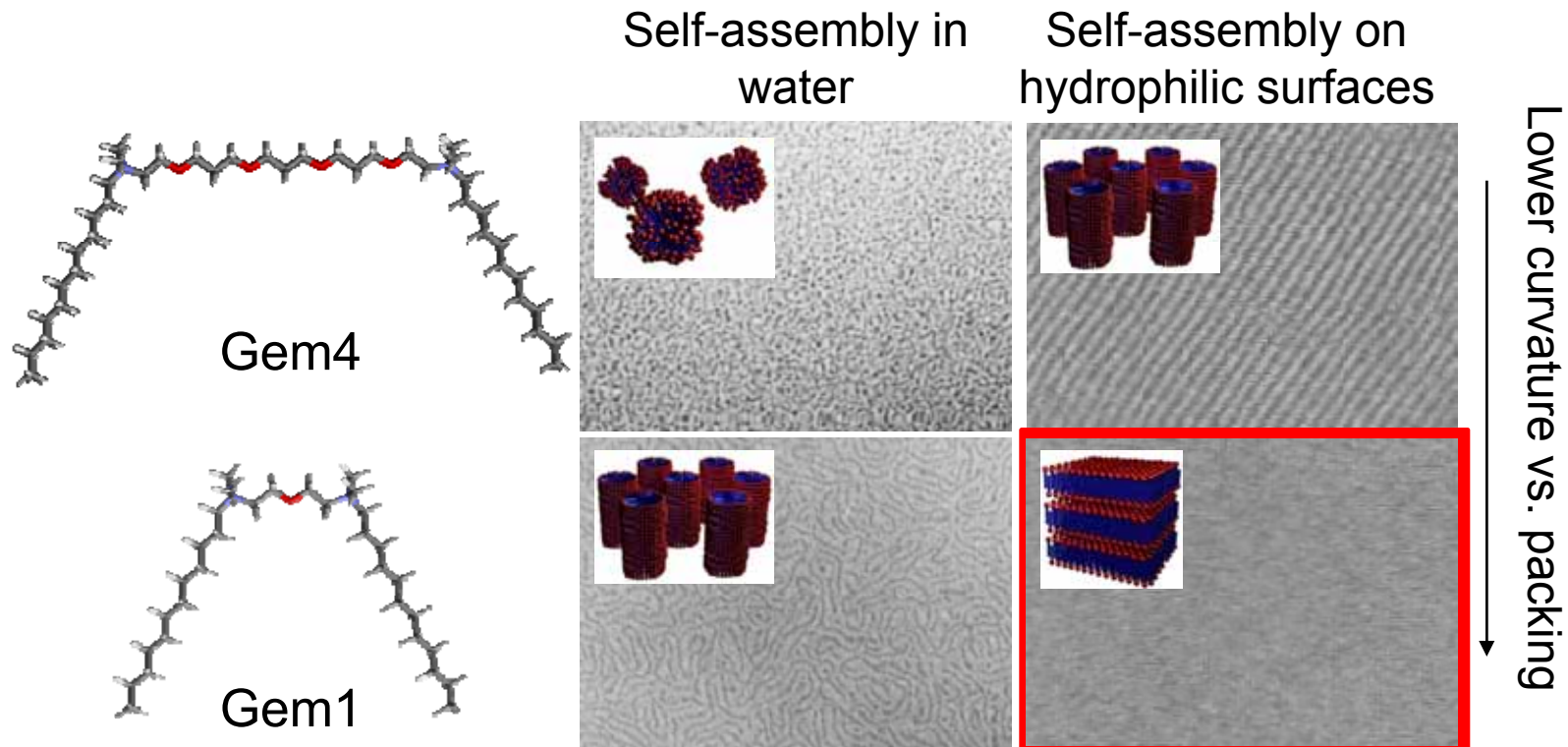
# Phospholipids vs. Gemini surfactants

***Gemini or dimeric surfactants*** are now available as excellent scaffolds for ***structurally mimicking the bilayer*** formation of ***lipids*** in water.

	<i>Conventional Surfactants</i>	<i>Gemini Surfactants</i>	<i>Phospholipids</i>
			
CMC	High	High → Low	Low
Water surface tension	High	High → Low	Low
Self-assembly in water	Spherical micelles	Spherical micelles → Rod-like micelles	Bilayer structures
Self-assembly on hydrophilic surfaces	Rod-like micelles	Rod-like micelles → Bilayer structures	Bilayer structures

# Self-assembly of gemini surfactants

**Gemini surfactants** with different **spacer lengths** lead to control over interfacial **aggregate geometry** at **solid-liquid interfaces**.

