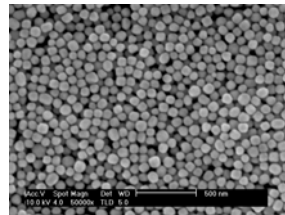
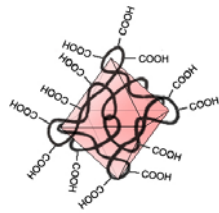


# Gold-Polymer Hybrids: Functionality and Morphology Control



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표준 주기율표  
Periodic Table of the Elements

																		18 (VIII A)	
																		He 헬륨	
																		17 (VII A)	
																		F 플루오린	
																		Ne 네온	
																		16 (VI A)	
																		S 황	
																		Ar 아르곤	
																		15 (V A)	
																		P 인	
																		Kr 크립톤	
																		14 (IV A)	
																		Si 실리콘	
																		Br 브로민	
																		Xe 제논	
																		13 (III A)	
																		Al 알루미늄	
																		I 아이오딘	
																		Rn 라돈	
																		12 (II A)	
																		Mg 마그네슘	
																		Pb 납	
																		11 (I B)	
																		Cu 구리	
																		Ag 은	
																		Au 금	
																		10 (VIII B)	
																		Ni 니켈	
																		Pd 팔라듐	
																		Pt 백금	
																		9 (VIII B)	
																		Co 코발트	
																		Rh 로듐	
																		Ir 아일랜드	
																		8 (VIII B)	
																		Fe 철	
																		Ru 루테튬	
																		Os 오스뮴	
																		7 (VII B)	
																		Mn 망가니즈	
																		Tc 테크네튬	
																		Re 레늄	
																		6 (VI B)	
																		Cr 크로뮴	
																		Mo 몰리브덴	
																		W 텅스텐	
																		5 (V B)	
																		V 바나듐	
																		Nb 나이오븀	
																		Ta 탄탈럼	
																		4 (IV B)	
																		Ti 타이타늄	
																		Zr 지르코늄	
																		Hf 하프늄	
																		3 (III B)	
																		Sc 스칸듐	
																		Y 이트륨	
																		2 (II A)	
																		Be 베릴륨	
																		Ca 칼슘	
																		Sr 스트론튬	
																		Ba 바륨	
																		Ra 라듐	
																		1 (I A)	
																		Li 리튬	
																		Na 나트륨	
																		K 칼륨	
																		Rb 루비듐	
																		Cs 세슘	
																		Fr 프랑슘	
																		0 (Lanthanoid and Actinoid series)	
																		Ce 세륨	
																		Pr 프라세오디뮴	
																		Nd 네오디뮴	
																		Pm 프로메튬	
																		Sm 사마륨	
																		Eu 유로퓸	
																		Gd 가돌리늄	
																		Tb 터븀	
																		Dy 디스프로슘	
																		Ho 홀름	
																		Er 에르븀	
																		Tm 터미늄	
																		Yb ytterbium	
																		Lu 루테튬	
																		Th 토륨	
																		Pa 프로악티늄	
																		U 우라늄	
																		Np 넵투늄	
																		Pu 플루토늄	
																		Am 아메리슘	
																		Cm 퀴륨	
																		Bk 버클륨	
																		Cf 캘리포늄	
																		Es 에스	
																		Fm 페르미움	
																		Md 멘델레븀	
																		Lr 로렌슘	

http://www.kcsnet.or.kr/

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## 재료 (材料, Material)

유기 재료  
(Organic)

저분자 재료  
고분자 재료

무기 재료  
(Inorganic)

금속 재료  
세라믹 재료  
반도체 재료

인공 재료  
(Artificial)

천연 재료  
(Natural)

생체적합재료  
(Bio-Compatible)

Bulk

석기시대 (구석기-신석기)

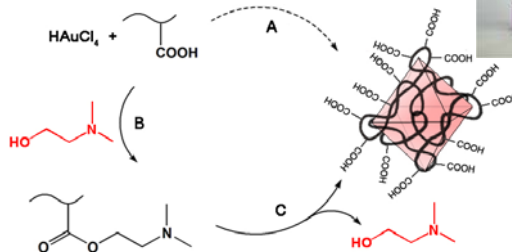
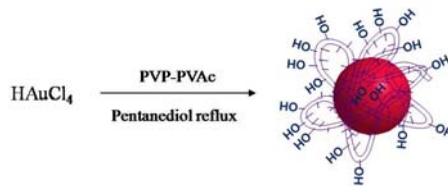
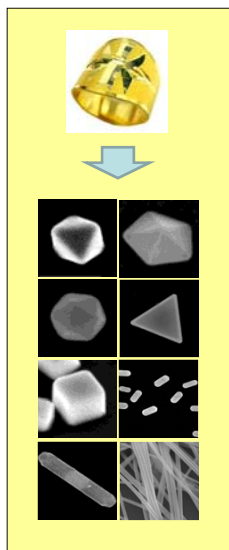
철기시대 (청동기-철기)

합성고분자시대



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## Hybrid Gold Architectures



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# 고분자 (高分子, Polymer)

