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Biosensors for food safety

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- Magnetic nanoparticle-based biosensors
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Some facts and data about food safety

Foodborne diseases encompass a wide spectrum of illnesses and are a growing public health problem worldwide (WHO, October 2017).

- Over 200 diseases are caused by unsafe food
- 1 in 10 people fall ill every year from eating contaminated food
- 420 000 people die each year as a result
- Children u… ith some 125 000 y… y year.

Detection!

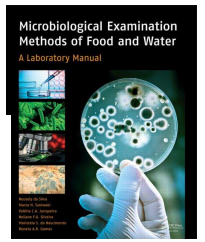
USDA: U.S. Foodborne Illnesses Cost More Than $15.6 Billion Annually

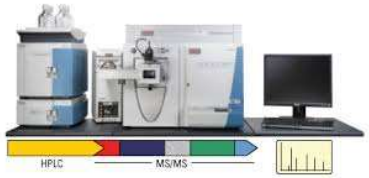
Poses major economic risks, especially in a globalized world.

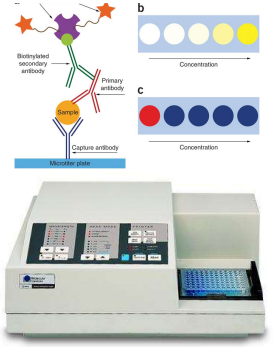
Germany's 2011 E.coli outbreak: US$ 1.3 billion in losses for farmers and industries; US$ 236 million in emergency aid payments to 22 European Union Member States.

Conventional detection methods

- **Bacterial plating or viral isolation:**
  - Specific, sensitive in isolation and identification, **but** very time-consuming (24 hrs to several days)
- **PCR, RT-PCR/rRT-PCR:**
  - Relatively rapid (6-8 h), specific, sensitive, **but** requires very complex sample preparation and skilled operators
- **HPLC,GC, GC/MS :**
  - Sensitive, specific, **but** need expensive instruments and highly skilled operator.
- **ELISA:**
  - Relatively rapid (4-8 h), **but** less specific, not sensitive and more false positives
- **Strips (lateral flow):**
  - Rapid (minutes to hours), simple and inexpensive, **but** not specific, not sensitive enough, and more false positives/negatives.



