

# Size and Zeta Potential of Colloidal Gold Particles

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# Colloid Definition

Two phases:

- **Dispersed phase** (particles)
- **Continuous phase** (dispersion medium, solvent)

May be solid, liquid, or gaseous

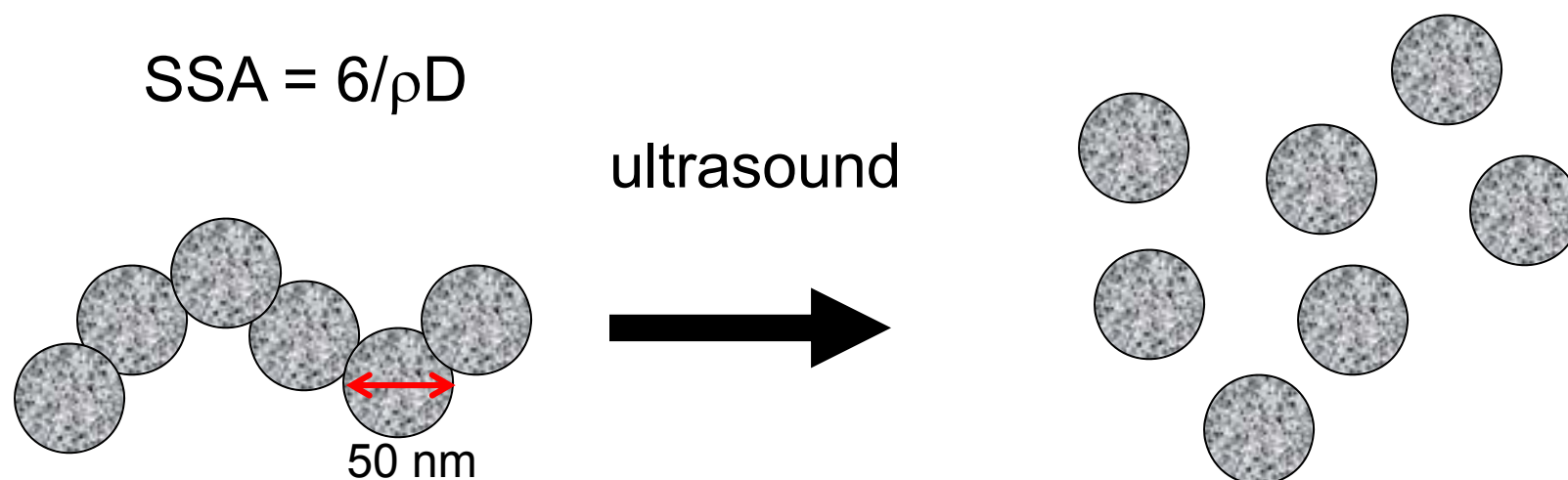
Size range 1 nm – 1 micron

High surface area creates unique properties

		Dispersed Medium		
		Gas	Liquid	Solid
Continuous Medium	Gas	<b>NONE</b> (All gases are mutually miscible)	<b>Liquid Aerosol</b> Examples: fog, mist, clouds	<b>Solid Aerosol</b> Examples: smoke, air particulates
	Liquid	<b>Foam</b> Examples: whipped cream	<b>Emulsion</b> Examples: milk, mayonnaise, hand cream	<b>Sol</b> (suspension) Examples: paint, pigmented ink
	Solid	<b>Solid Foam</b> Examples: aerogel, styrofoam, pumice	<b>Gel</b> Examples: gelatin, jelly, cheese, opal	<b>Solid Sol</b> Examples: cranberry glass, ruby glass

# Nanoparticle Definition

Nanoparticle: size below 100 nm



D from SEM ~50 nm  
D from SSA ~60-70 nm  
D from DLS ~250 nm  
So: is this a nanoparticle?

Used ultrasound to disperse  
to primary particles or use  
weak acid to break bonds  
D from DLS ~50 nm

# SZ-100: Nanoparticle Analyzer

- Size: .3 nm - 8  $\mu$ m
  - 90° and 173°
- Zeta potential: -200 - +200 mV
  - Patented carbon coated electrodes
- Molecular weight:  $1 \times 10^3$  -  $2 \times 10^7$  g/mol
- Optional titrator

- Nanoparticles
- Colloids
- Proteins
- Emulsions
- Dispersions stability

nano **partica**  
SZ-100 series



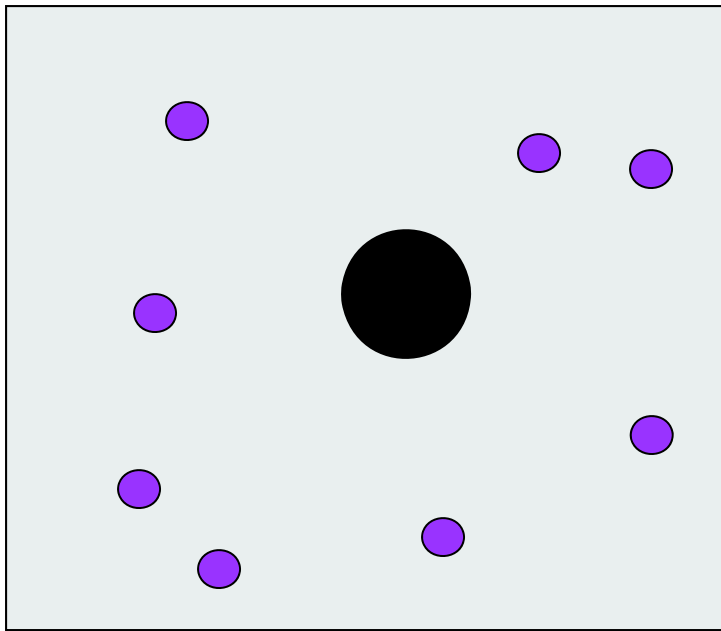
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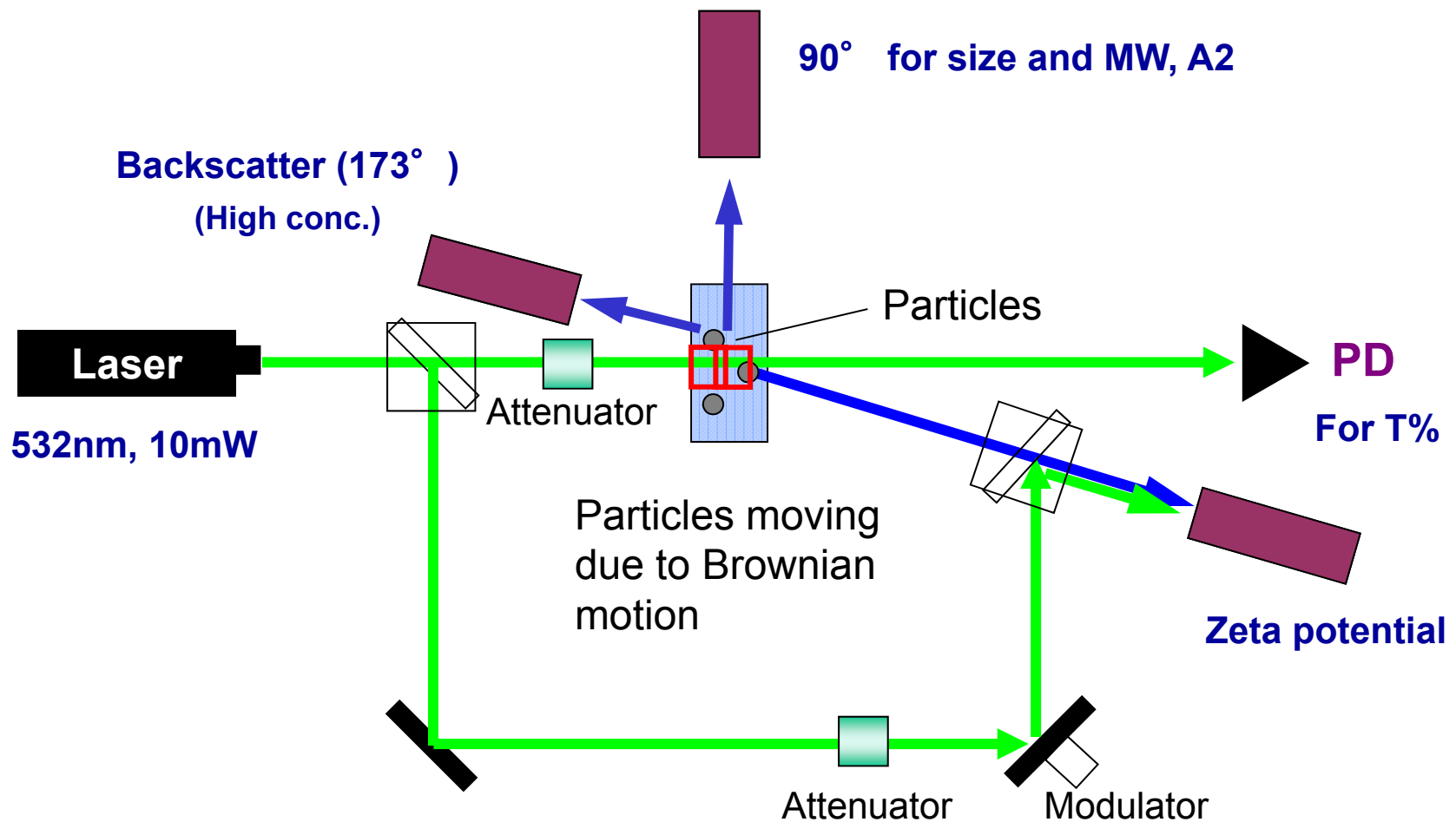
# Dynamic Light Scattering

