Implement smell and taste with nanosensors

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Prof. Inkyu Park/KAIST
Prof. Yong Chen/UCLA
Dr. Alec Talin/Sandia National Lab

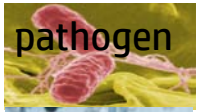
A mobile sensing solution in a ‘Tricorder’

Portable
Fast
Accurate
Reliable
Low Cost

food inspection

safe???

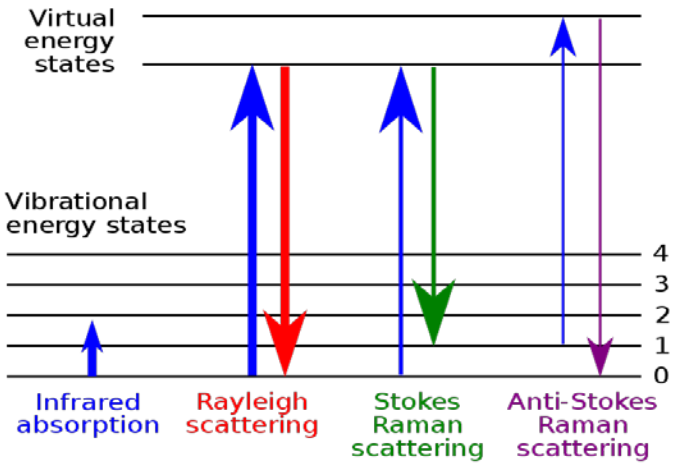
environmental protection

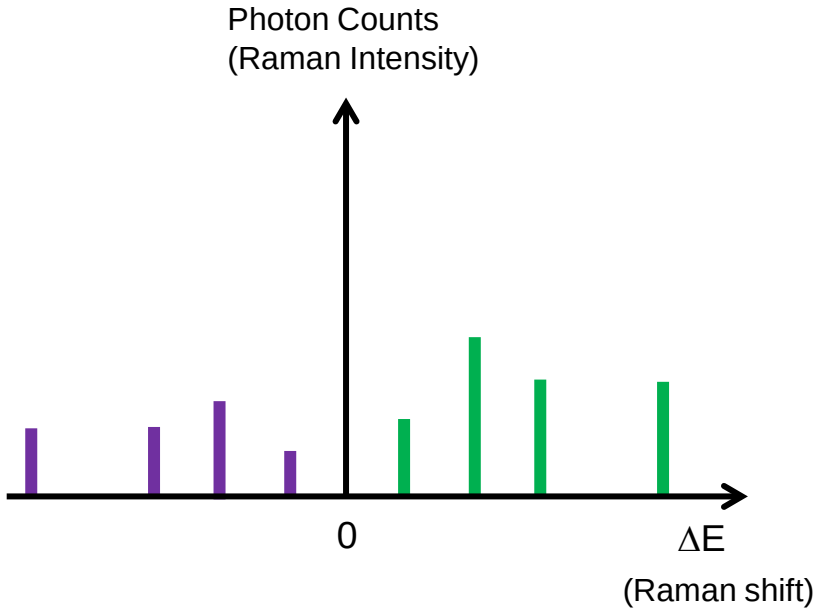


anti-counterfeiting

Raman Spectroscopy