Natural Polymers

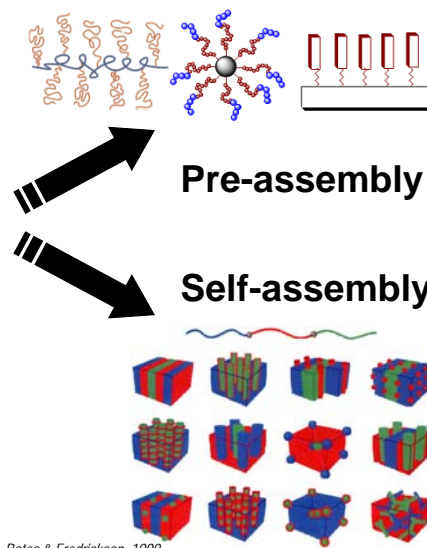
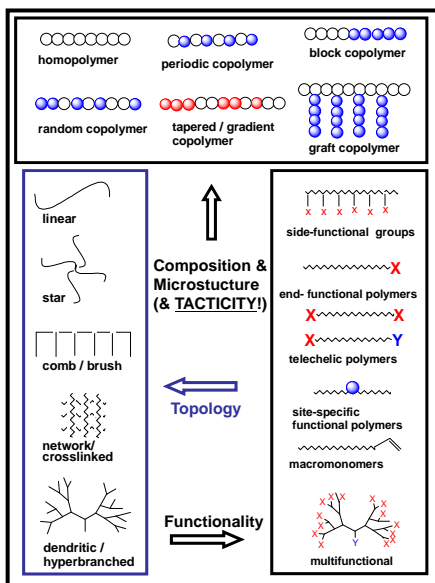
Synthetic Polymers

*Cheap, Light, Tough*

*Property Control via Molecular Structure*

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## (참성) 고분자가 가지는 분자 구조 및 나노 구조



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## 나노 (Nano, 사(沙), 10<sup>-9</sup>)

수	첨두어	기호	수	첨두어	기호
10 <sup>1</sup>	데카	D	10 <sup>-1</sup>	데시	d
10 <sup>2</sup>	헥토	h	10 <sup>-2</sup>	센티	c
10 <sup>3</sup>	킬로	k	10 <sup>-3</sup>	밀리	m
10 <sup>6</sup>	메가	M	10 <sup>-6</sup>	마이크로	μ
10 <sup>9</sup>	기가	G	10 <sup>-9</sup>	나노	n
10 <sup>12</sup>	테라	T	10 <sup>-12</sup>	피코	p
10 <sup>15</sup>	페타	P	10 <sup>-15</sup>	펨토	f
10 <sup>18</sup>	엑사	E	10 <sup>-18</sup>	아토	a
10 <sup>21</sup>	제타	Z	10 <sup>-21</sup>	젱토	z
10 <sup>24</sup>	요타	Y	10 <sup>-24</sup>	옥토	y

크기 (size, m)

Nano

면적 (area, m<sup>2</sup>)

부피 (area, m<sup>3</sup>)

시간 (time, sec)

Femto

찰나 (刹那)  
10<sup>-19</sup>

진동 (frequency, Hz)

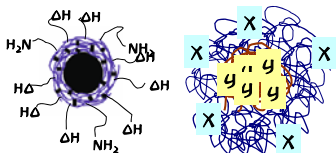
Giga

기억 (memory, Byte)

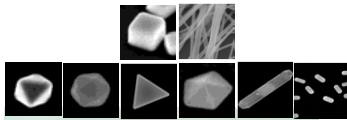
Tera

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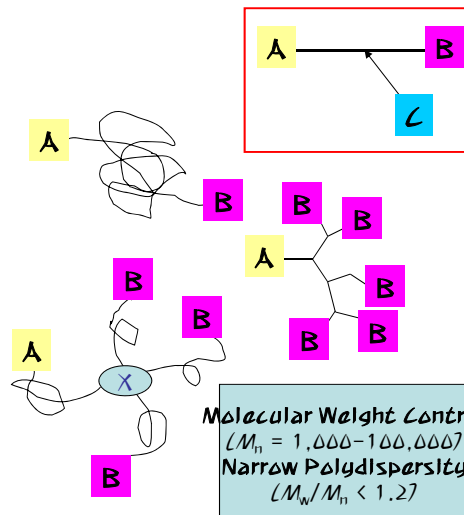
## 연구 개요



생체적합기능성 고분자 나노입자



다기능 금나노결정/고분자 복합체

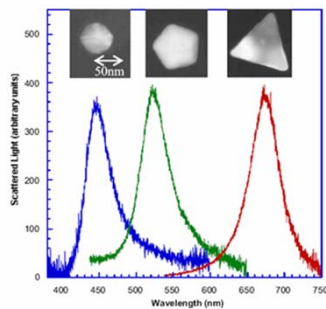


새로운 생체분자 결합용 연결체

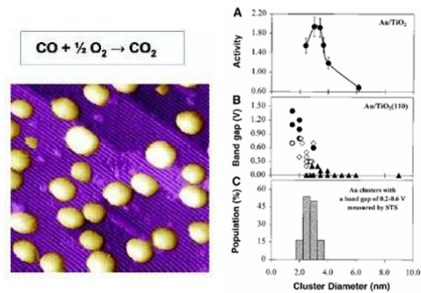
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## Metal Nanocrystals