Particles in suspension undergo **Brownian motion** due to solvent molecule bombardment in random thermal motion.  $\sim 1 \text{ nm}$  to  $1 \text{ }\mu\text{m}$

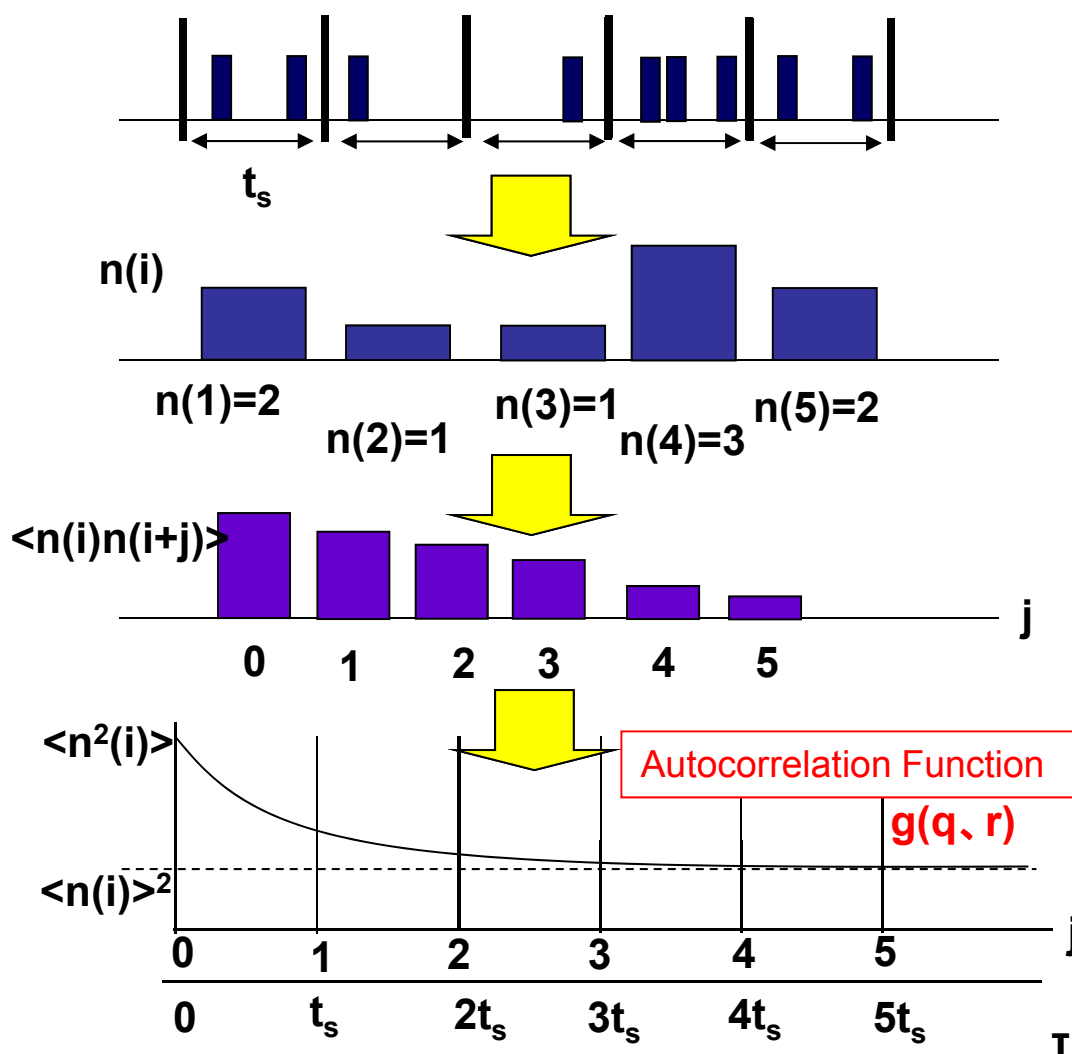


Particle moves due to interaction  
with liquid molecules  
Small – faster  
Large - slower

# SZ-100 Optics



# SZ100 Measurement Principle



$$\frac{1}{\tau_R} = -\lim_{\tau \rightarrow 0} \left\{ \frac{\partial \ln[g(q, r)]}{\partial \tau} \right\}$$