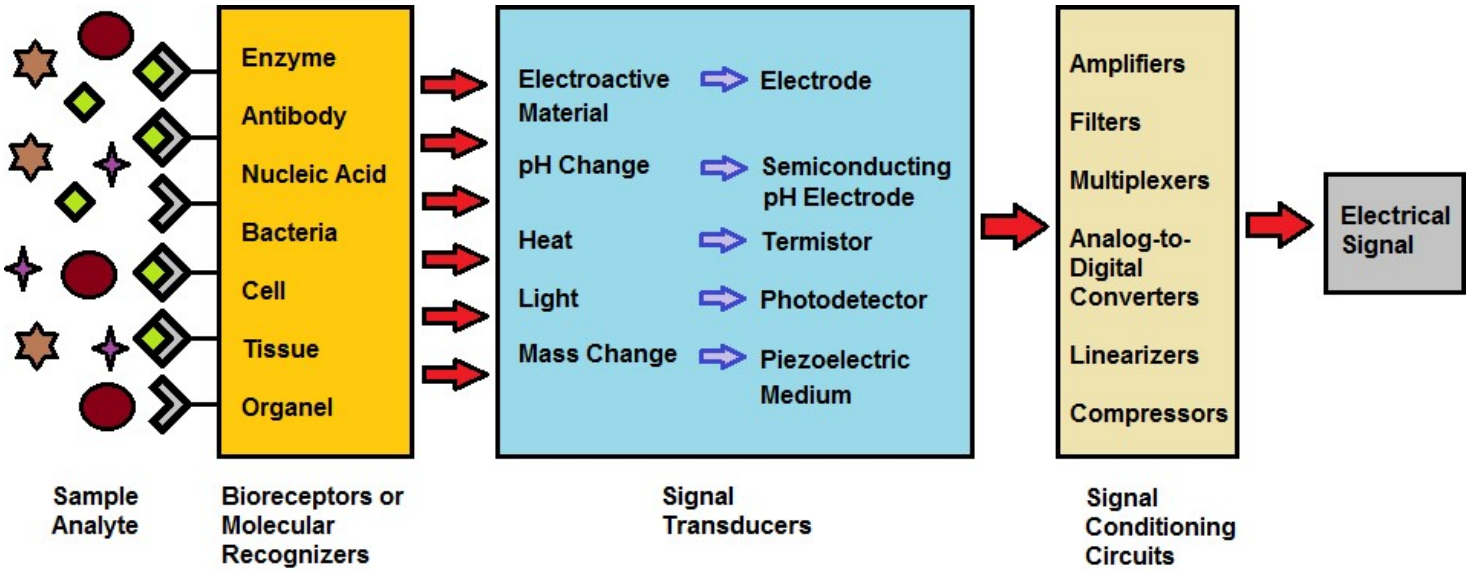




Biosensor

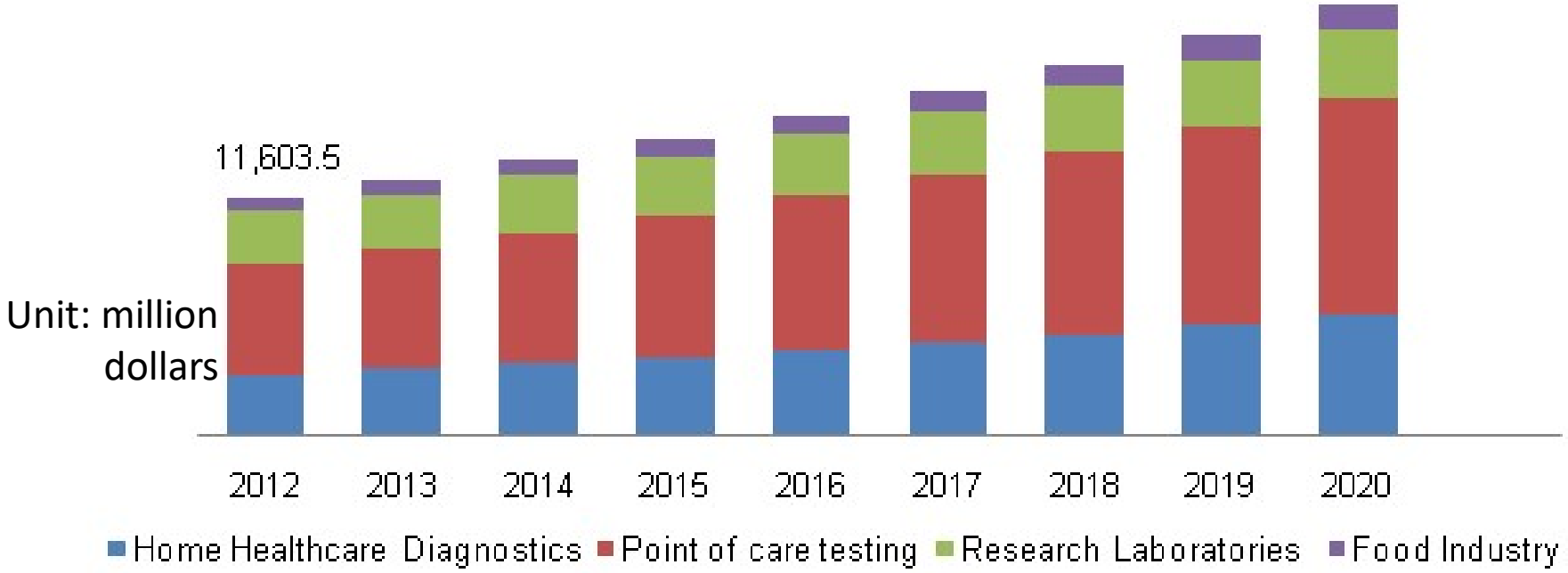
Biosensors are devices which use a biological recognition element retained in direct spatial contact with transduction system (IUPAC definition)