Photon-Matter interaction



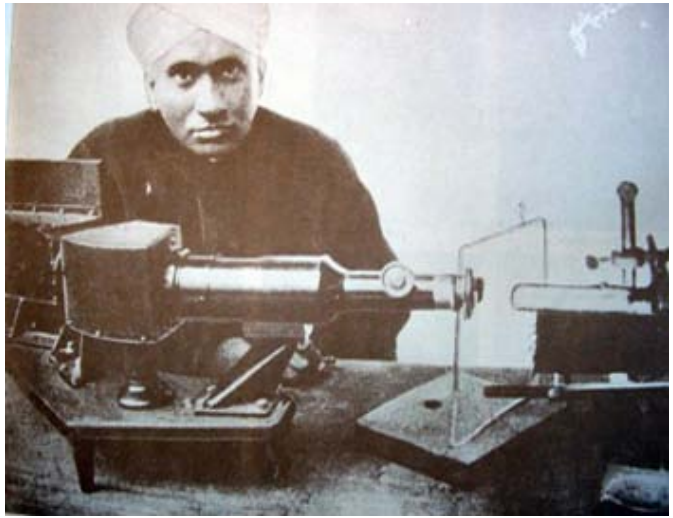


1/100,000,000 photons are Raman scattering

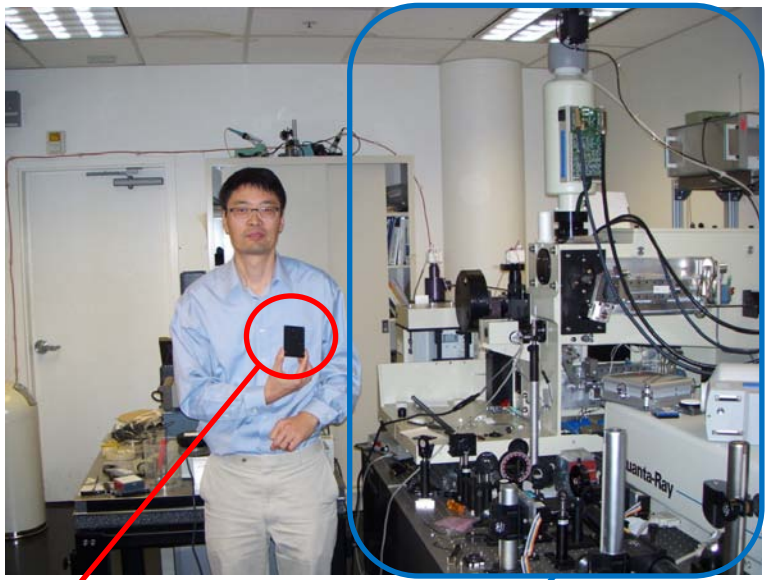
Require bulky, expensive instrument

Raman Spectrometer 85 Years Later

C.V. Raman,1928



2013

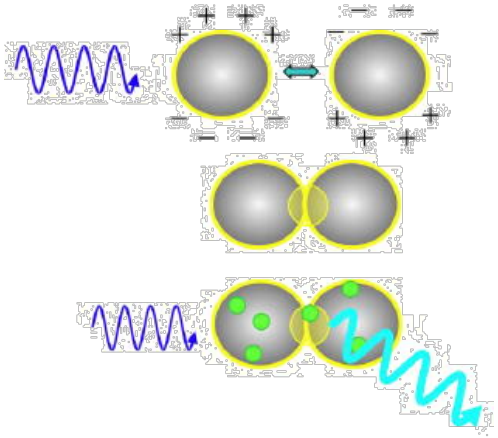


Mini-SERS prototype
@ HP Labs

Laboratory Raman Instrument

Surface-enhanced Raman scattering

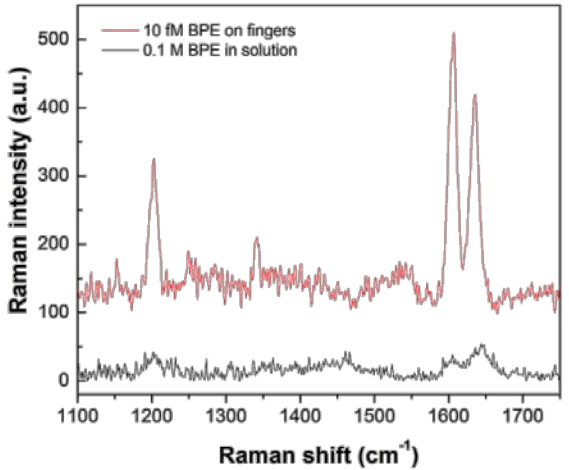
Raman scattering enhanced by localized surface plasmon on nanostructure