- **Optical properties** – surface plasmon waveguide, sensors  
surface enhanced Raman spectroscopy (SERS)  
(Ag, Au, Cu)
- **Catalytic properties** – fuel cell, deNO<sub>x</sub>, high performance catalysts,  
(Au, Pt, Pd, Rh)



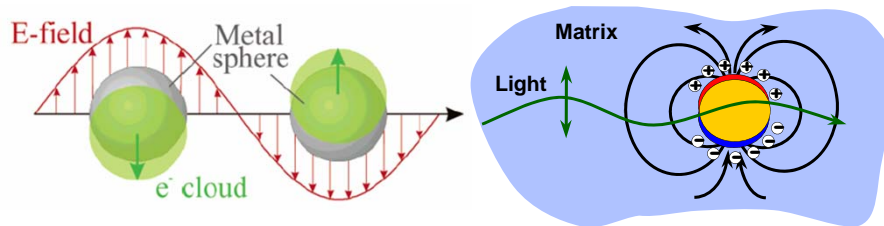
Schultz, S. *et al. J. Chem. Phys.* **2002**, 116, 6755



Goodman, D. W. *et al. Science* **1998**, 281, 1647

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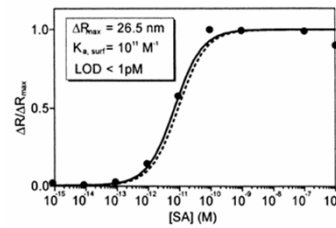
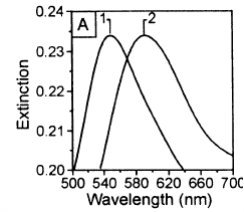
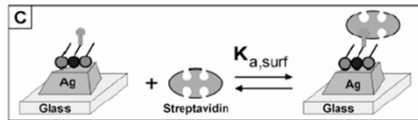
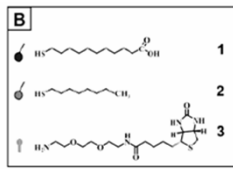
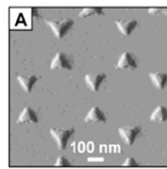
## Vision for Sensing Applications



- **Localized surface plasmons (LSPs)**:  
charge density oscillations confined to  
metallic nanostructures

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## Application: Localized SPR Biosensor

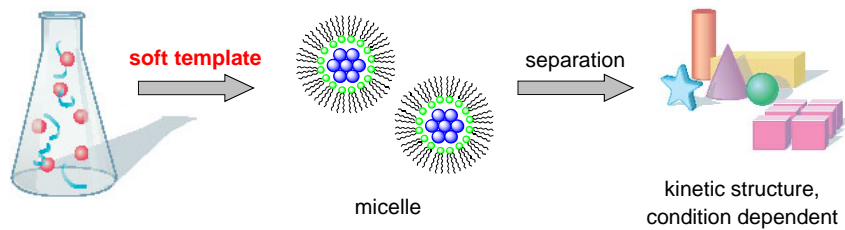


- using biotinylated Ag nanoparticles – streptavidin (SA) interaction
- Ag nanostructures can be used as a biosensing platform.
- simple, small, light, robust, low cost instrumentation

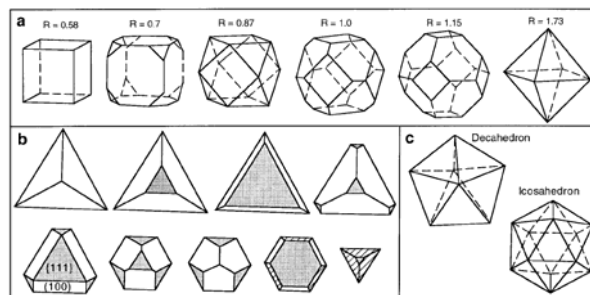
Van Duyne, R. P. *et al. J. Am. Chem. Soc.* **2002**, *124*, 10596.

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## Size and Shape Control

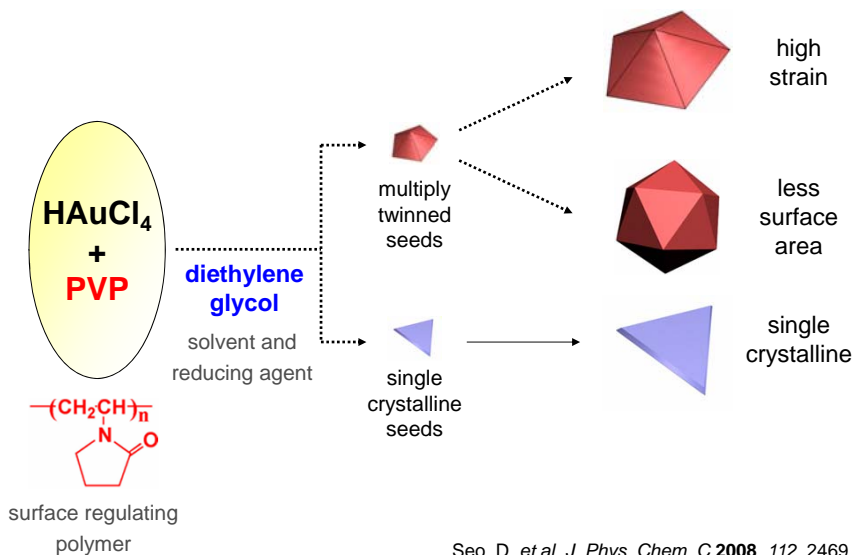


- plausible metal polyhedral structures



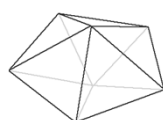
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## Modified Polyol Process with PVP