Sensitive, specific, …



Rapid, portable, in-field detection

Industry analysis of biosensor



http://www.grandviewresearch.com/industry-analysis/biosensors-market

Our biosensing researches

Technologies

Biosensing

Instruments

J. Mater. Chem. A, 2018, 6, 3402;
Anal. Chem., 2017, 89, 12145;
J. Physical Chem. C, 2017, 121, 6229;
Anal. Chem., 2016, 88, 8542;
Sens. Actuat. B-Chem., 2016, 234, 98;
Analyst, 2016, 141, 1136;
Food Control, 2015, 56, 135;
Sci. Rep., 2015, 5;
Biosens. Bioelectron., 2014, 54, 64;
Anal. Chem., 2014, 86, 1965;
Adv. Funct. Mater. 2014, 24, 5011;
Chem. Eur. J., 2014, 20, 2623；
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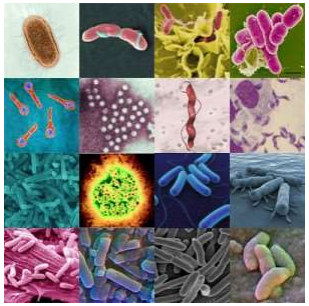
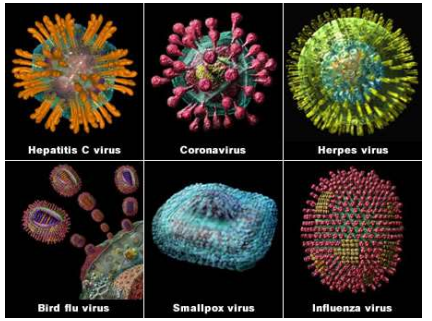
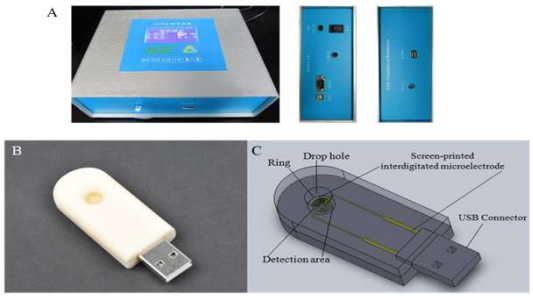
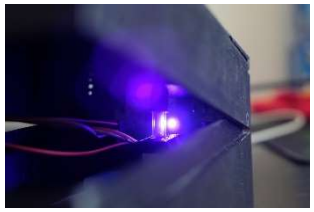








Systematic consideration of Biosensor

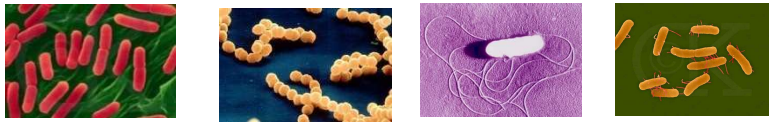
Biosensor = system

- sample pretreatment + detection
- technology + instrument
- sensitivity/specificity… + simplicity/cost/portability…

Function-integration based on advanced nano-/bio-technology

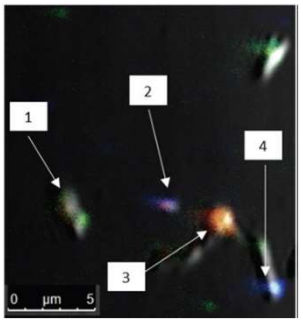
- **Magnetic materials: magnetic separation + multi-role**
- **Multi-functional composites: integrated system**