Relaxation time

$$\langle |\gamma(t) - \gamma(t + \tau)|^2 \rangle \cong 6D\tau$$

Particle's moving distance

Diffusion constant

$$D = \frac{1}{q^2 \tau_R} = \frac{k_B T}{6\pi\eta a}$$

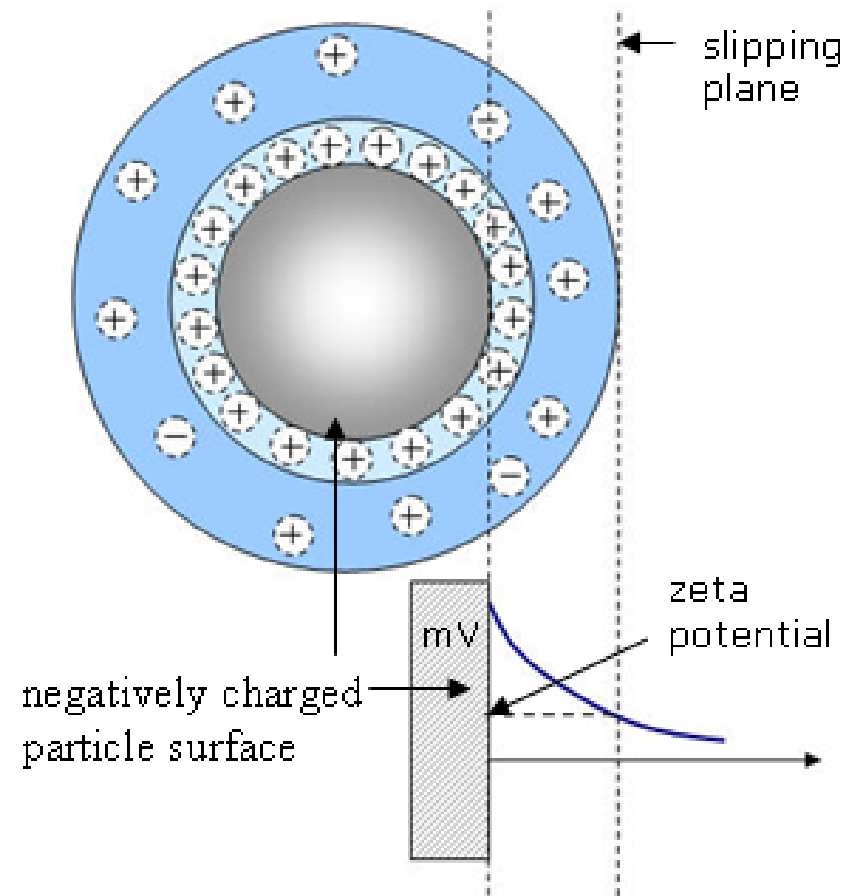
Relaxation time

Particle radius

$q$ : Scattering vector  $\eta$ : Viscosity  
 $k_B$ : Boltzmann constant

# Zeta Potential

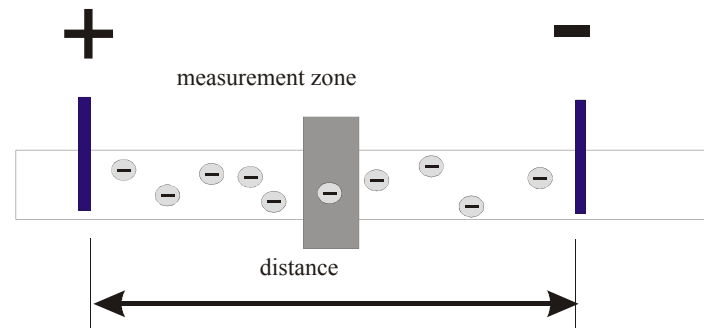
- If surface has + charge, then - ions attracted to surface
- + ions attracted to - ions, builds electric double layer
- Slipping plane: distance from particle surface where ions move with particle
- ZP = potential (mV) at slipping plane



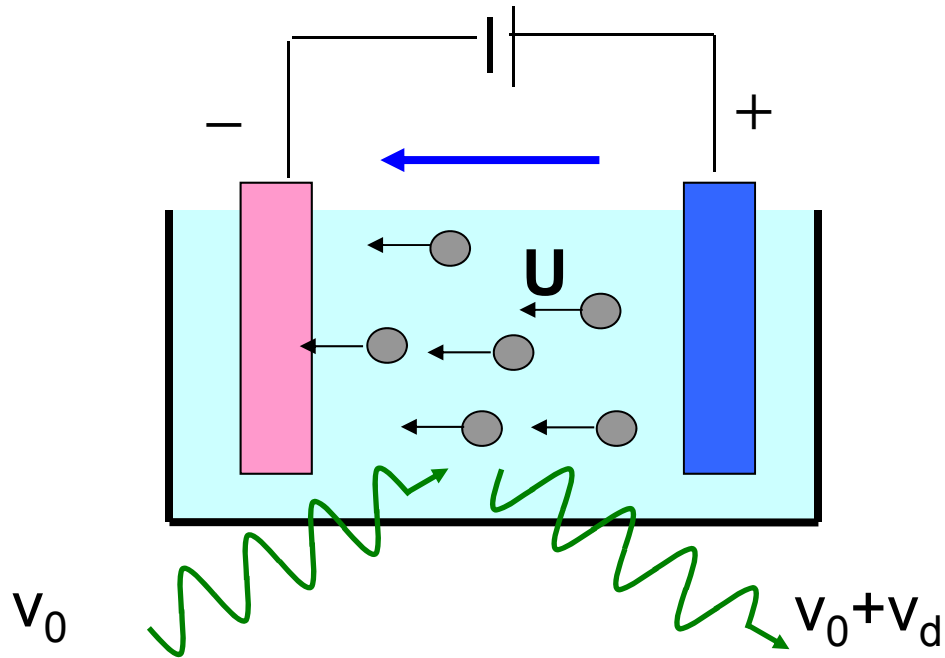


# Zeta Potential: Measurement

- Apply electric field
- Measure particle motion
- Direction tells + or –
  - + particles move to –
  - - particles move to +
- Speed tells amplitude
  - Get speed from frequency shift from motion of particles



# Zeta Potential Measurement



Particle motion causes Doppler shift  
Frequency  $\rightarrow$  mobility  
Mobility  $\rightarrow$  zeta potential

## Mobility

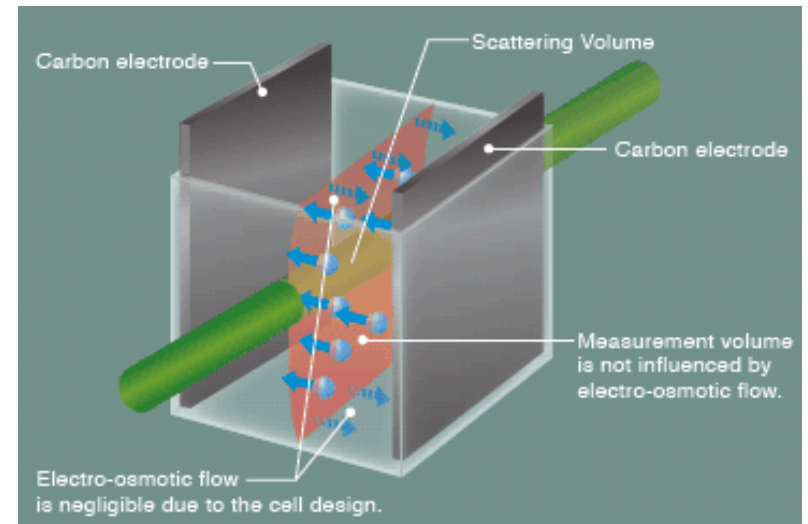
$$U = \frac{\lambda \Delta \nu_d}{2En \sin(\theta/2)}$$