SERS Enhancement Factor $\propto |E(\omega)|^2 |E(\omega')|^2$

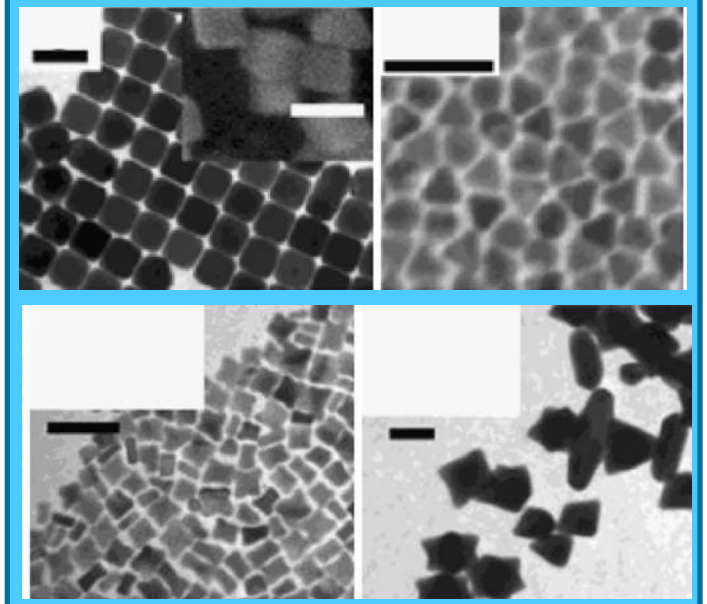
also approx. to ~ $|E|^4$

Electromagnetic field induced EF: 10^6 - 10^{12}



SERS will enable single molecule level detection with compact devices

Two Approaches to Nano-scale

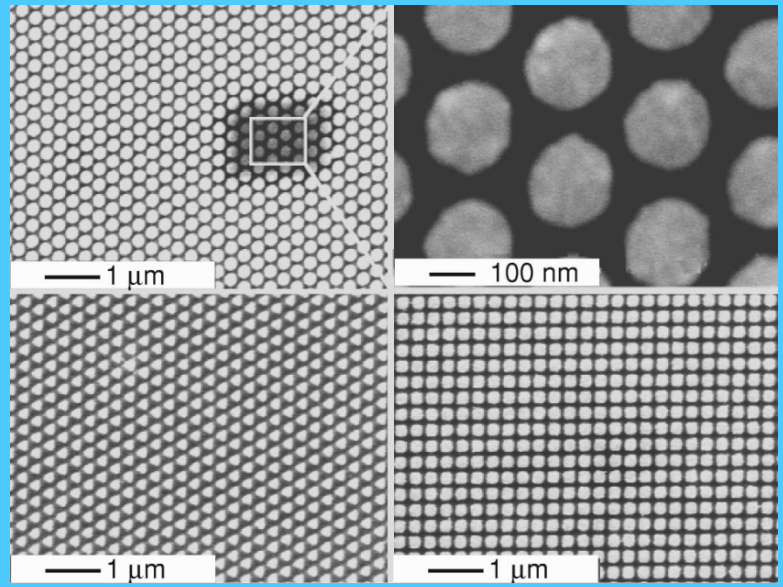


C. Murphy (2004), M. Natan (1998); P. Yang (2007)

Bottom-up synthesis

Advantage: low cost, close packing of NP possible.

Disadvantage: Random, difficult to produce long range order and uniform structure.