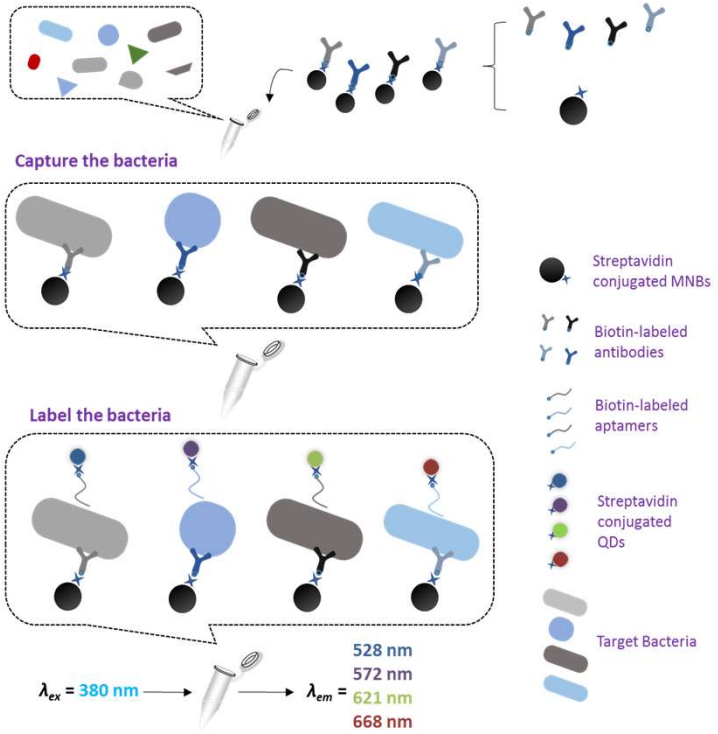
I. Fluorescence biosensing:
simultaneous detection of four bacteria