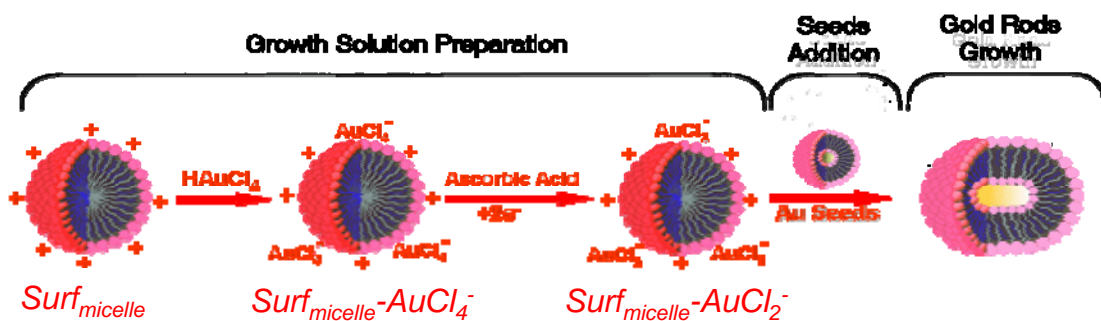


(oligooxa)alkanediyl- $\alpha,\omega$ -  
bis(dimethyldodecylammonium bromide)

Tieke et al. *Langmuir* **1999**, 15, 391  
Manne et al. *Langmuir* **1997**, 13, 6382

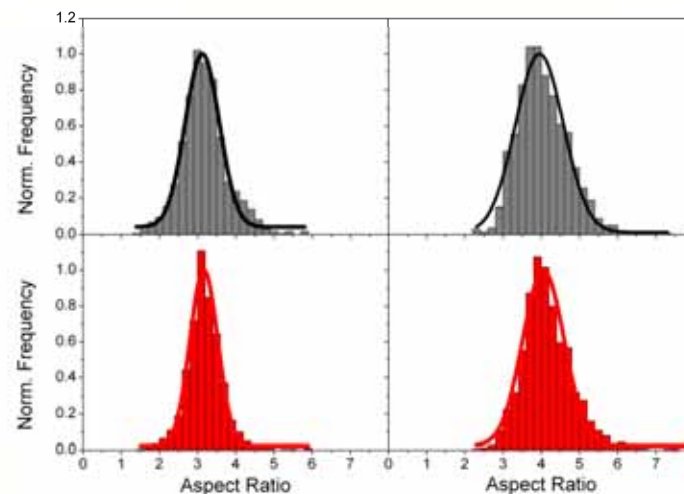
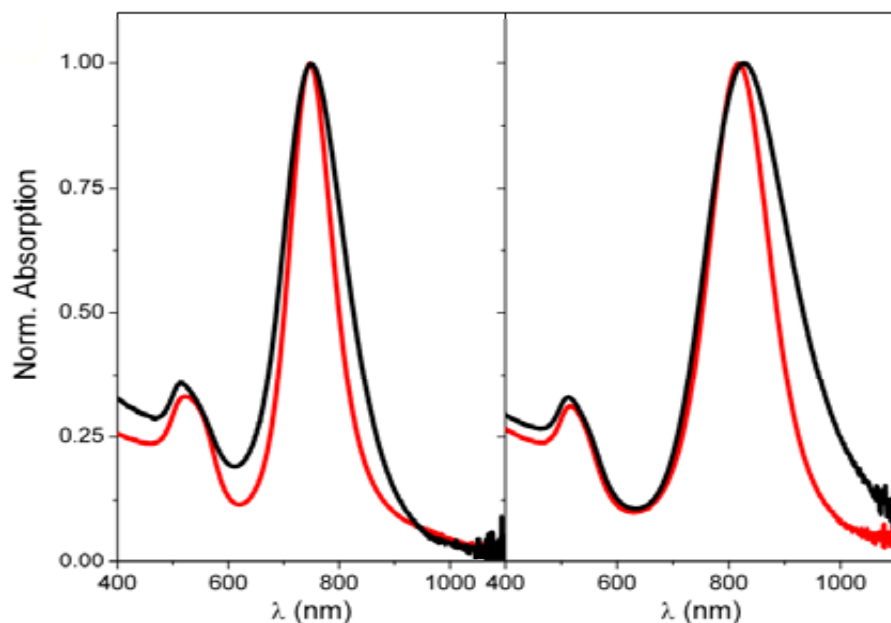
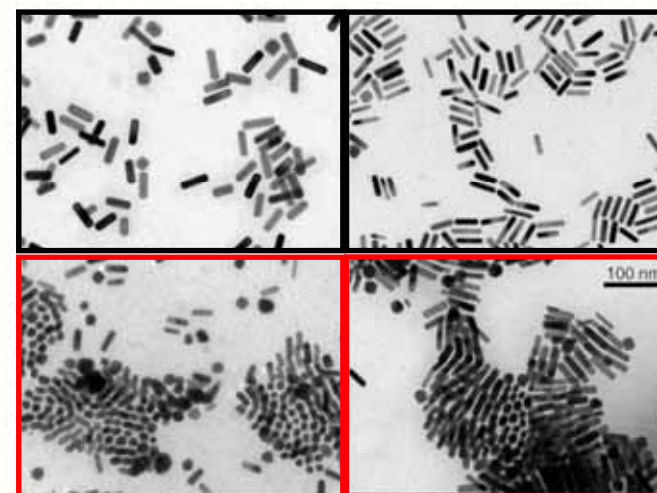
# Synthesis of gold nanorods using gemini surfactants