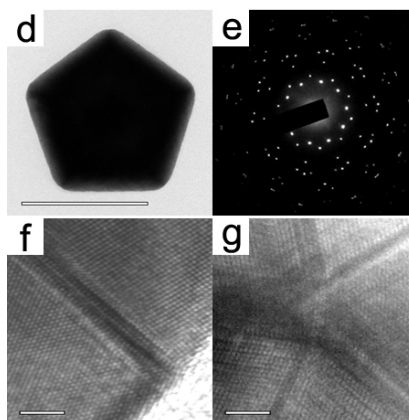
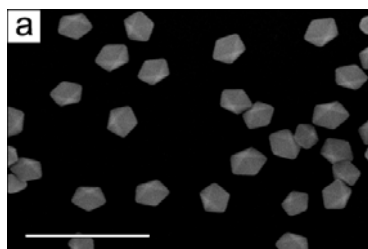
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## Synthesis of Decahedrons



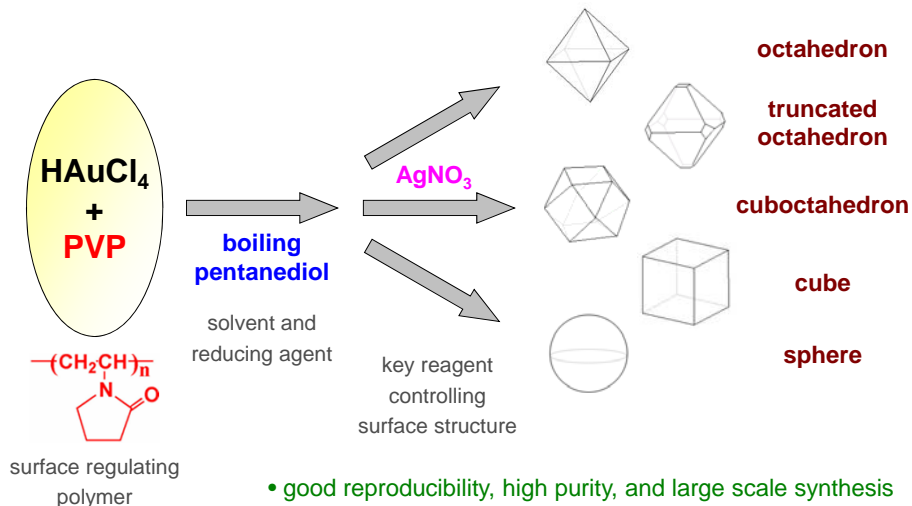
**Decahedron**  
PVP/Au = 360

- in DEG with high PVP concentration (360 ~ 1200 equiv)
- average edge length:  $88 \pm 9$ ,  $67 \pm 8$ , and  $38 \pm 7$  nm



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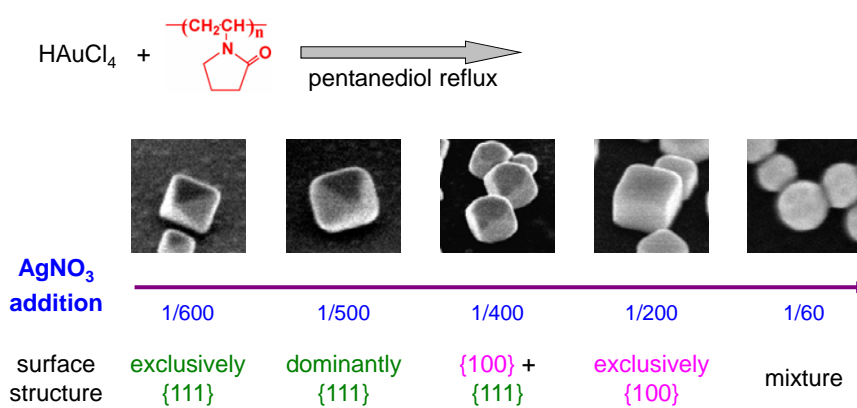
## Modified Polyol Process with AgNO<sub>3</sub>