## Zeta potential

$$\zeta = \frac{3U \cdot \eta}{2\varepsilon \cdot f(ka)}$$

# Measurement Details

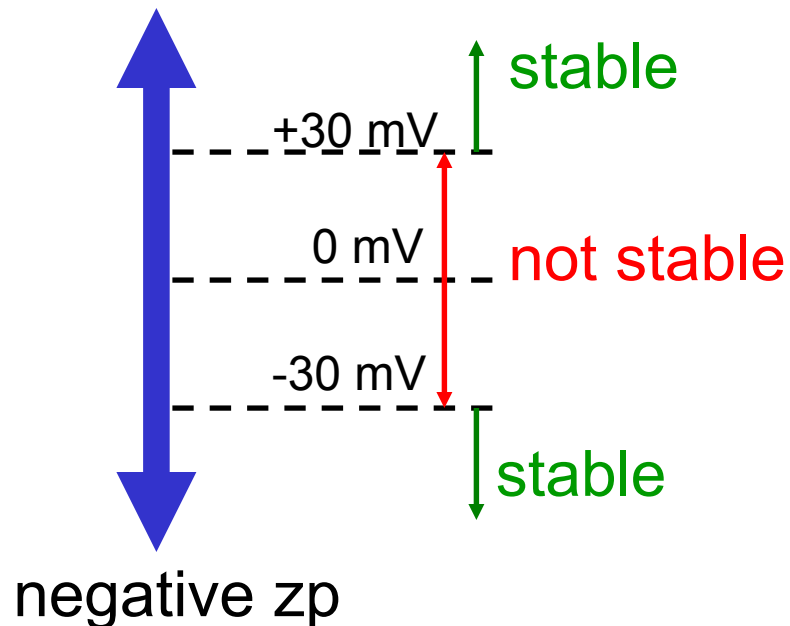
- First measure conductivity
- Then decide applied electric field
  - Auto or manually
- Reverse electric field to avoid polarization & electroosmosis
- To avoid electroosmotic effect near cell walls
  - “Uzgiris” type cells avoid this problem



# Zeta Potential Predicts Stability

## Different guidelines

positive zp



## Sample Dependency

- Oil/water emulsions > 10 mV
- Polymer latices > 15 mV
- Oxides > 30 mV
- Metal sols > 40 mV

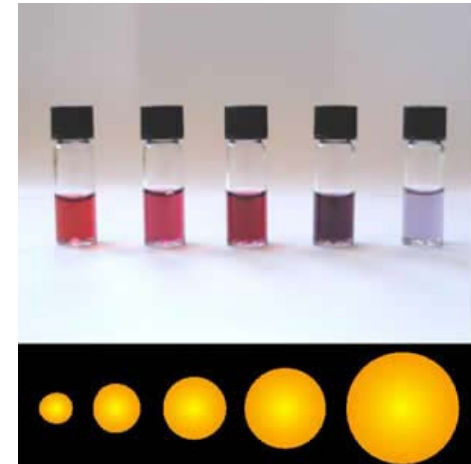
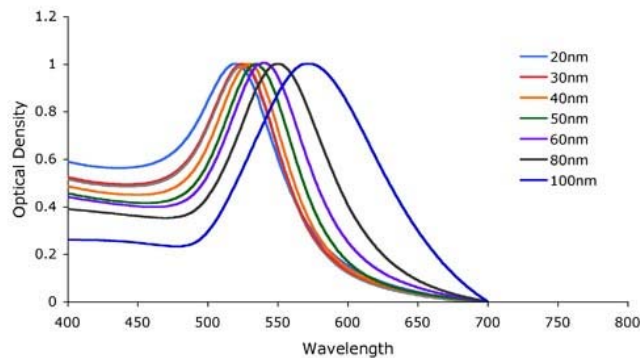
# Colloidal Gold: Not so New

- Lycurgus cup 4<sup>th</sup> century AD
- Faraday experiments in 1857  
“Experimental relations of gold (and other metals) to light”
- Mie in 1908 “Contributions on the optics of turbid media, particularly colloidal metal solutions”

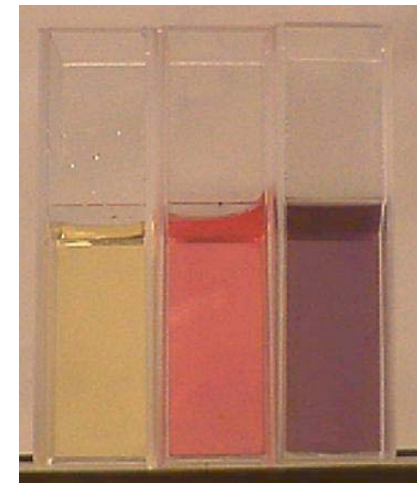


# Applications: Colloidal Gold

- Some properties change with size\*
- Electronics
- Sensors
- Probes
- Diagnostics
- Drug Delivery
- Catalysis



Red  Blue

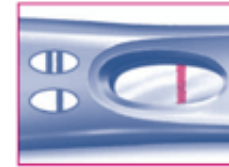


\*graph from to Cytodiagnostics.com

# Gold Nanoparticles In Use

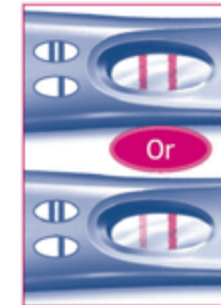
- Pregnant women have excess of hormone HcG\*
- HcG binds to complementary DNA base pair sequence
- That lock for HcG key is attached to gold nanoparticles
- Those gold nanoparticles reflect light of specific color
- If HcG detected: line reflects red

**NOT PREGNANT  
ONE PINK LINE**



One pink line in the results window

**PREGNANT  
TWO PINK LINES**



Two pink lines in the results window

One may be lighter than the other

Appearance of the result may vary

\*human gonadotropic hormone

# Gold Nanoparticle Standards

## ● Nano-materials; Gold colloid

Au Colloid	RM8011(10 nm), 8012(30 nm), 8013 (60 nm)
Hydrodynamic Dia.	13.5 nm, 32.4 nm, 58.4 nm

### Conditions

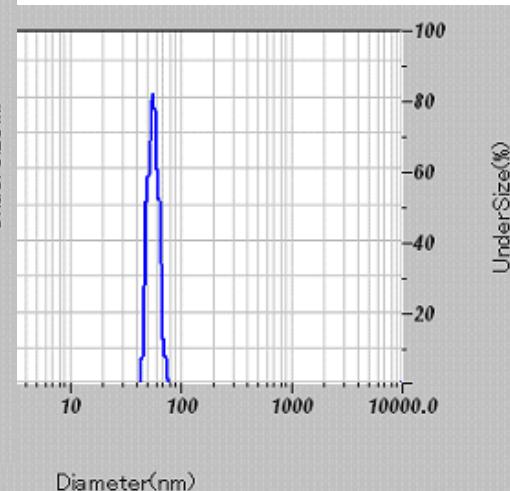
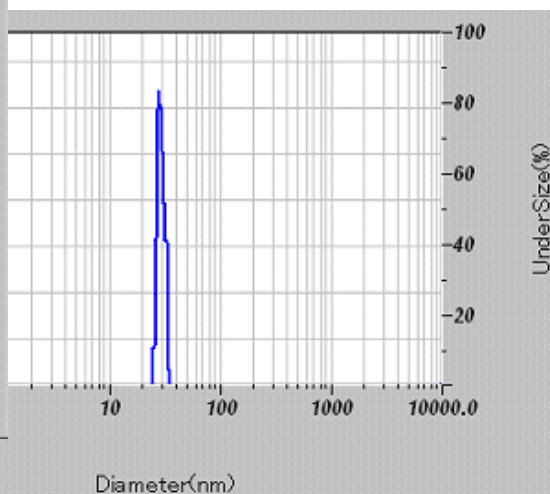
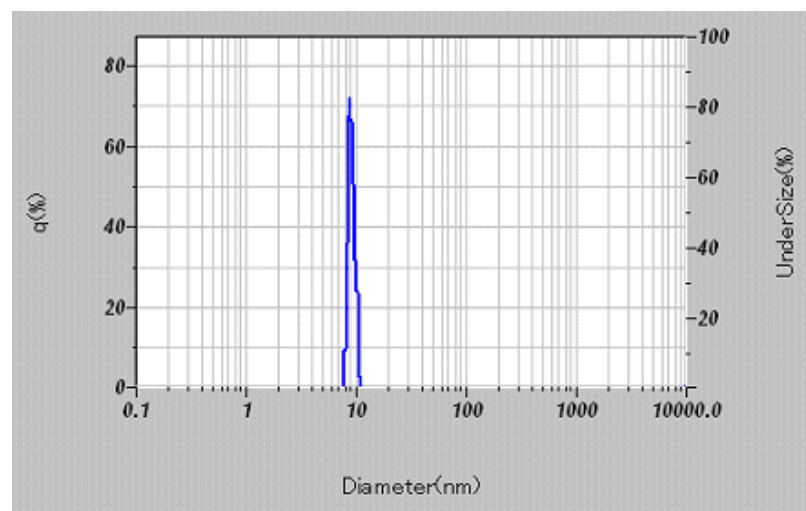
Temperature; 25 C degree