## *Gem1-NRs* vs. *CTAB-NRs*

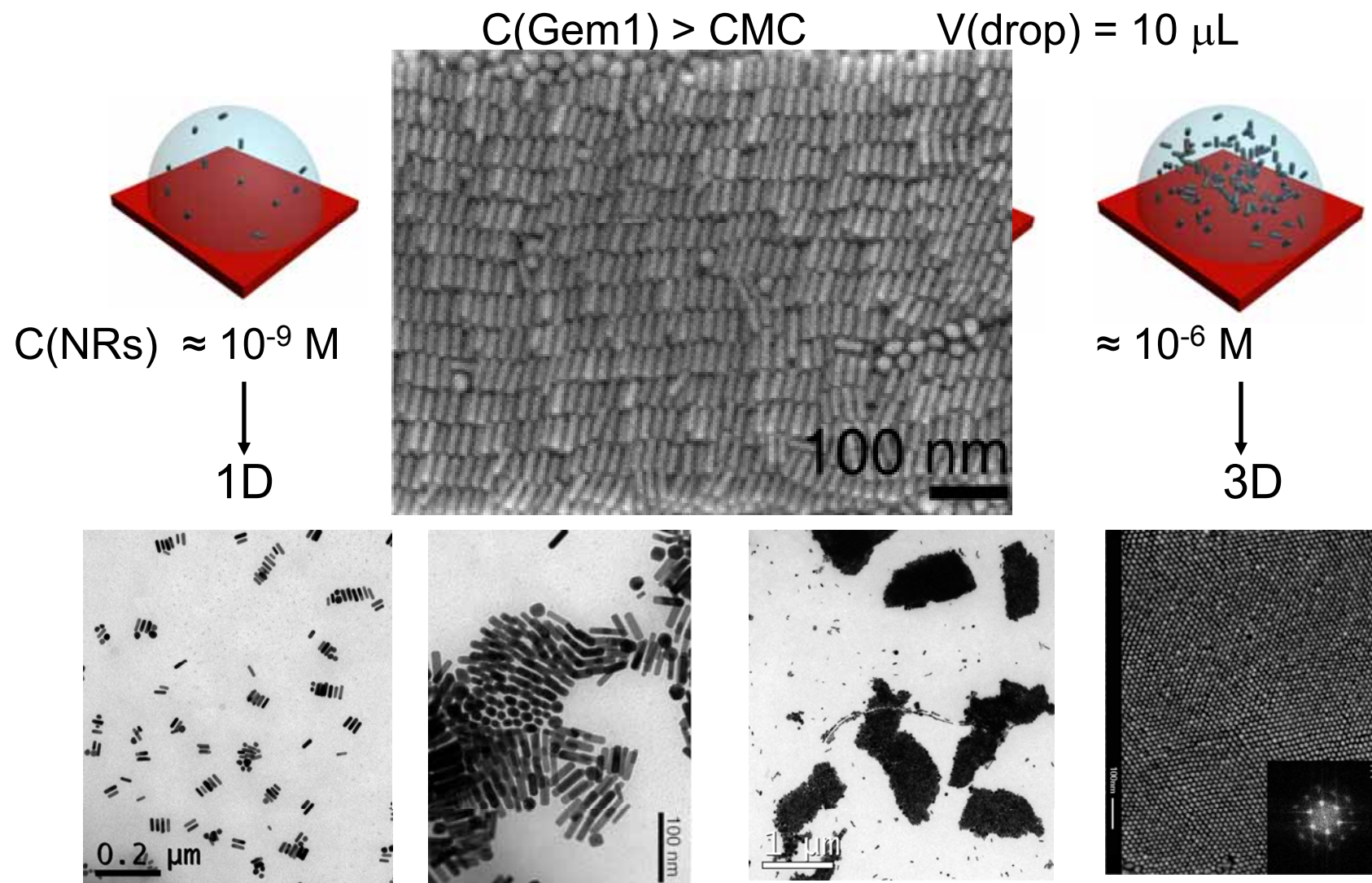


A. R. ~ 3.0

A. R. ~ 4.0

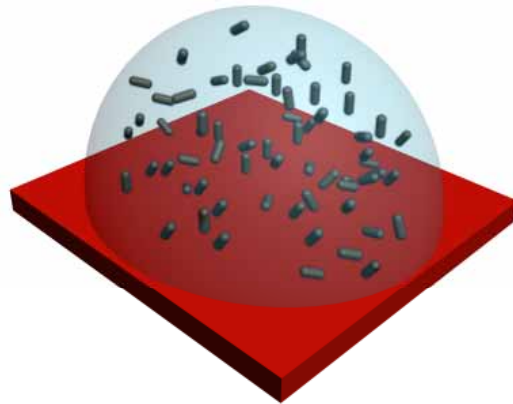


# Self-assembly of Gem1 Au nanorods

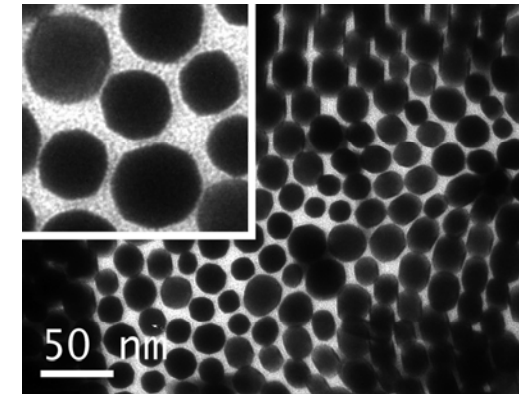


# Au nanorod Self-assembly: CTAB vs. Gem1

$C(\text{Gem1 or CTAB}) > \text{CMC}$



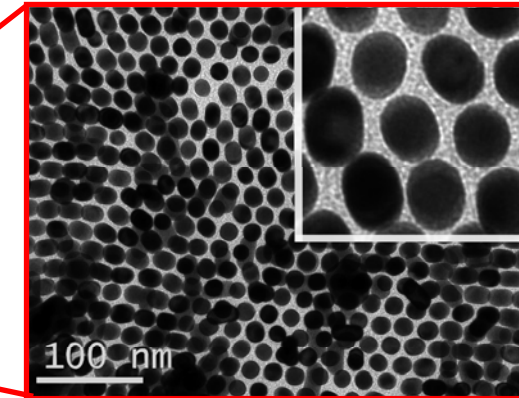
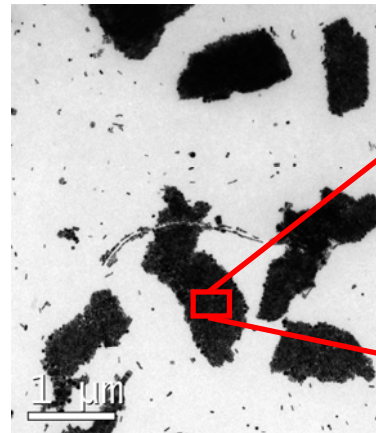
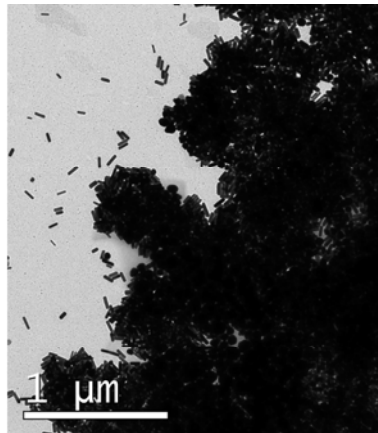
i) CTAB  
Synthesis  
→  
ii) Gem1  
Exchange