Seo, D. *et al.* *J. Am. Chem. Soc.* **2006**, 128, 14863

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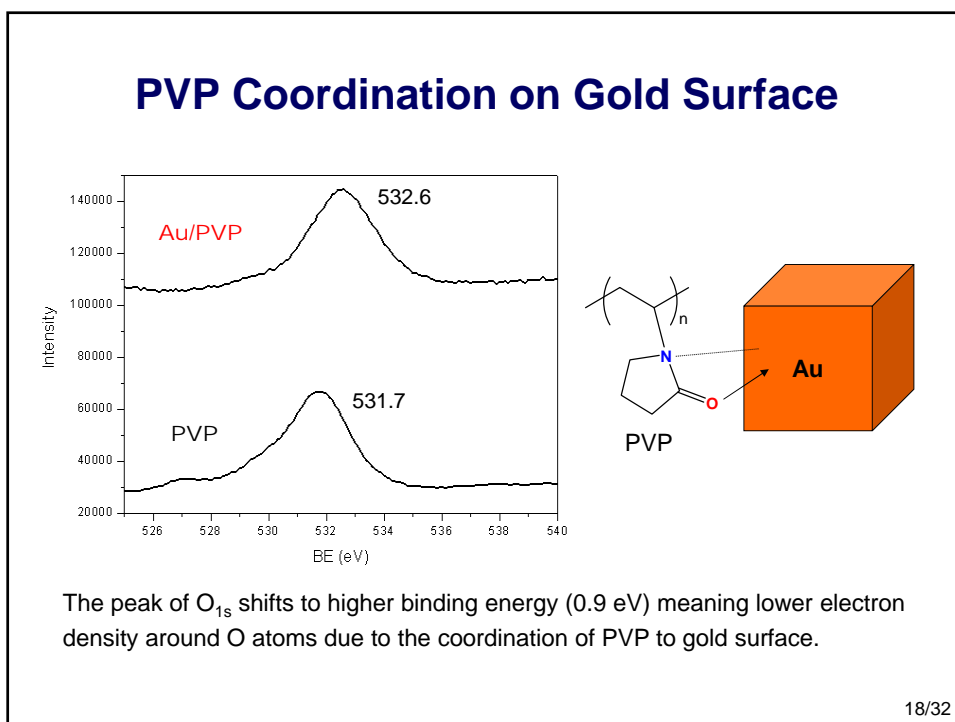
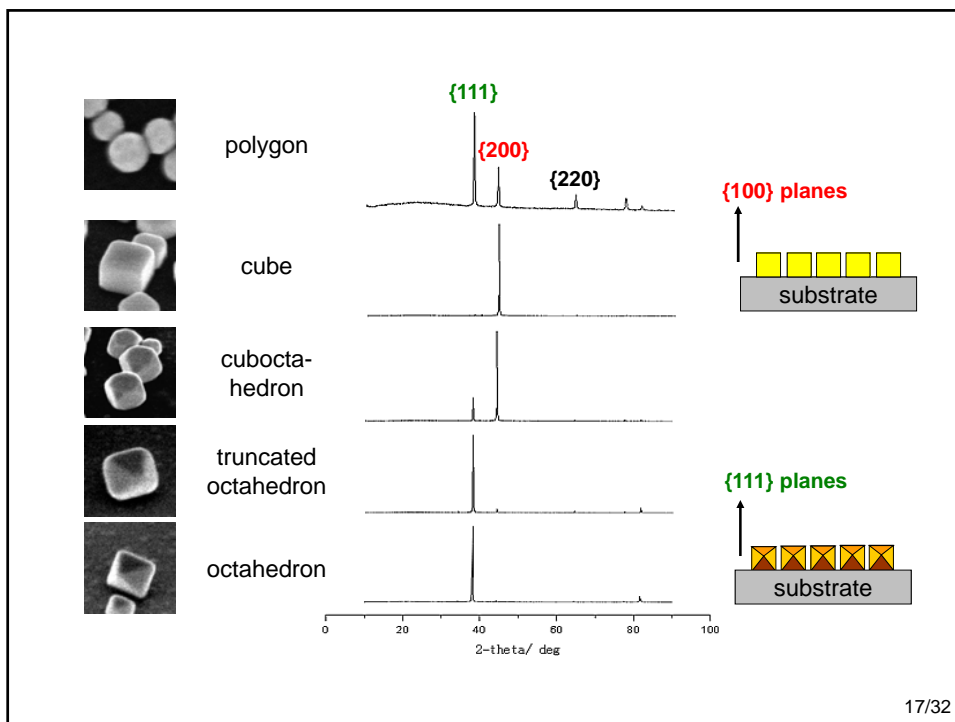
## Gold Polyhedral Structures



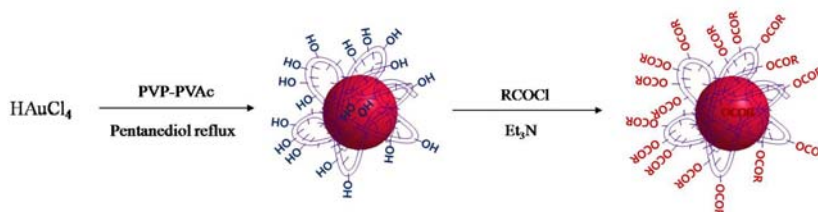
**Ag ions enhance isotropic growth along <111> direction and/or suppress along <100> → Preferential Ag underpotential deposition on {100}**

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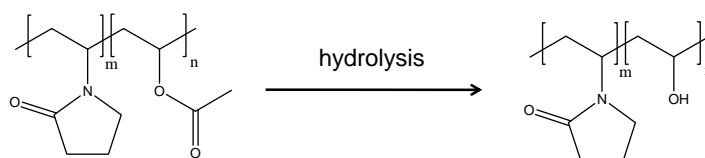