Solvent; Water

Refractive Index; 1.333

Distribution base; Scattering light

	Z ave. (nm)
RM8011	13.0
RM8012	32.0
RM8013	58.0





# NIST Gold Nanoparticle RMs

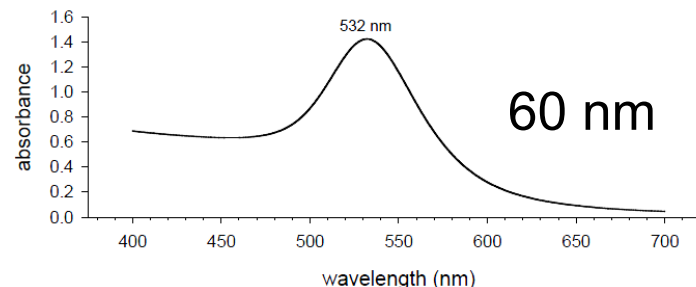
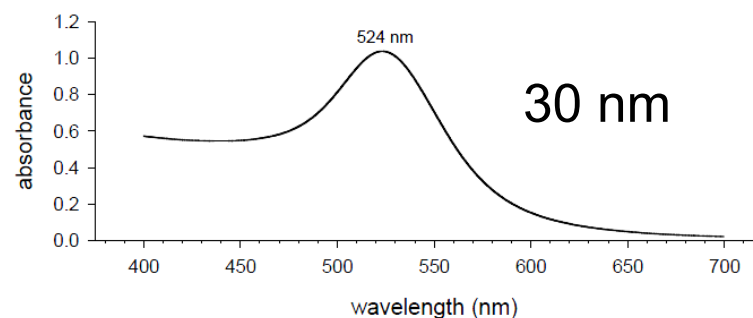
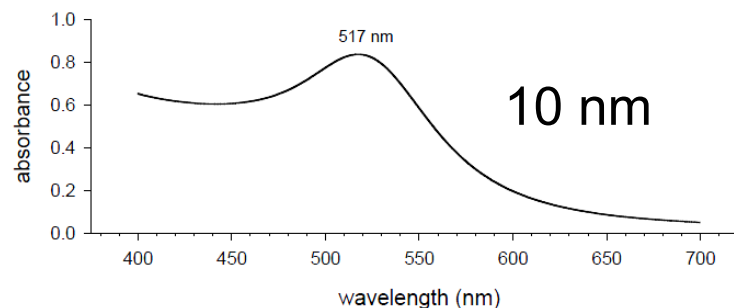


National Institute of Standards & Technology

## Report of Investigation

Reference Material 8011

Gold Nanoparticles, Nominal 10 nm Diameter

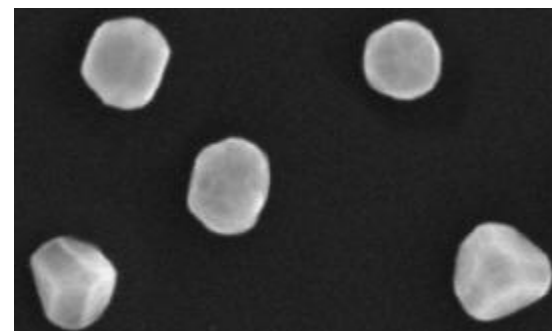


Technique	Analyte Form	Particle Size (nm)	
Atomic Force Microscopy	dry, deposited on substrate	8.5	$\pm 0.3$
Scanning Electron Microscopy	dry, deposited on substrate	9.9	$\pm 0.1$
Transmission Electron Microscopy	dry, deposited on substrate	8.9	$\pm 0.1$
Differential Mobility Analysis	dry, aerosol	11.3	$\pm 0.1$
Dynamic Light Scattering	liquid suspension	13.5	$\pm 0.1$
Small-Angle X-ray Scattering	liquid suspension	9.1	$\pm 1.8$

# ASTM Interlaboratory Study RM 8011

Material	Average <sup>1</sup>	Standard Deviation of the lab averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit	Number of Reporting Laboratories
	$\bar{x}$	$s_{\bar{x}}$	$s_r$	$s_R$	$r$	$R$	$n$
Sample A-combined	15.8	4.2	2.0	4.7	5.7	13.1	13
Sample B-combined	31.2	3.6	2.0	4.1	5.7	11.5	13
Sample C-combined	59.8	5.0	5.0	6.8	13.9	19.2	13
Sample D-combined	8.0	2.4	0.9	2.6	2.6	7.2	12
Sample E-combined	6.7	1.8	0.9	2.0	2.6	5.6	12

# NIST Colloidal Gold



## NIST Certificates

Technique	Size nm
Atomic Force Microscopy	8.5 ± 0.3
Scanning Electron Microscopy	9.9 ± 0.1
Transmission Electron Microscopy	8.9 ± 0.1
Differential Mobility Analysis	11.3 ± 0.1
Dynamic Light Scattering	13.5 ± 0.1
Small-Angle X-ray Scattering	9.1 ± 1.8

Technique	Size nm
Atomic Force Microscopy	24.9 ± 1.1
Scanning Electron Microscopy	26.9 ± 0.1
Transmission Electron Microscopy	27.6 ± 2.1
Differential Mobility Analysis	28.4 ± 1.1
Dynamic Light Scattering	
173° scattering angle	28.6 ± 0.9
90° scattering angle	26.5 ± 3.6
Small-Angle X-ray Scattering	24.9 ± 1.2

Technique	Size nm
Atomic Force Microscopy	55.4 ± 0.3
Scanning Electron Microscopy	54.9 ± 0.4
Transmission Electron Microscopy	56.0 ± 0.5
Differential Mobility Analysis	56.3 ± 1.5
Dynamic Light Scattering	
173° scattering angle	56.6 ± 1.4
90° scattering angle	55.3 ± 8.3
Small-Angle X-ray Scattering	53.2 ± 5.3

## SZ-100 Results

8011		
HORIBA	<b>Average</b>	<b>St dev</b>
Sample 1	13.4 nm	1,8
Sample 2	12.6nm	1,9
<b>ASTM</b>	<b>Z ave</b>	<b>st dev</b>
Combined	15.8 nm	4,2

8012		
HORIBA	<b>Average</b>	<b>St dev</b>
Sample 1	31.5nm	3,9
Sample 2	32.4 nm	5,9
<b>ASTM</b>	<b>Z ave</b>	<b>st dev</b>
Combined	31.2 nm	3,6

8013		
HORIBA	<b>Average</b>	<b>St dev</b>
Sample 1	57.6 nm	3,5
Sample 2	58.4 nm	3,9
<b>ASTM</b>	<b>Z ave</b>	<b>st dev</b>
Combined	59.8 nm	5,0