Four types of bacteria

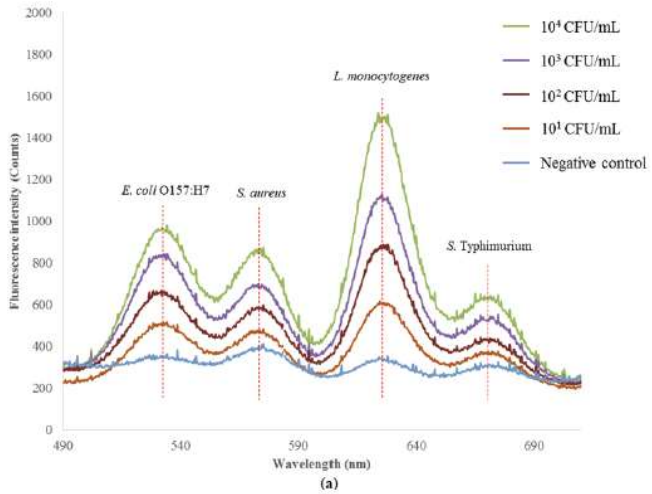
Four types of quantum dots

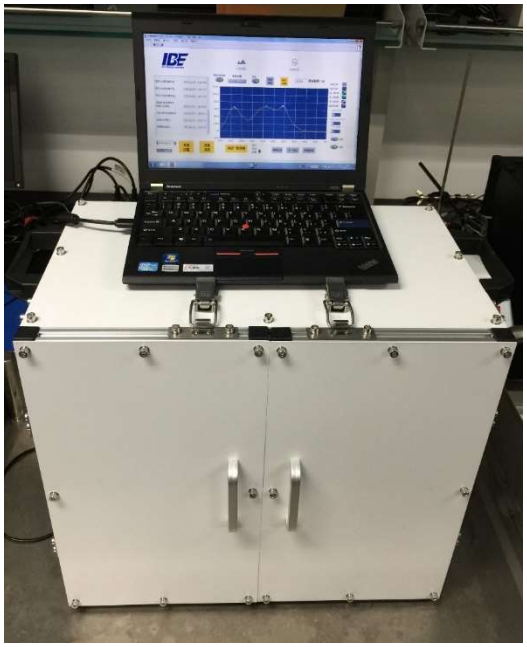




Transactions of ASABE, 2015, 58, 891

I. Fluorescence biosensing:
simultaneous detection of four bacteria





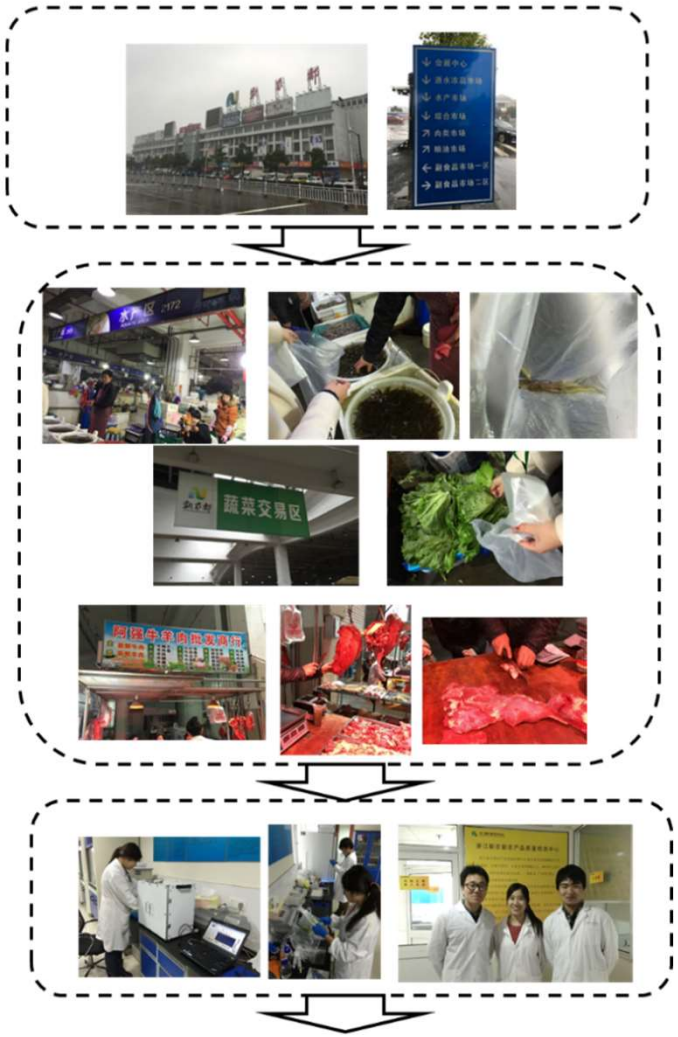
Wavelength: qualitative
Intensity: quantitative