CTAB Synthesis

NRs  $\approx 10^{-7}$  M

Gem1 Synthesis





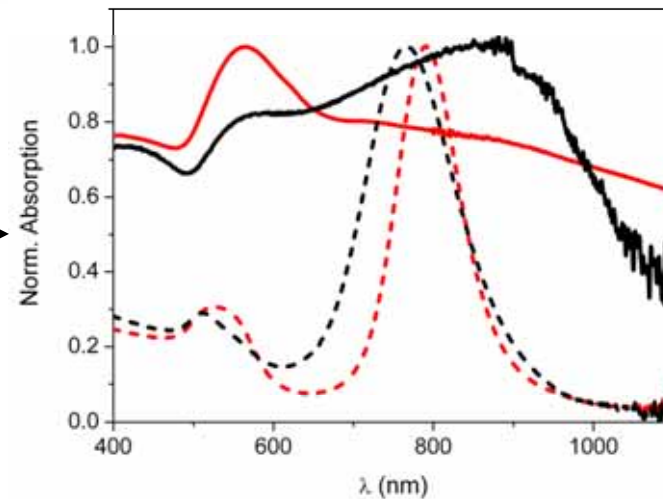
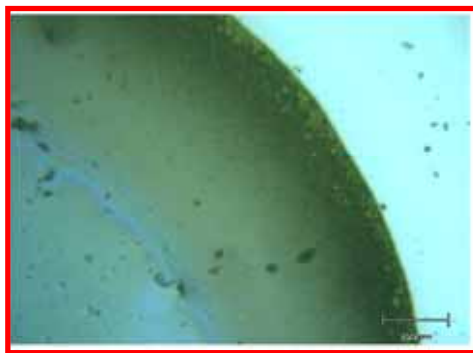
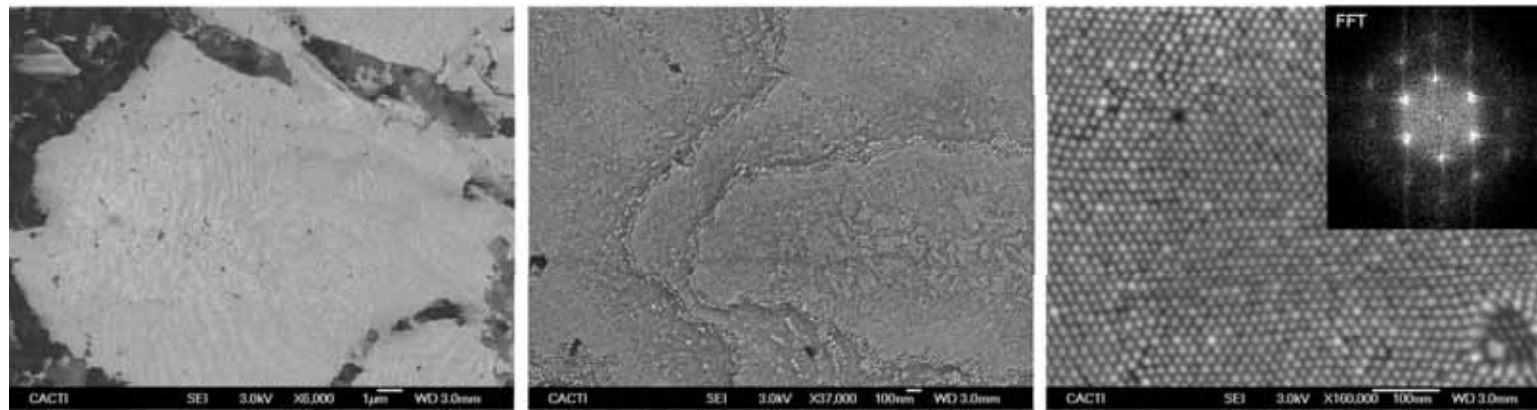
# Self-assembled Gem1 Au nanorods: Optical response