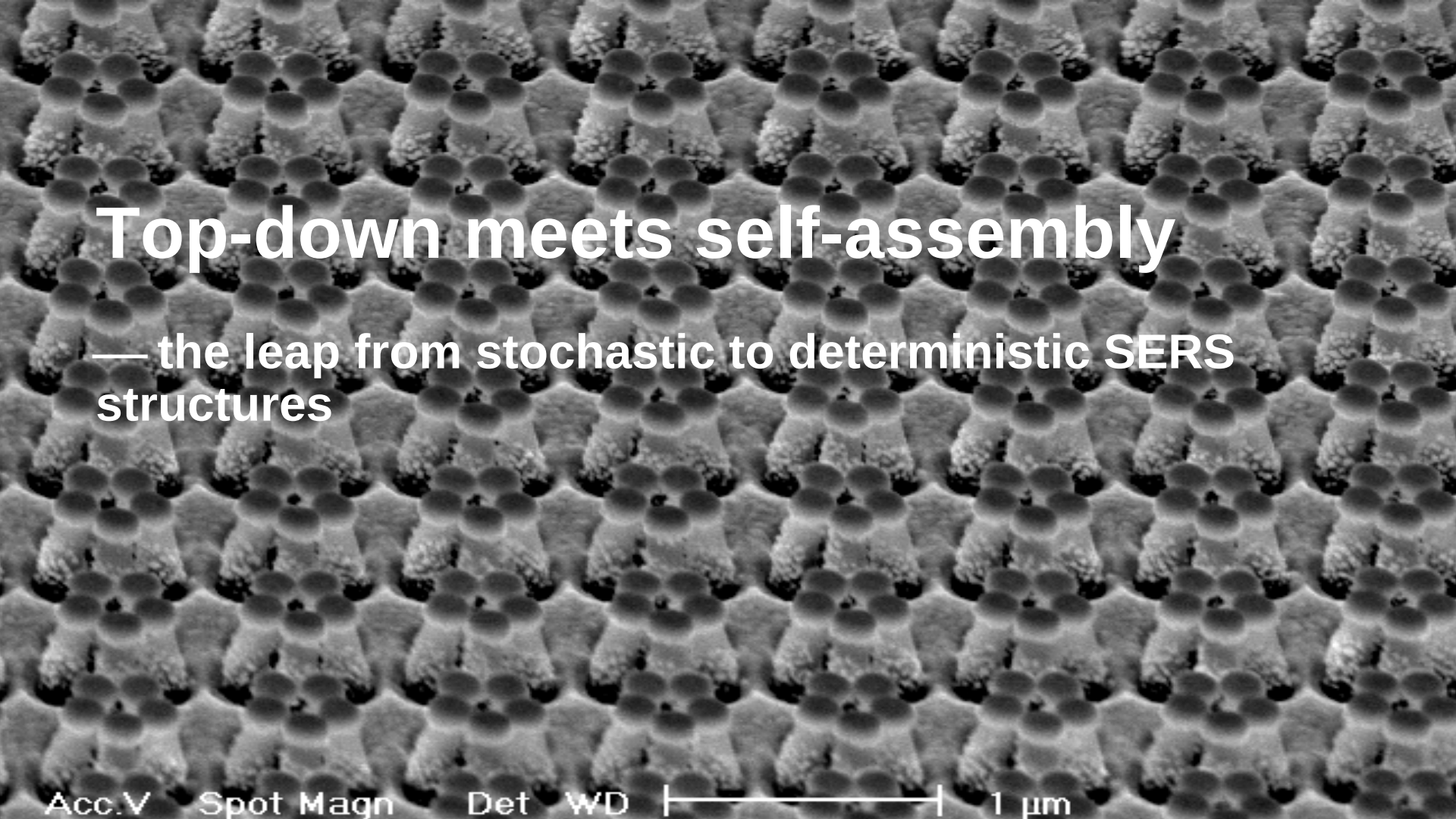


M. Kall (2001), H. Fenniri (2007)

Top-down fabrication

Advantage: Uniformity over large area

Disadvantage: difficult to obtain nm spacing for ultrahigh enhancement.



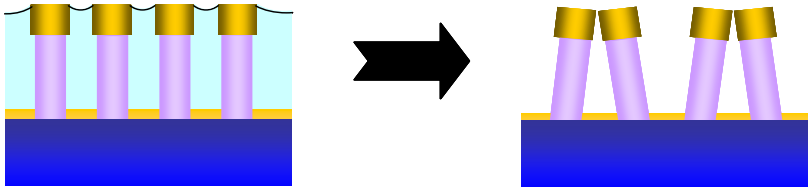
Top-down meets self-assembly

— the leap from stochastic to deterministic SERS structures

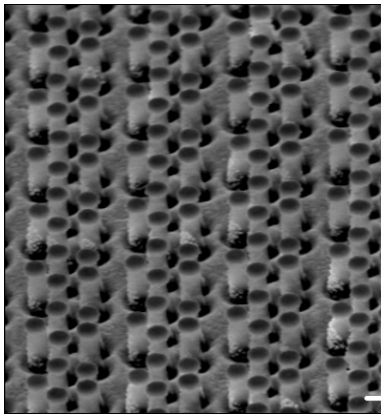
Hybrid nanostructure to mimic “Venus Fly Trap”

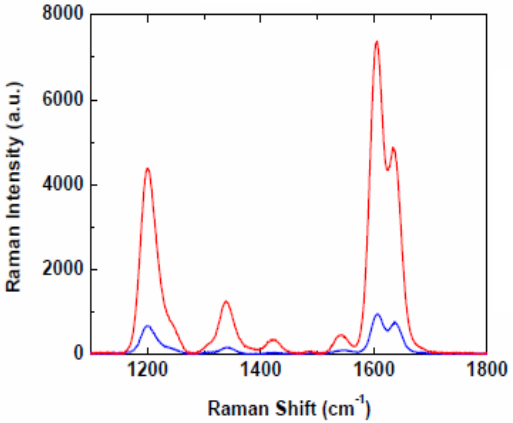
-- Polymer Finger + Metal Nanotips

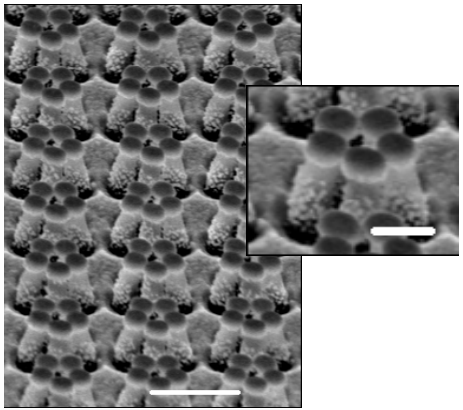
(a)



(b)