Limit of detection: 100 CFU/mL

Software interface

Transactions of ASABE, 2015, 58, 891

I. Fluorescence biosensing:
simultaneous detection of four bacteria



Three markets in three provinces

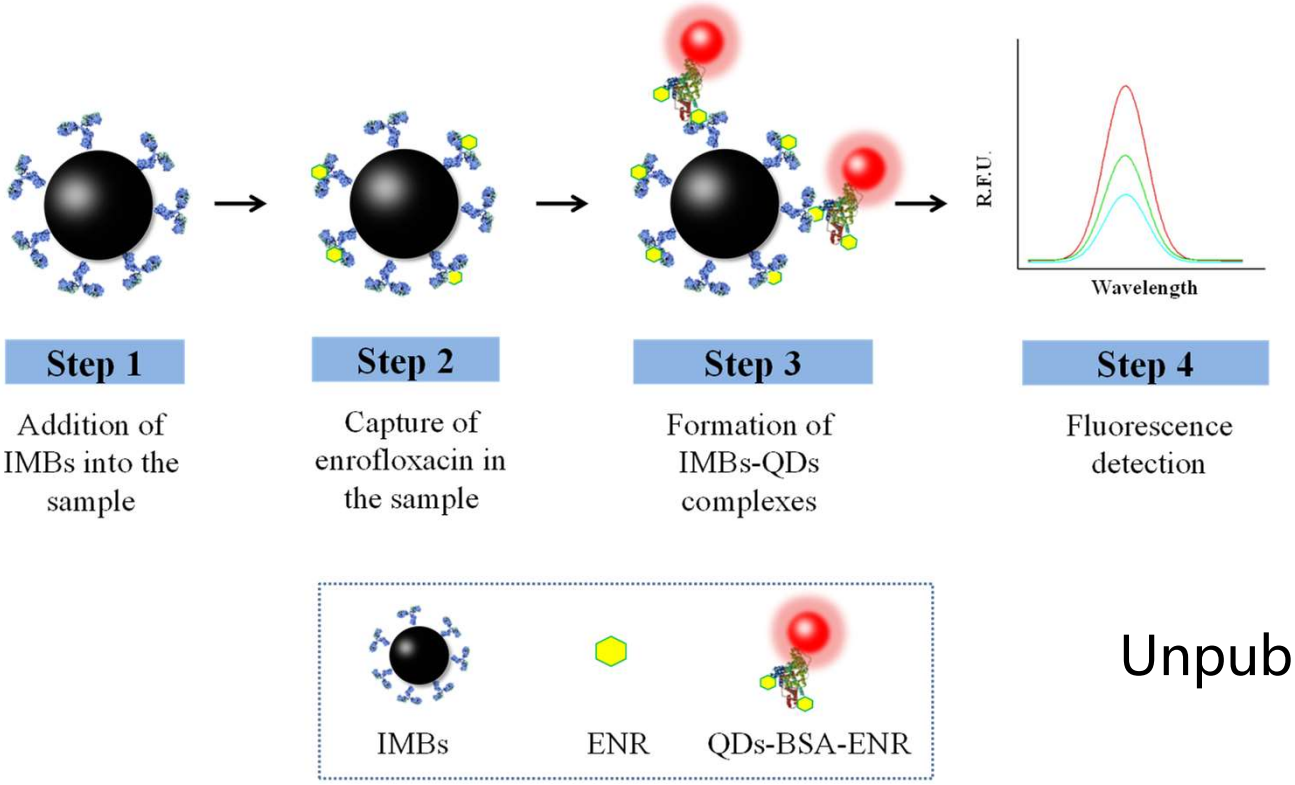
Sample pretreatment (lettuce, beef, shrimp)

Detection

Results analysis. Results agreed well with those of bacterial plating

Food Control, 2015, 56, 135

I. Fluorescence biosensing: antibiotics (enrofloxacin)



Unpublished work

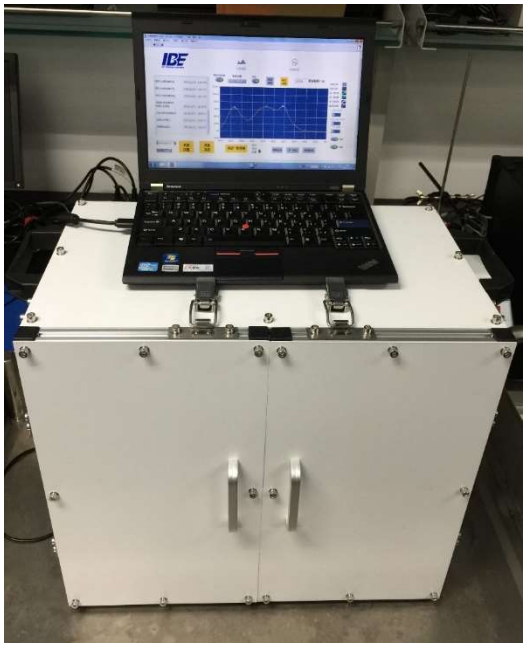
Limit of detection: 10 μg/kg in chicken meat samples