# Colloidal Gold, Real World Data\*

**Summary Table**  
**(Three Measurements of Each Sample)**

	Sample ID	Zeta Potential, mV		Z-Average Diameter, nm	
		Avg. of 3 repeats	S.D.	Avg. of 3 repeats	S.D.
Sample 1	20 nm Gold NP	-54.4	0.1	29.5	0.1
Sample 2	50 nm Gold NP	-39.1	0.3	57.9	0.2
Sample 3	100 nm Gold NP	-59.5	2.7	106.2	0.5

\*thank-you to Cytodiagnostics, [www. cytodiagnostics.com](http://www.cytodiagnostics.com)

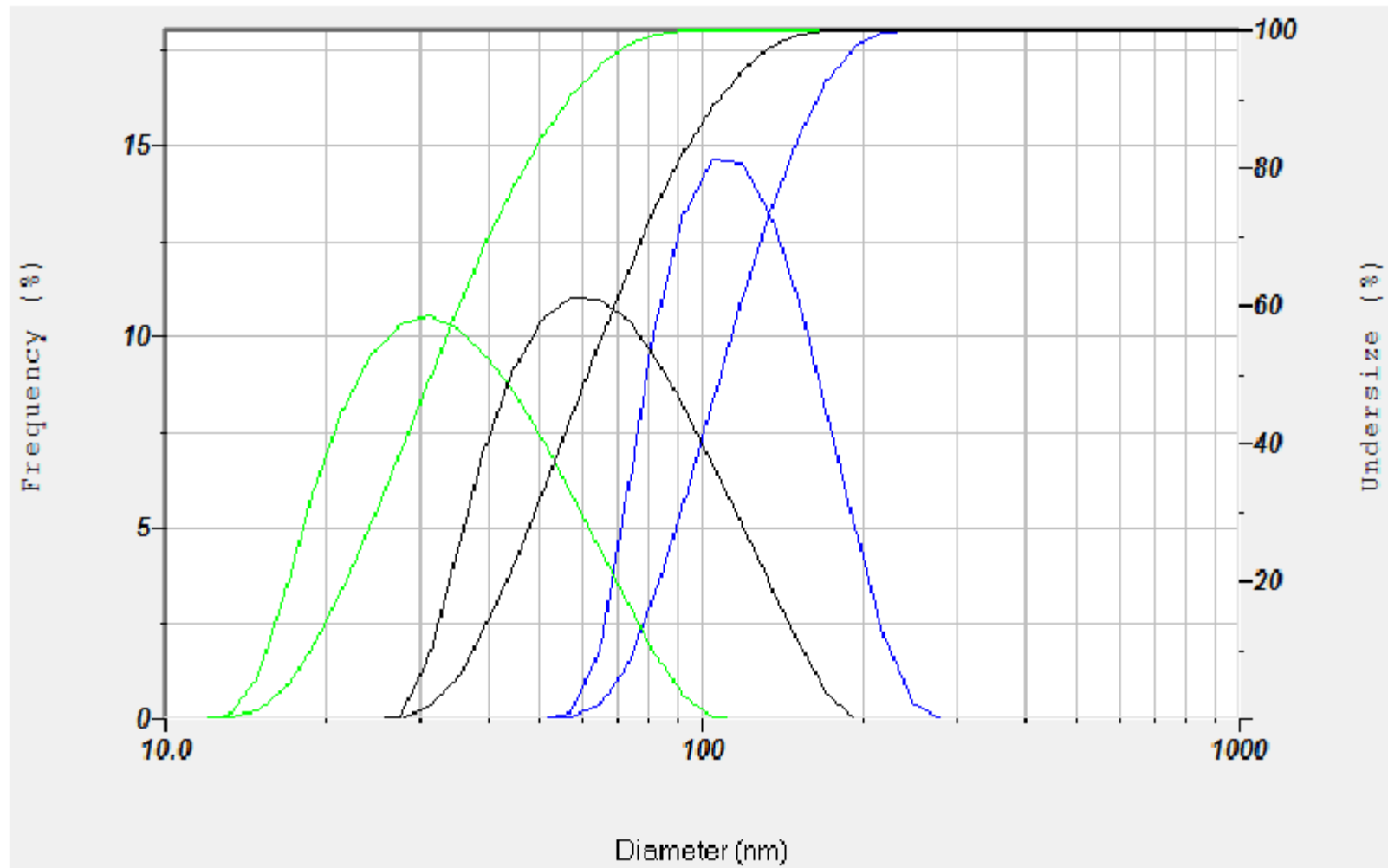


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# Colloidal Gold, Real World Data\*



\*thank-you to Cytodiagnostics, [www.cytodiagnostics.com](http://www.cytodiagnostics.com)

cYtodiagnos<sup>t</sup>ics

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# Colloidal Gold, Real World Data \*

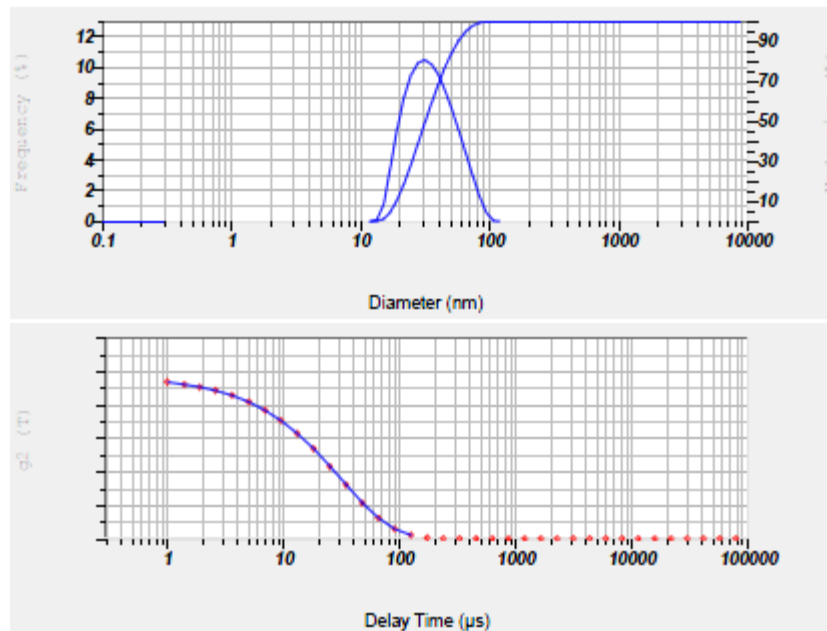
## Measurement Results

Sample Name : 20nm Gold NP  
Date : Wednesday, November 23, 2011 12:53:41 PM  
Measurement Type : Particle Size  
Scattering Angle : 173  
Temperature of the holder : 24.9 °C  
Form Of Distribution : Standard  
Representation of result : Scattering Light Intensity  
Count rate : 3869 kCPS

## Calculation Results

### Cumulant Operations

Z-Average : 29.4 nm  
PI : 0.094



\*thank-you to Cytodiagnosics, [www.cytodiagnosics.com](http://www.cytodiagnosics.com)

cytodiagnosics

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# Colloidal Gold Real World Data\*