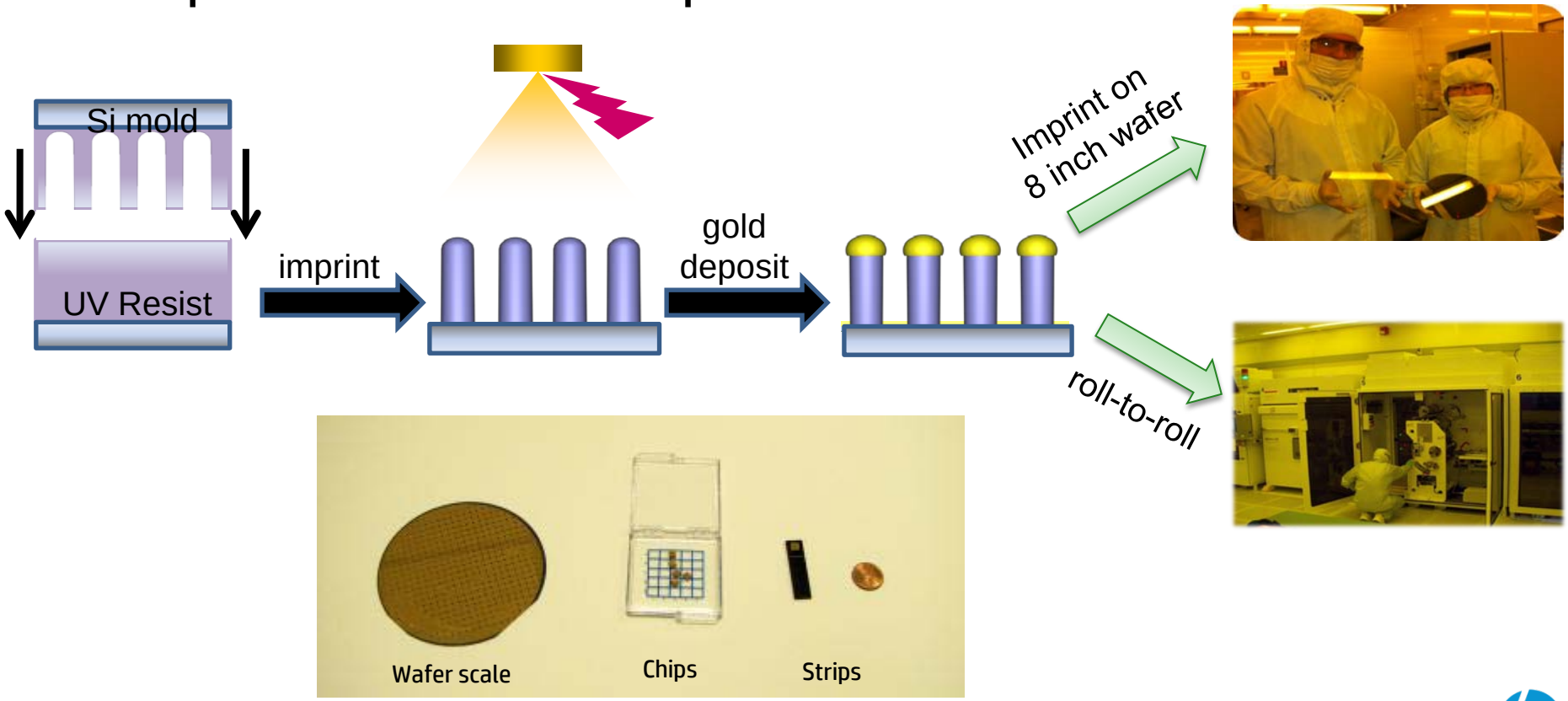


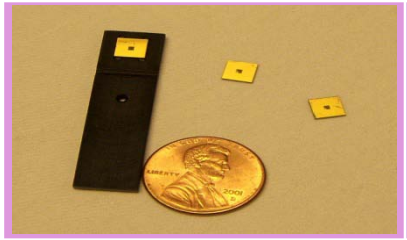


Advantages of nanofinger structures

- Leverage advantages from both top-down and bottom-up approaches – No need of costly critical dimension control.
- Easy scale-up for large area uniformity and reliable hot spots – Nanoimprinting.
- Micro-capillary driven “finger” closing – Easy for fluidic interface, no power nor complicated controls needed.
- Molecule self-limiting of the gap sizes, as small as sub-nm – Physical limit of the smallest separation manufacturable, hence strongest coupling effect.
- Active molecule trapping by the fingers – Molecular tweezer with build-in sensing functionality.