**Gem1-NRs**

$C(\text{Gem1}) > \text{CMC}$

$C(\text{NRs}) \approx 10^{-6} \text{ M}$

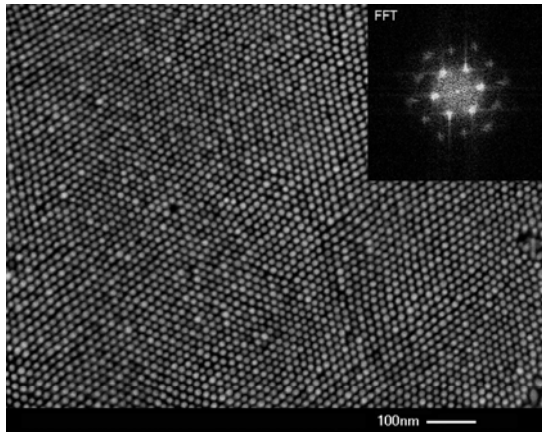
ITO substrate



**Gem1-NRs-ITO**  
**CTAB-NRs-ITO**

**Gem1-NRs-water**  
**CTAB-NRs-water**

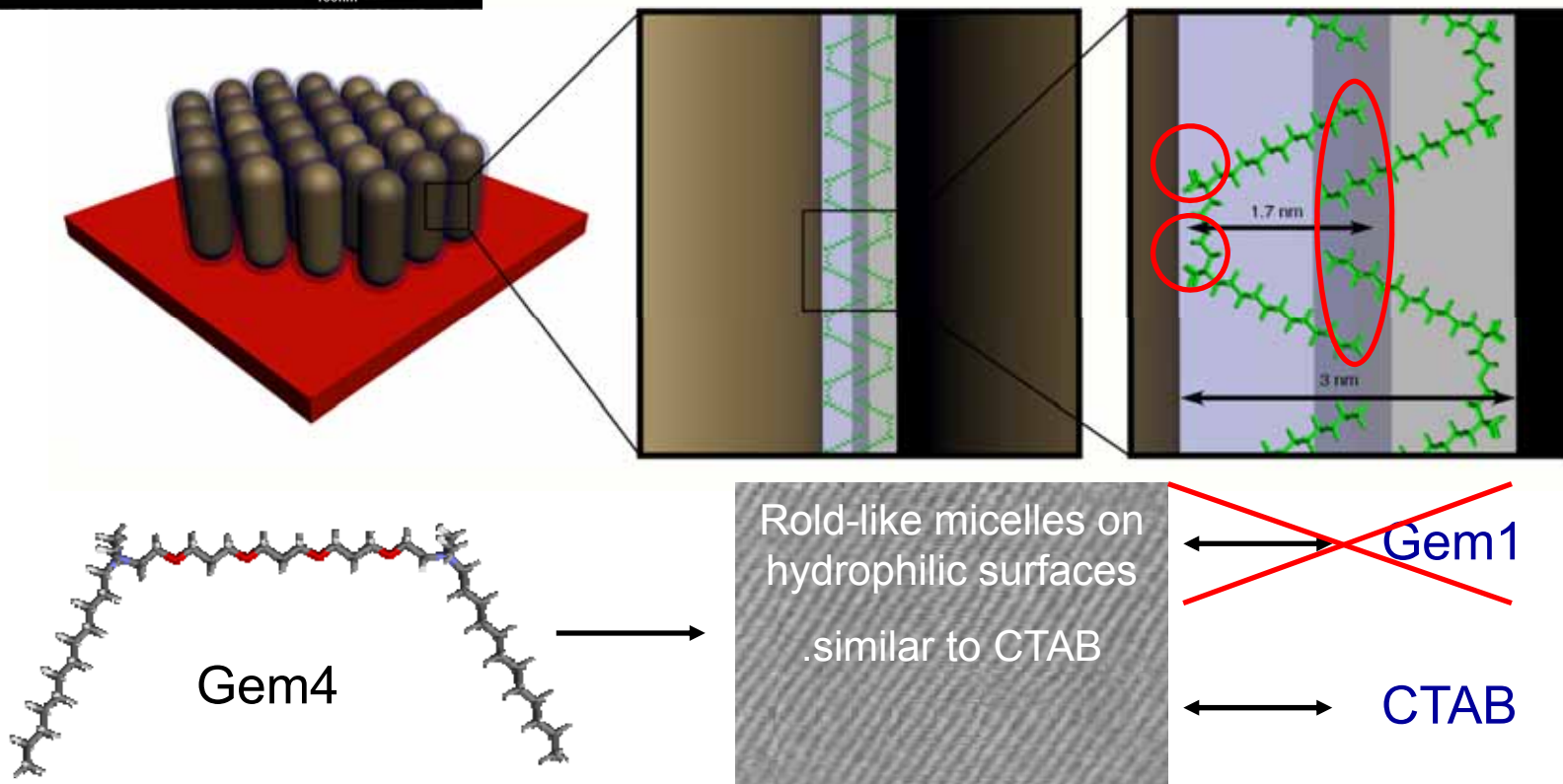
# Au nanorod Self-assembly: mechanism?



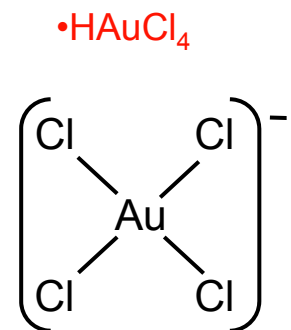