## Hydroxyl-Functionalized Gold Nanocrystals by Copolymers



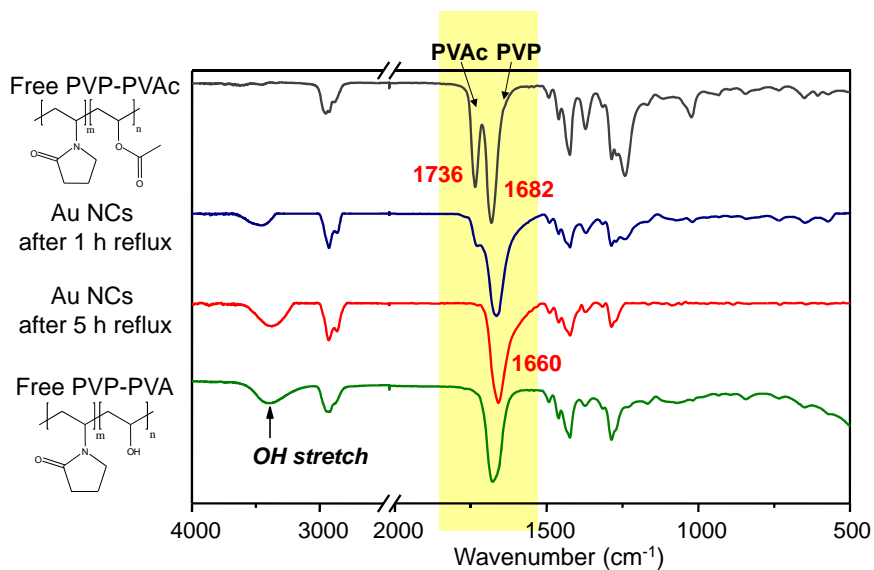
A facile one-pot synthesis of hydroxyl functionalized Au nanocrystals



Yoo, C. I. et al. *Chem. Mater.* **2009**, ASAP

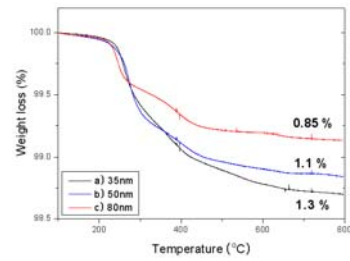
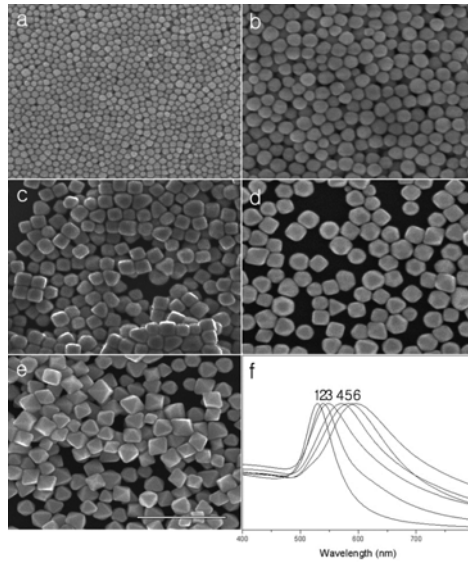
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## Conversion of PVP-PVAc-Coated Gold NCs



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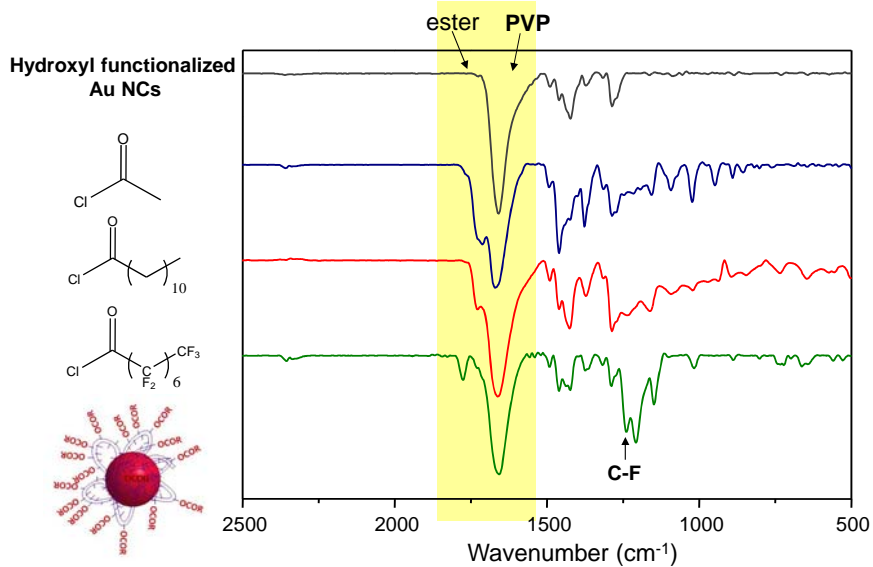
## Hydroxyl-Functionalized Gold NCs