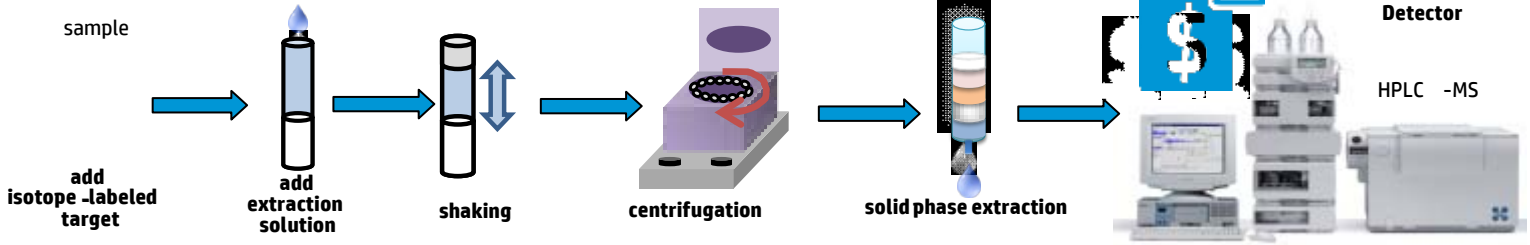
Inexpensive Nanochips Fabrication Process



Sensor Systems		Total # of Olfactory Receptor Cells	Total Olfactory Epithelium Surface Area	Receptor Area Density
	Bloodhound (the most sensitive animal on land)	4 billion	380 cm^2	~10 million/cm^2
	Human Nose	12 million	10 cm^2	~1 million/cm^2
	Nanofingers (man-made SERS sensor)	~1 billion	1 cm^2	~1 billion fingers/cm^2

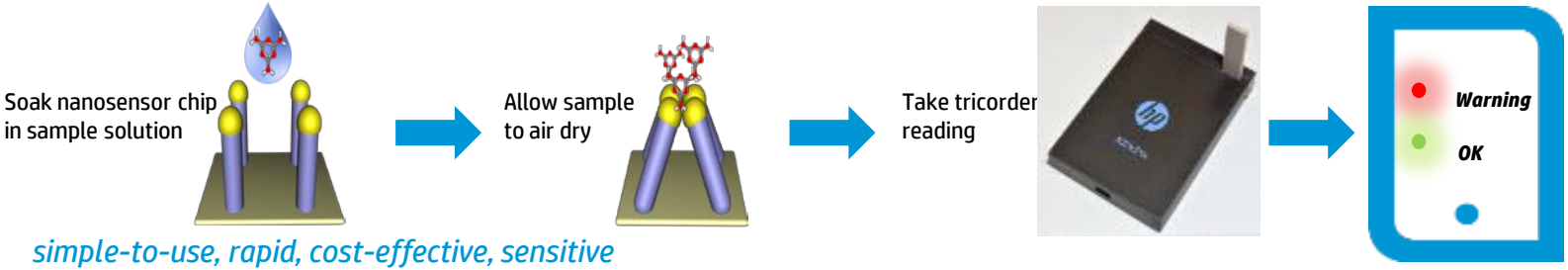
Technology Advantages

Current molecular analytical process



complicated, expensive, time-consuming, labor-intensive, and limited to lab testing

Our solution: 'Taste and Smell' on a mobile device

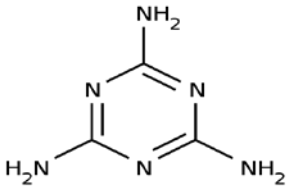


simple-to-use, rapid, cost-effective, sensitive

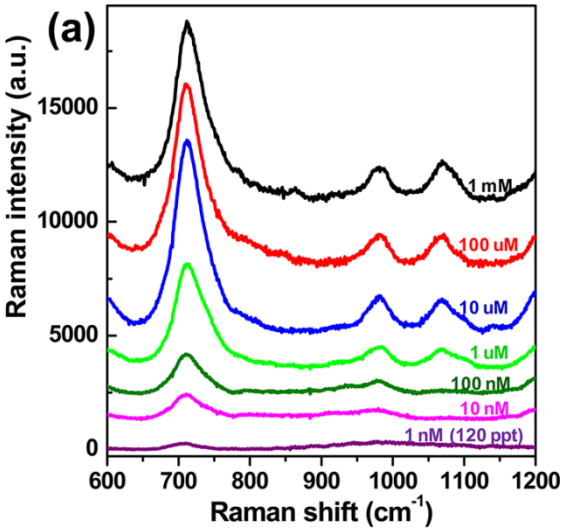
Demonstration of Melamine Sensing

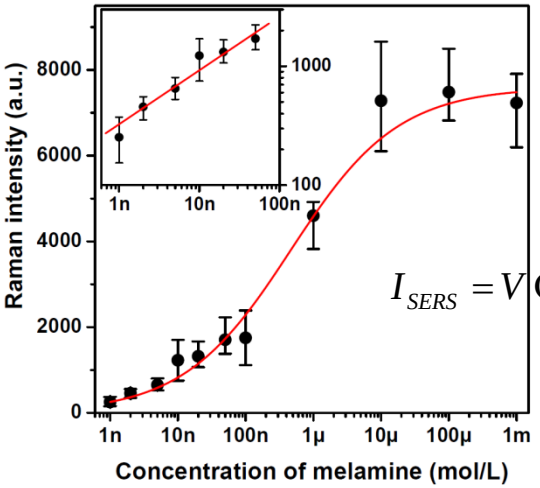
Melamine contamination in milk, 300,000 victims in China