Distance between two neighboring Au centers in the same layer:  
 $14.9 \pm 0.9$  nm

NRs width:  $12 \pm 2$  nm

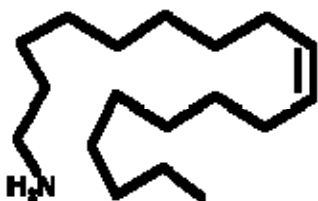
Interparticle distance: 3 nm



# Synthesis of Au Nanowires



• Oleylamine



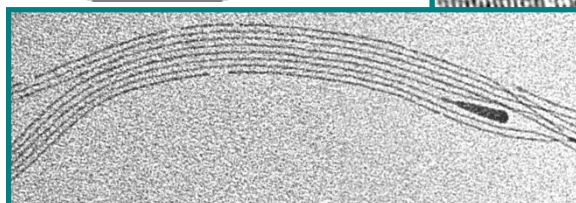
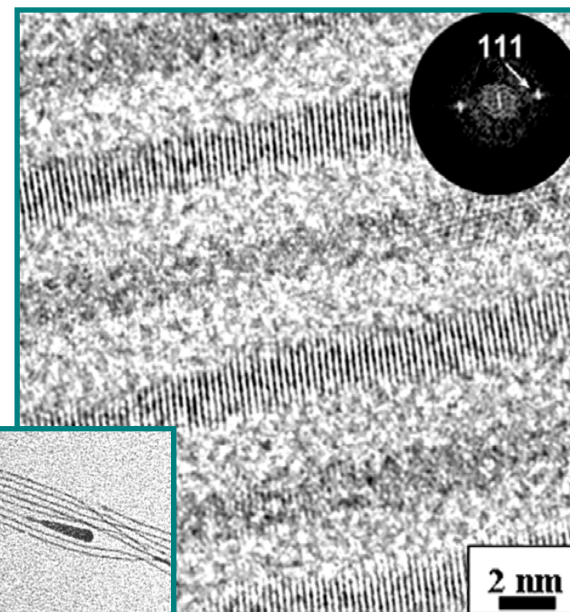
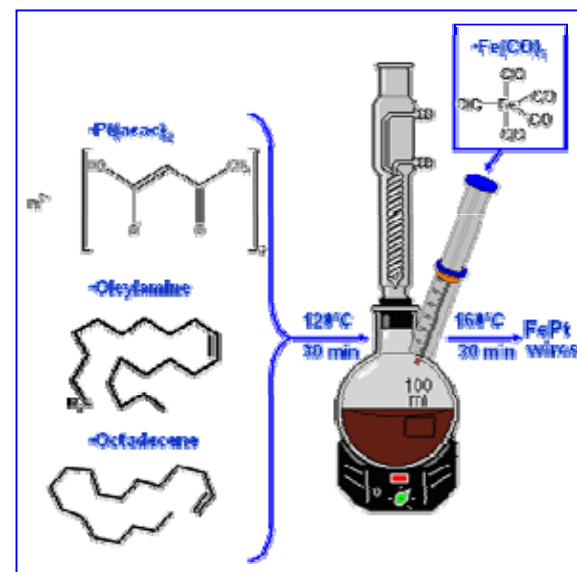
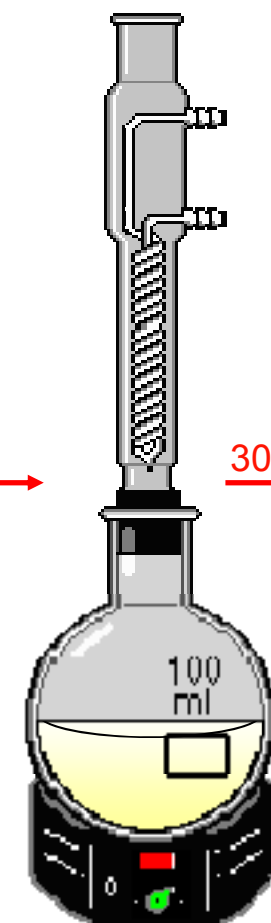
• Solvent