$1.3 \times 10^{-17}$  g polymers (1.0%),  
 $3.7 \times 10^4$  hydroxyl groups  
 per PVP-PVA-coated  
 gold nanoparticles

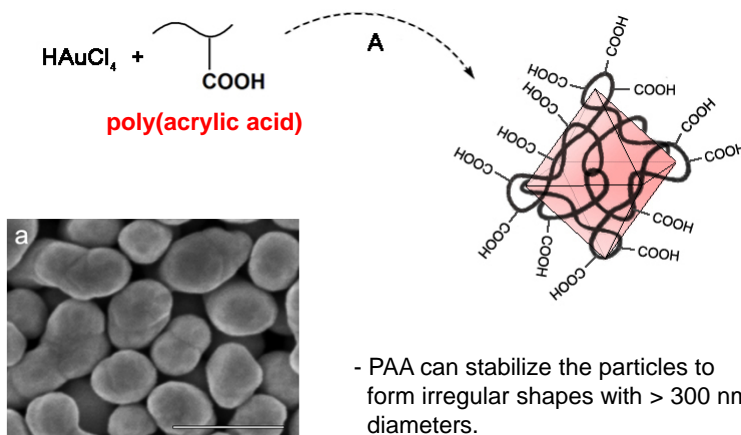
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## Esterification of Gold NCs



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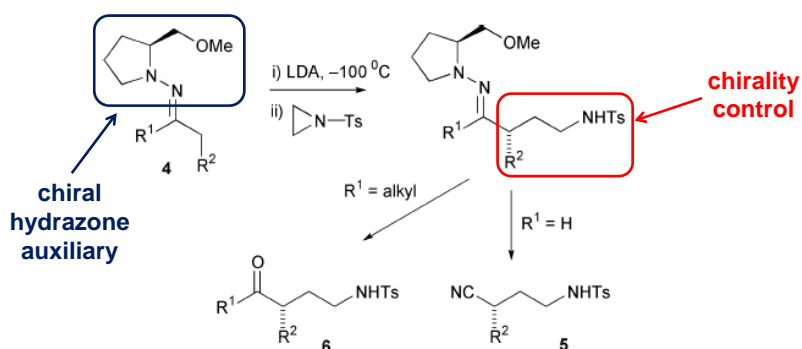
## Unsuccessful Shape Control Using PAA



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## Shape Auxiliary Approach

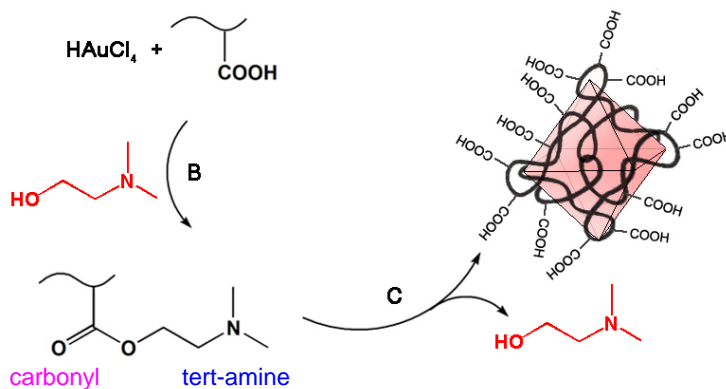
**Chiral auxiliary:** a chemical compound or unit that is temporarily incorporated into an organic synthesis so that it can be carried out asymmetrically with the selective formation of one of two enantiomers



Jones, S. *J. Chem. Soc., Perkin Trans. 1* **2002**, 1

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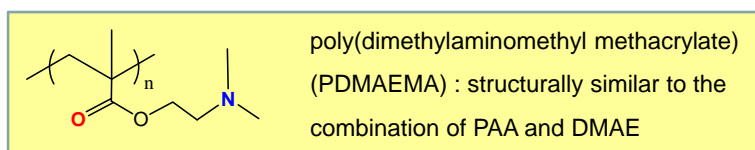
## Introduction of Shape Auxiliary



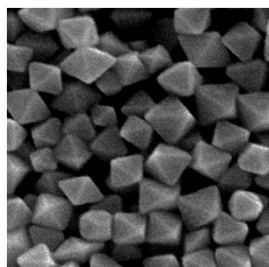
- 2-(Dimethylamino)ethanol can dangle on the side chain of PAA through esterification.

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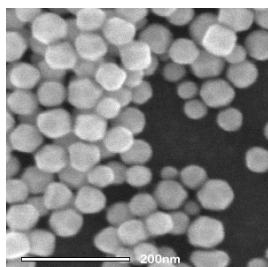
## PDMAEMA as a Surface Regulating Polymer