2008



Max. amount in infant formula (FDA):
1 mg/kg (1part per million)





$$I_{SERS} = V\Theta = V\frac{c^n}{k^n + c^n}$$

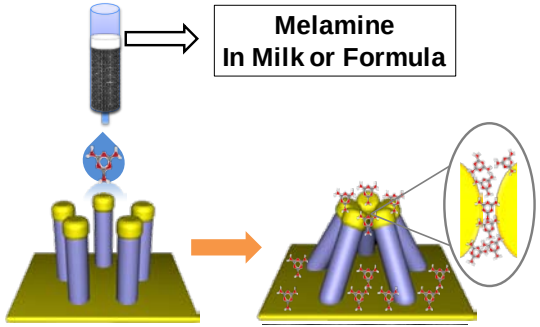
A. Kim, et al, *Analytical Chemistry*, 2012

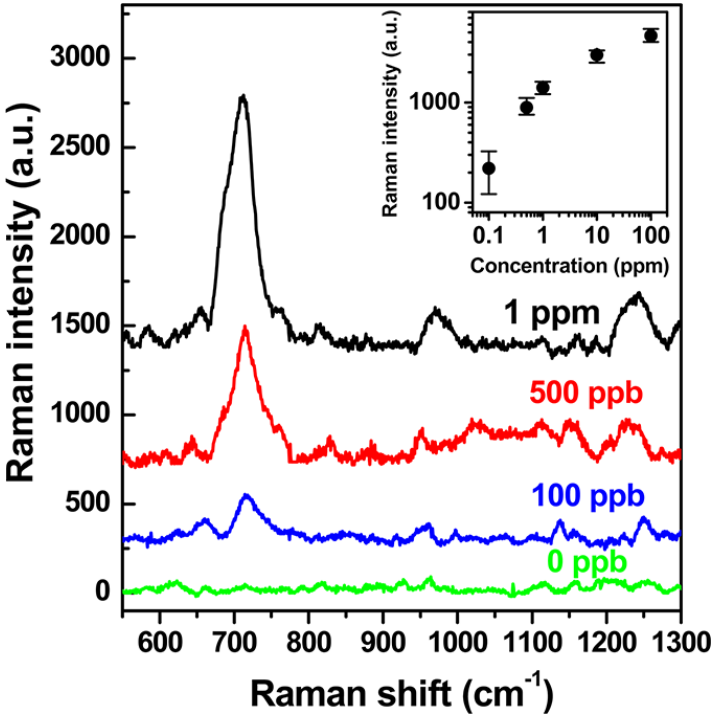
Melamine Sensing Results

Melamine in whole milk or infant formula

Dialysis method:

Filtration method:

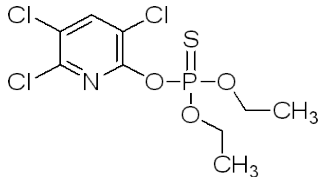




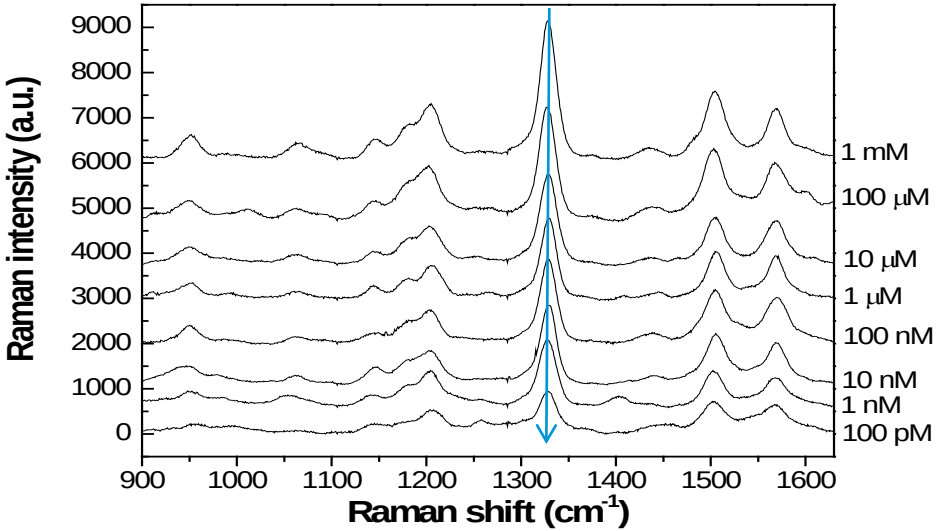
A. Kim, et al, *Analytical Chemistry*, 2012