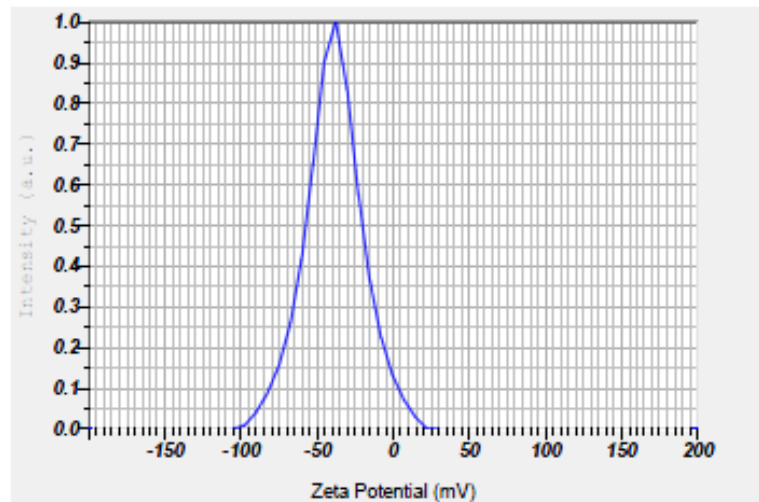
## Zeta Potential

### Measurement Results

Sample Name : 50nm Gold NP  
Date : Wednesday, November 23, 2011 2:51:34 PM  
Measurement Type : Zeta Potential  
Temperature of the holder : 25.0 °C  
Electrode Voltage : 3.4 V

### Calculation Results

Zeta Potential (Mean) : -38.9 mV  
Electrophoretic Mobility mean : -0.000302 cm<sup>2</sup>/Vs



\*thank-you to Cytodiagnosics, [www.cytodiagnosics.com](http://www.cytodiagnosics.com)

cytodiagnosics

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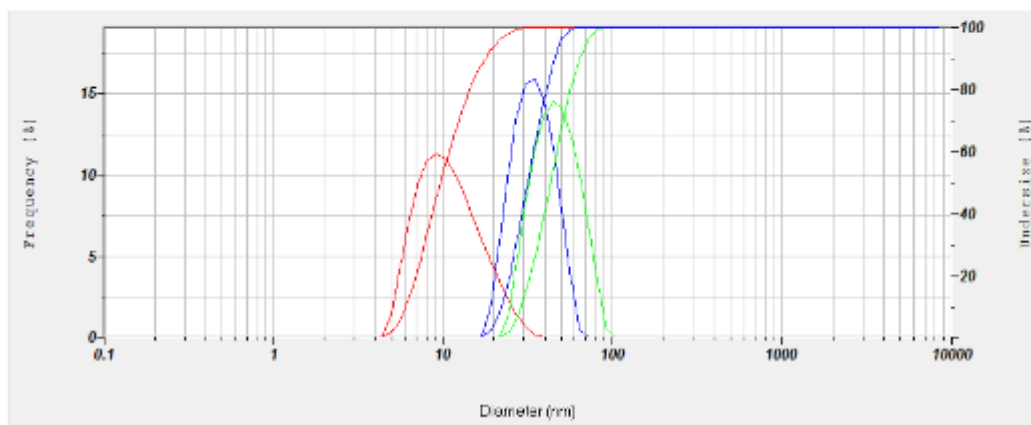


# Colloidal Gold, Real World Data \*

Summary Table  
(Three Measurements of Each Sample)

	Sample ID	Z-Average Diameter, nm	
		Avg. of 3 repeats	S.D.
Sample 1	258-106	27.1	0.1
Sample 2	272-004	10.9	0.6
Sample 3	272-008	37.7	0.1



Overlay of 3 Samples

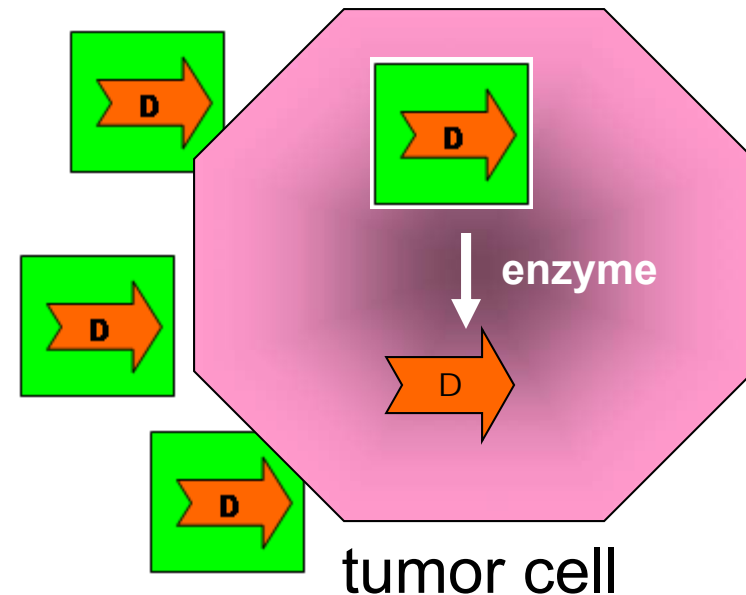


Blue: 258-106  
Red: 272-004  
Green: 282-008

\* Un-named customer at their request

# Colloidal Gold: Drug Delivery\*

- Cancer therapy delivers drug to all rapidly dividing cells
- Prodrugs delivered in inactive form 
- Once delivered, metabolized in vivo into active metabolite 
- Study: Immobilize prodrug activating enzyme onto colloidal gold particles
- Enzymes: genetically modified nitroreductase from *E. coli*; NfnB and Cys-NfnB



Colloidal Gold Modified with a Genetically Engineered Nitroreductase: Toward a Novel Enzyme Delivery System for Cancer Prodrug Therapy, Vanessa V. Gwenin, Chris D. Gwenin, and Maher Kalaji *Langmuir*, **2011**, 27 (23), pp 14300–14307

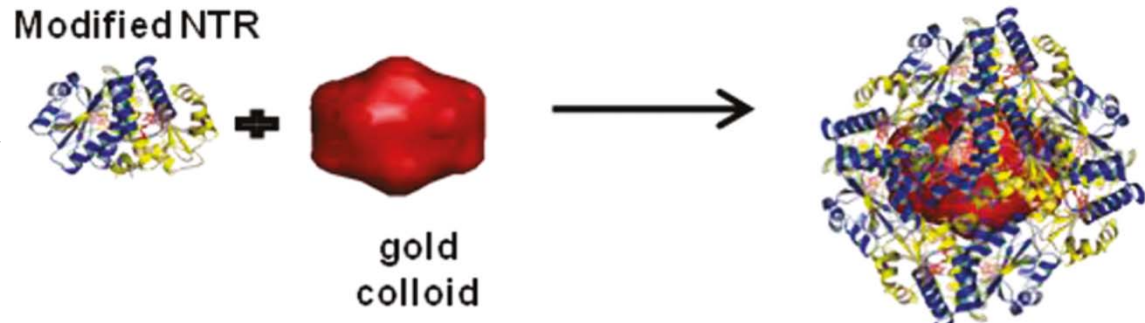
# Colloidal Gold: Drug Delivery\*

- Start with 50nm gold particles
- Incubate with varying molar equivalents (90:1, 180:1, 270:1, 360:1, and 450:1) of purified recombinant Cys-NfnB or His-NfnB overnight at 4C
- Analyzed on SZ-100 for particle size and zeta potential

Colloidal Gold Modified with a Genetically Engineered Nitroreductase: Toward a Novel Enzyme Delivery System for Cancer Prodrug Therapy, Vanessa V. Gwenin, Chris D. Gwenin, and Maher Kalaji *Langmuir*, **2011**, 27 (23), pp 14300–14307