- Octadecene
- Chloroform
- Toluene...

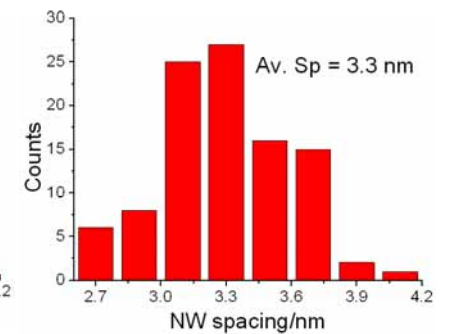
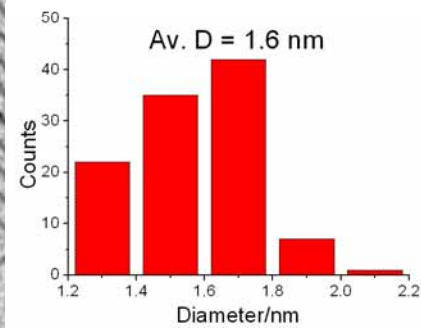
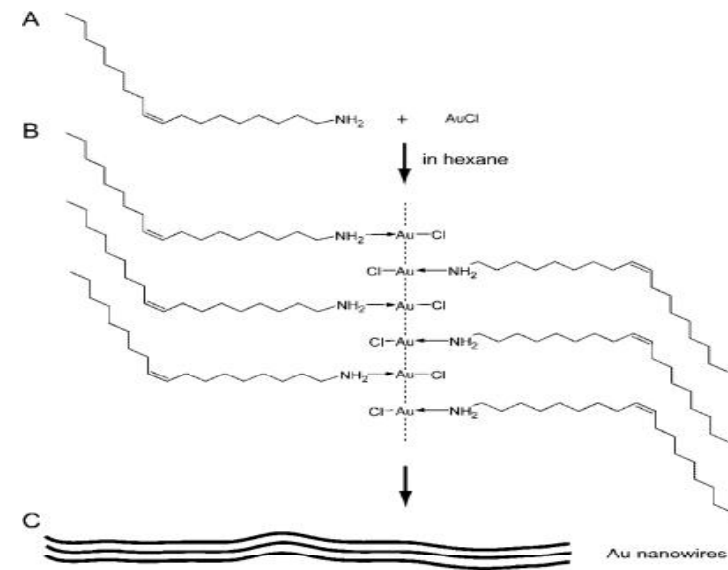
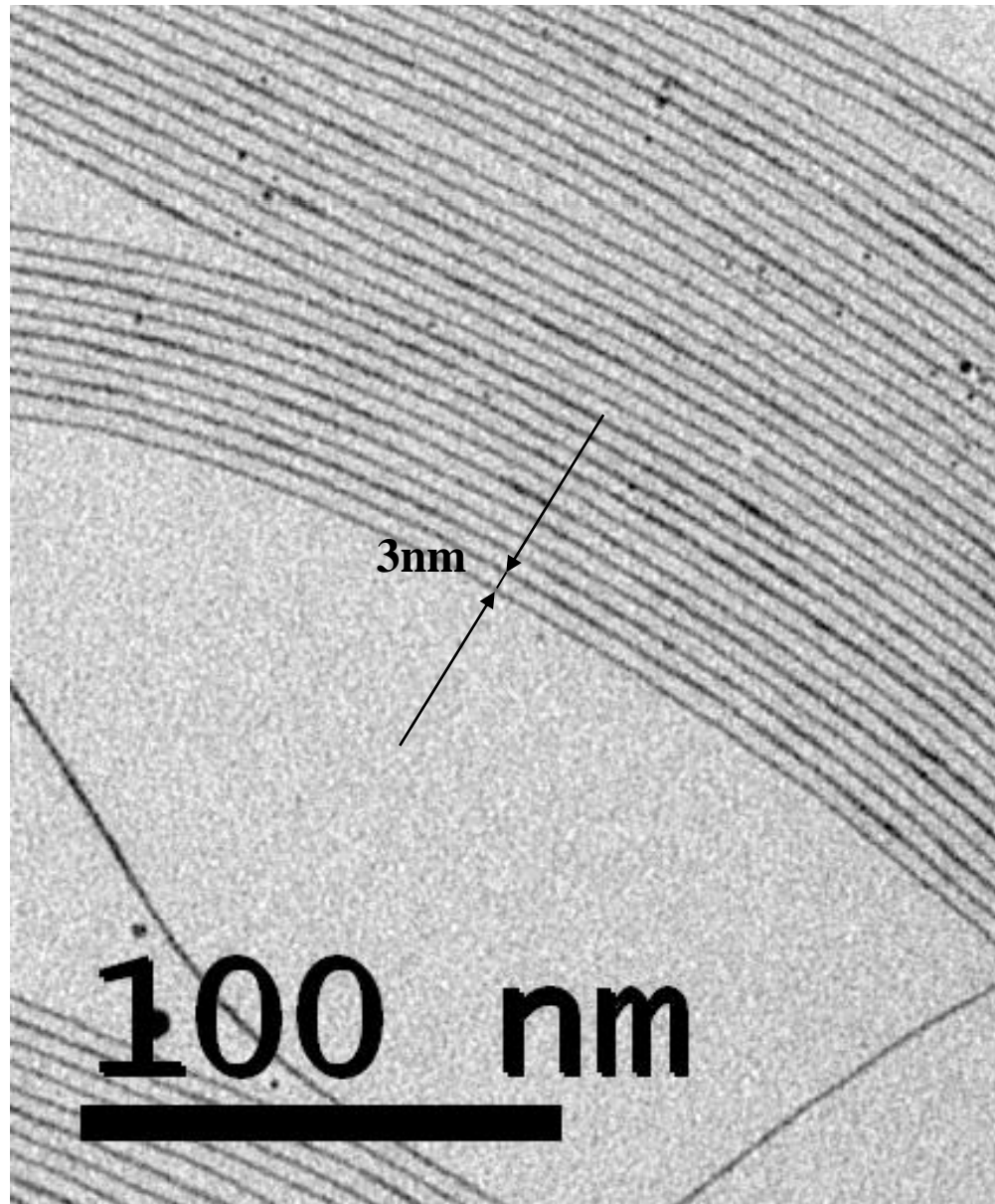
25°C, 24 h

30- 50°C, 5 days

Au (wires)



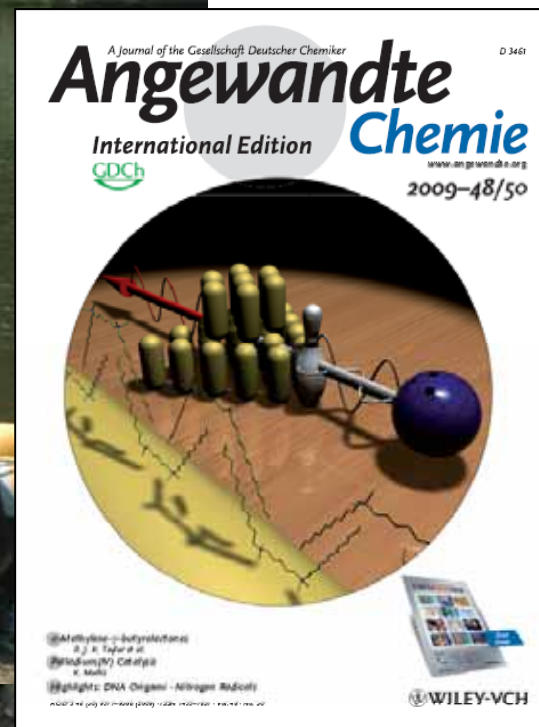
# Self-assembly of Au NWs@oleylamine





U. Melbourne

# THANK YOU!



KU Leuven  
FZ Jülich  
U. Utrecht  
U. Minho  
U. Aveiro  
U. Hamburg  
Bilkent U.  
CNRS  
FORTH  
CSIC  
USC  
U. Almería  
**U. Trieste**



Alexander von Humboldt  
Stiftung/Foundation