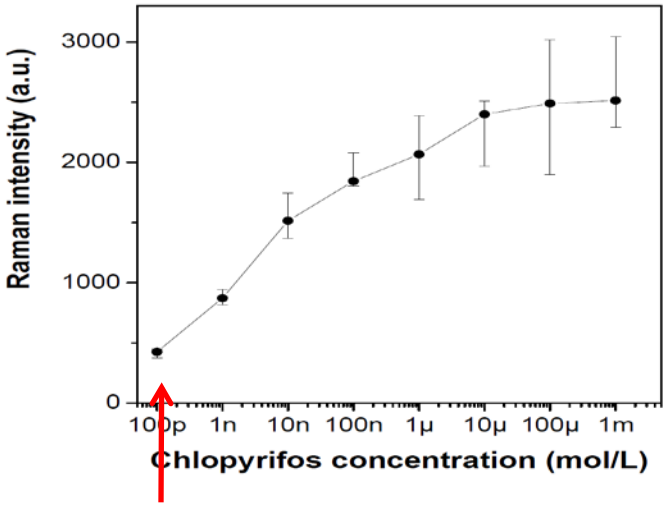
Demonstration of Pesticide Sensing

Chlropyrifos, is a **neurotoxin, carcinogen,** once popular pesticide used worldwide, and the residue can be found in vegetables, fruits, etc.



EPA regulation:
0.1 parts per million
on citrus fruits



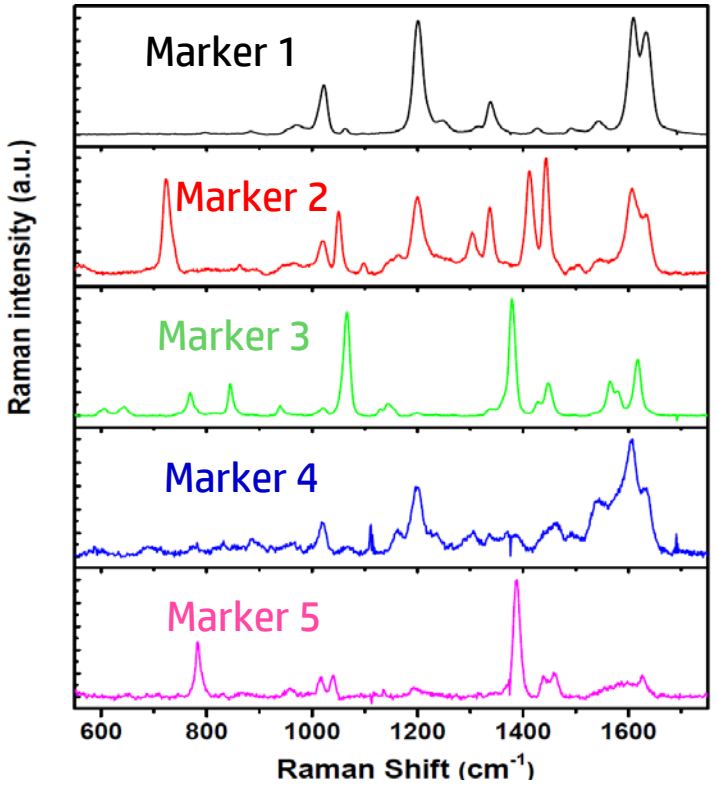


Detection limit of 35 parts per trillion

Demonstration of ‘Chemical Barcode’ for Authentication

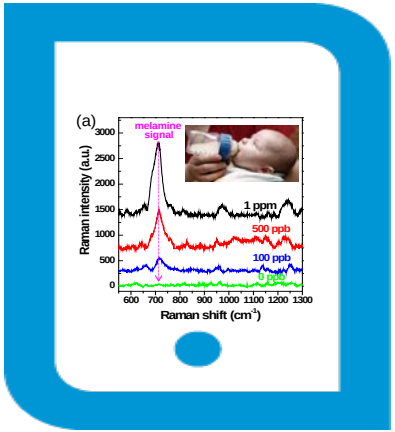
Different molecules as **“chemical barcode”** based on their specific fingerprints on Raman spectrum

- Mix special marker(s) in product at trace levels
- Detect with SERS
- Real-time authentication
- Remote monitoring/reporting



Future is around the corner!

Nanosensor chip as consumables



Conceptual mobile device for data collection & on-ramp to cloud system

Data analysis, storage, networking as cloud service to government, enterprise, consumers

Thank you

Q&A