# Colloidal Gold: Drug Delivery\*

- Base particle  
Size 51 nm  
Zeta potential - 52 mV
- NfnB ~ 5 nm
- Combined ~ 60 nm



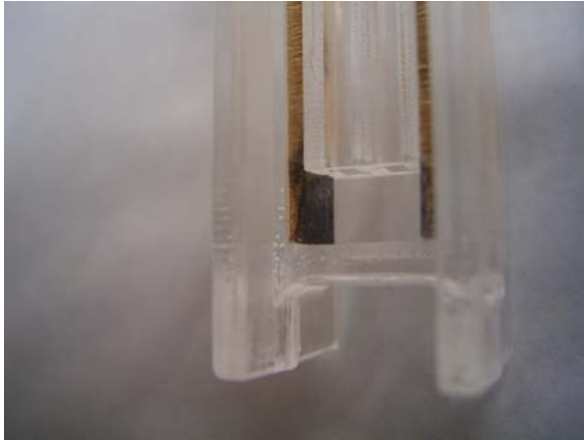
		Molar ratio of enzyme to gold colloid				
		90:1	180:1	270:1	360:1	450:1
His-NfnB-gold colloid	Size (nm)	53.5	57.5	82.6	69.7	75.4
	Zeta-potential (mV)	-43	-31.7	-30.7	-33.3	-30.4
Cys-NfnB-gold colloid	Size (nm)	56.3	59.8	61.1	69.8	69.7
	Zeta-potential (mV)	-23.4	-25.3	-26.0	-27.7	-34.2

less ordered

more ordered

Colloidal Gold Modified with a Genetically Engineered Nitroreductase: Toward a Novel Enzyme Delivery System for Cancer Prodrug Therapy, Vanessa V. Gwenin, Chris D. Gwenin, and Maher Kalaji *Langmuir*, **2011**, 27 (23), pp 14300–14307

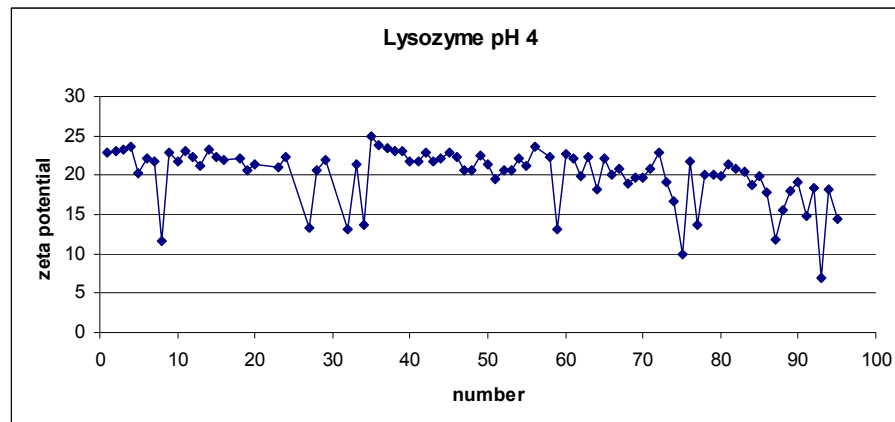
# Zeta Potential Cells



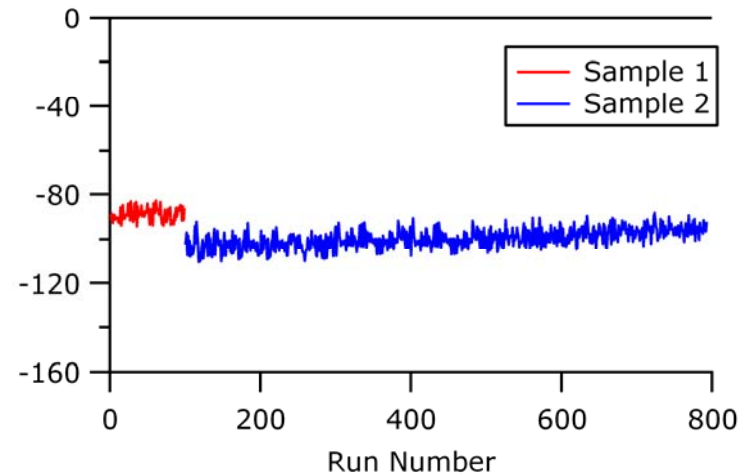
Gold coated electrodes (ruined)



Carbon coated electrodes



Lysozyme protein



800 measurements with one cell

# Resources: [www.horiba.com/particle](http://www.horiba.com/particle)

The screenshot shows the HORIBA Scientific website. The top navigation bar includes links for Automotive Test Systems, Process & Environmental, Medical, Semiconductor, Scientific (selected), and All Segment Product Browser. Below this is a secondary navigation bar with links for Products, Markets & Industries, Service & Support, News & Events, Newsletter, About Us, Employment, and Feedback. The main content area is titled 'Particle Characterization' and features a sidebar with a list of links: Particle Size Analysis, Particle Shape Analysis, Zeta Potential Analysis, Surface Area Analysis, Applications, Technology, Bibliography, Request Information, and Download Center. The main text area describes HORIBA's particle characterization instruments, their range of particle sizes (1 nm to 30 mm), and the techniques used (laser diffraction, dynamic light scattering, etc.). It also mentions the company's history and commitment to innovation. On the right side of the page, there are several interactive elements: a 'Request Information' form, a 'Quick Request' button, a 'Particle Size Essentials' eBook download link, a 'Newsletter' sign-up button, and a 'Download Center' link. At the bottom right, there is a 'Member login' section with fields for E-Mail Address and Password, and a 'Login' button.

**HORIBA Scientific**

Choisissez un pays ou une zone

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Products | Markets & Industries | Service & Support | News & Events | Newsletter | About Us | Employment | Feedback

## Particle Characterization

Home → Scientific → Products → Particle Characterization

### Particle Characterization

HORIBA designs, manufactures, and supplies state of the art particle characterization instruments.

Every instrument across the five business segments must meet stringent requirements before the HORIBA name is attached. The Particle Characterization group of analyzers has incorporated this principle into each new design since entering the business in 1979. Relentless innovation united with high performance to attain the ultimate goal: a new standard in usability.

#### Particle Characterization Products

HORIBA offers instruments for particle size, particle shape, zeta potential, and surface area analysis. Measurable particle size range is from 1 nanometer to 30 millimeters, at concentrations ranging from 1 ppm to 50 vol% with shape determination available starting at 1 micrometer. A range of analytical techniques are employed including laser diffraction (Mie Theory), dynamic light scattering, acoustic and electroacoustic spectroscopy, and dynamic and static image analysis. (measuring both particle size and shape information).

HORIBA's advanced designs and powerful software, combined with flexible sample handling systems are available to meet every analysis need. These instruments can incorporate small volume pumping systems for precious materials, high throughput automation, dry powder dispersers and temperature controlled flow systems in order to provide the user with the best possible solution with none of the trade-offs that might otherwise be necessary.

#### Particle Size

- Laser diffraction
  - LA-950V2
  - LA-300
- Dynamic light scattering
  - SZ-100

**Request Information**

**Quick Request**

**E-mail us**

**Particle Size Essentials**

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**Member login**

Please enter your e-mail address and password in order to login on to [www.horiba.com](http://www.horiba.com). We may ask you later to answer additional questions if you are the first time to this area.

E-Mail Address:

Password:

**Login**

Receive news of updates

View application notes, webinars, etc.

# Thank-you

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