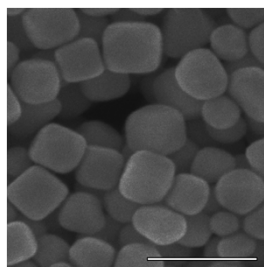
gold octahedrons



cubeoctahedrons

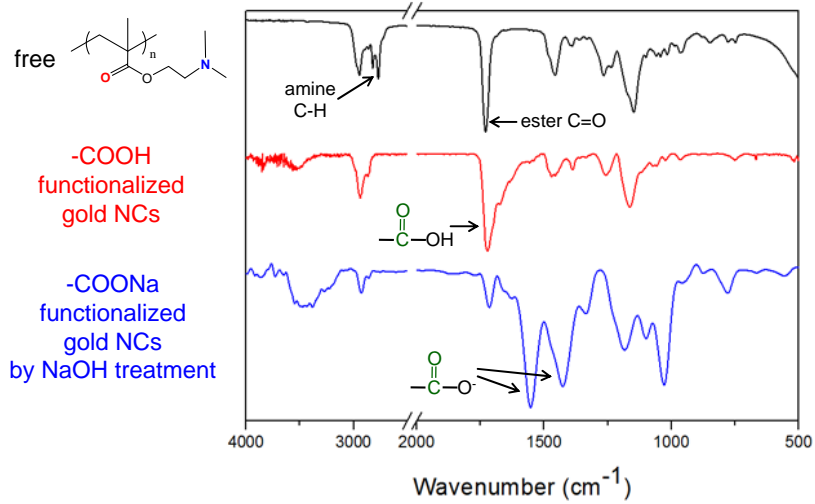


cubes



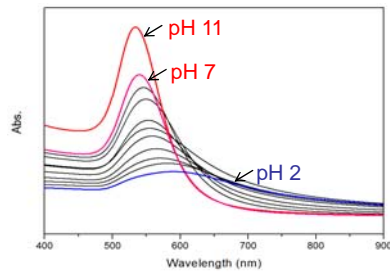
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## Carboxylate-Functionalized Gold Nanocrystals

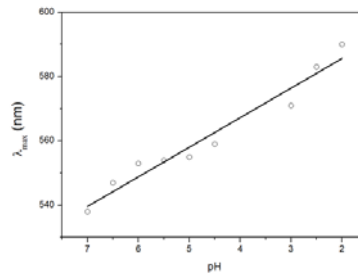


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## pH-Dependent Assembly / Disassembly

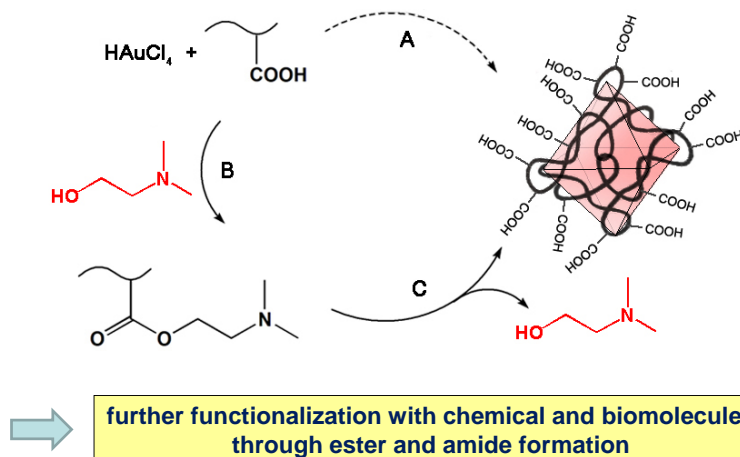


- A **pH-induced assembly/disassembly** process occurs in the carboxylate-functionalized gold nanocrystals.
- A **linear relation** between pH and the extinction peak maximum is observed.



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## Shape Auxiliary Approach for Carboxylate-Functionalized Gold Polyhedrons



Seo, D. *et al. Chem. Commun.* **2009**, *Advanced Article*

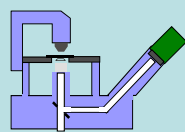
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## Topics for Surface Plasmon Sensors

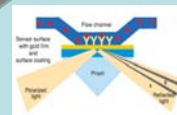
Morphology Control



Single Particle Optics



Surface Functionalization

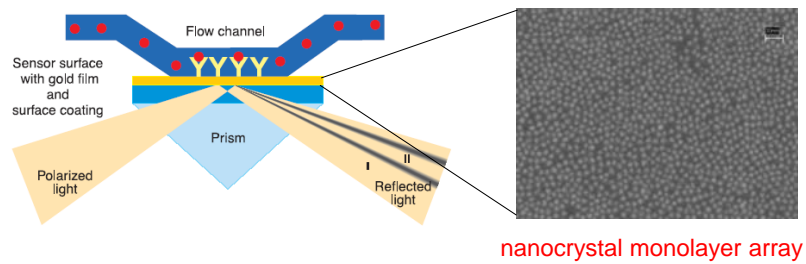


Integration

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## Application for SPR Sensors


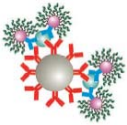
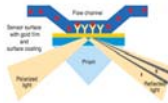
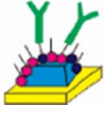
- LSPR sensor employing nanocrystal arrays



- gold nanocrystal monolayer array as a sensing scaffold
- high sensitivity and fast response will be desired.

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## Comparison with Other Biosensors

	Conventional assays	Bio-Barcodes	SPR	LSPR
				
Sensitivity	low (~pM)	very high (~aM)	low (~nM)	very high (< aM)
Labels	required	required	free	free
Speed	very slow	slow	real time	real time
Identification	no	no	Raman	SERS X-ray, IR

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