Walmart 食品安全协作中心

Poultry Excellence in China: Improving Food Safety in Poultry Supply Chains

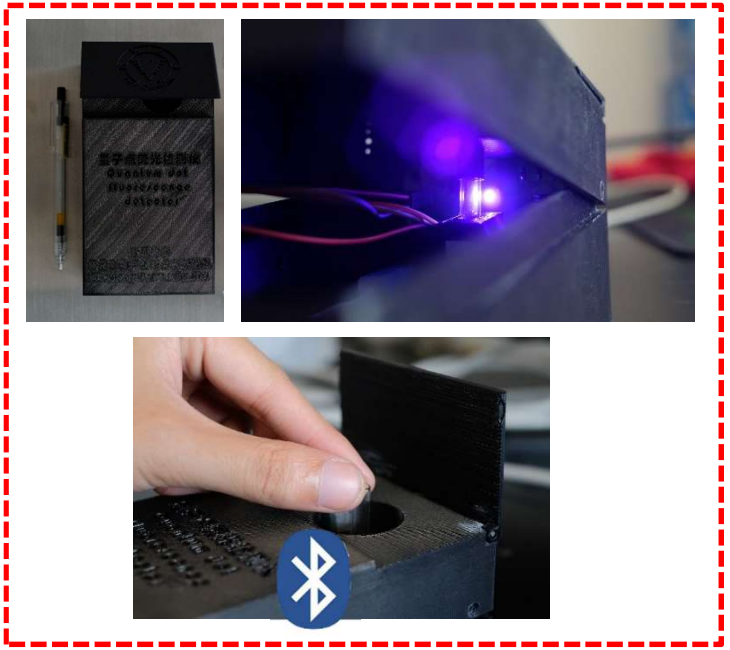
I. Fluorescence biosensing: portable analyzer

1st Version



Software interface

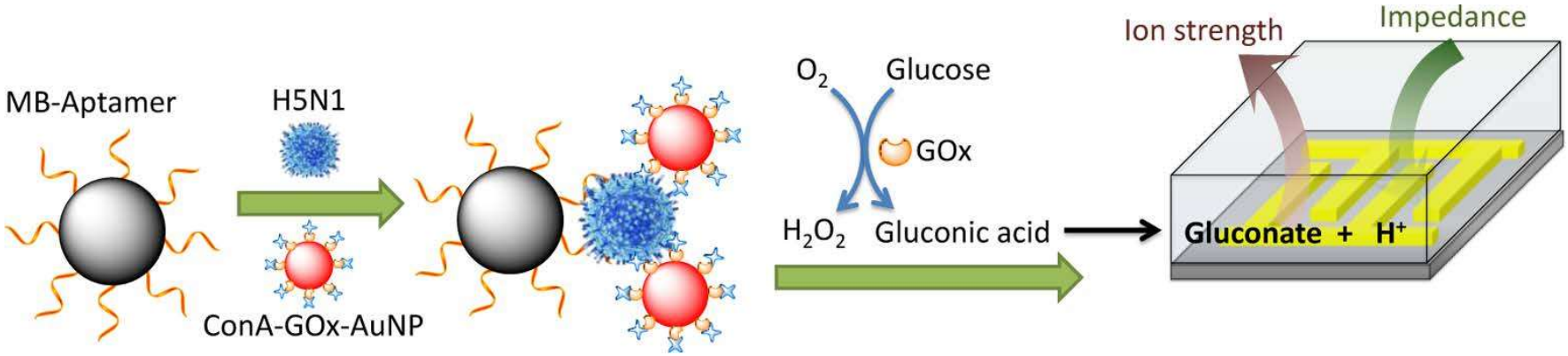
2nd Version



II. Impedance biosensing: one-piece-of-electrode strategy

A key hindrance of electrochemical biosensors:

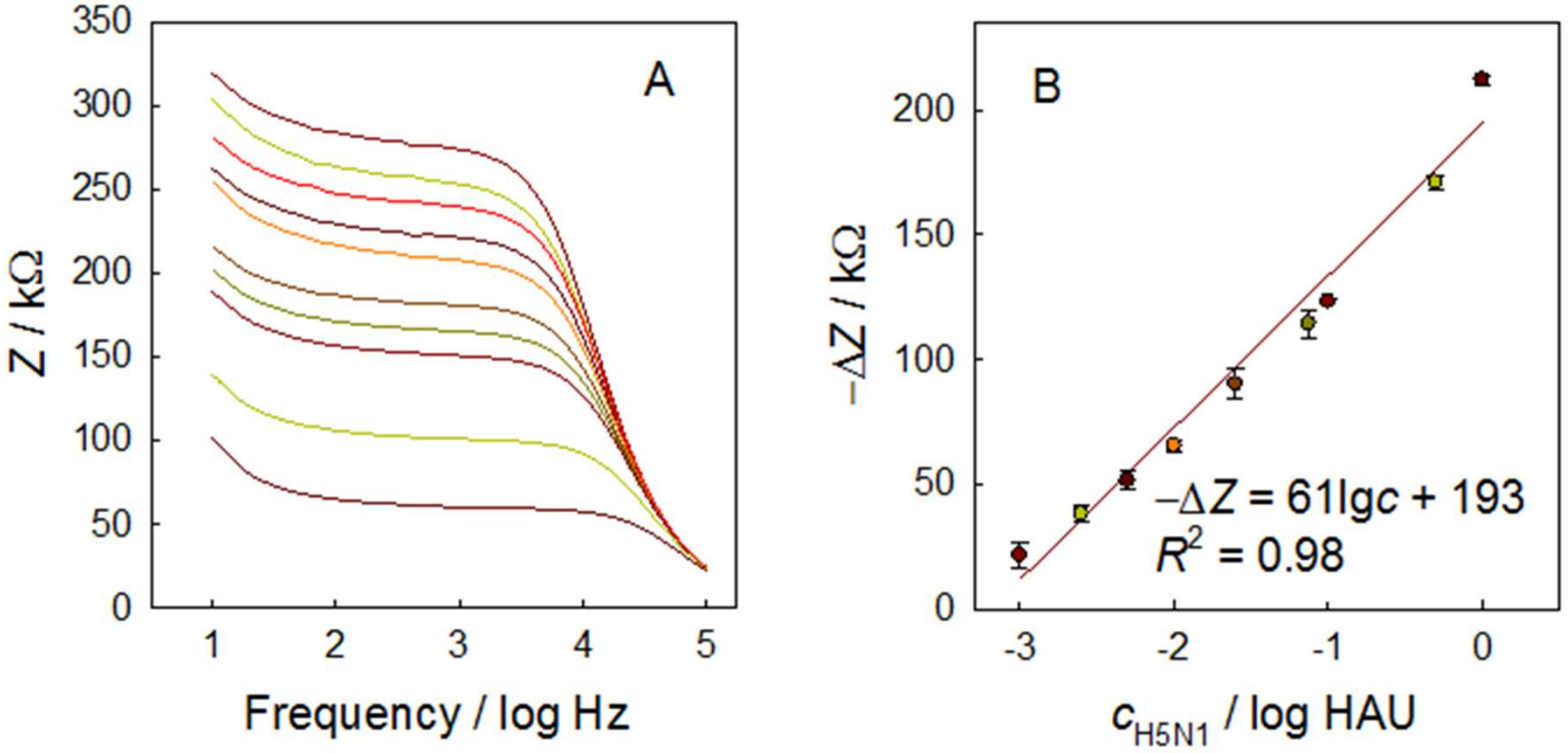
- requiring to replace or regenerate electrodes after each detection
- making instrument complicated and cost high



Detecting the change of ion concentration caused/amplified by enzymatic catalysis → no requirement of electrode modification and no pollution of electrode

Anal. Chem., 2014, 86, 1965; Biosens. Bioelectron. 2015, 74, 504

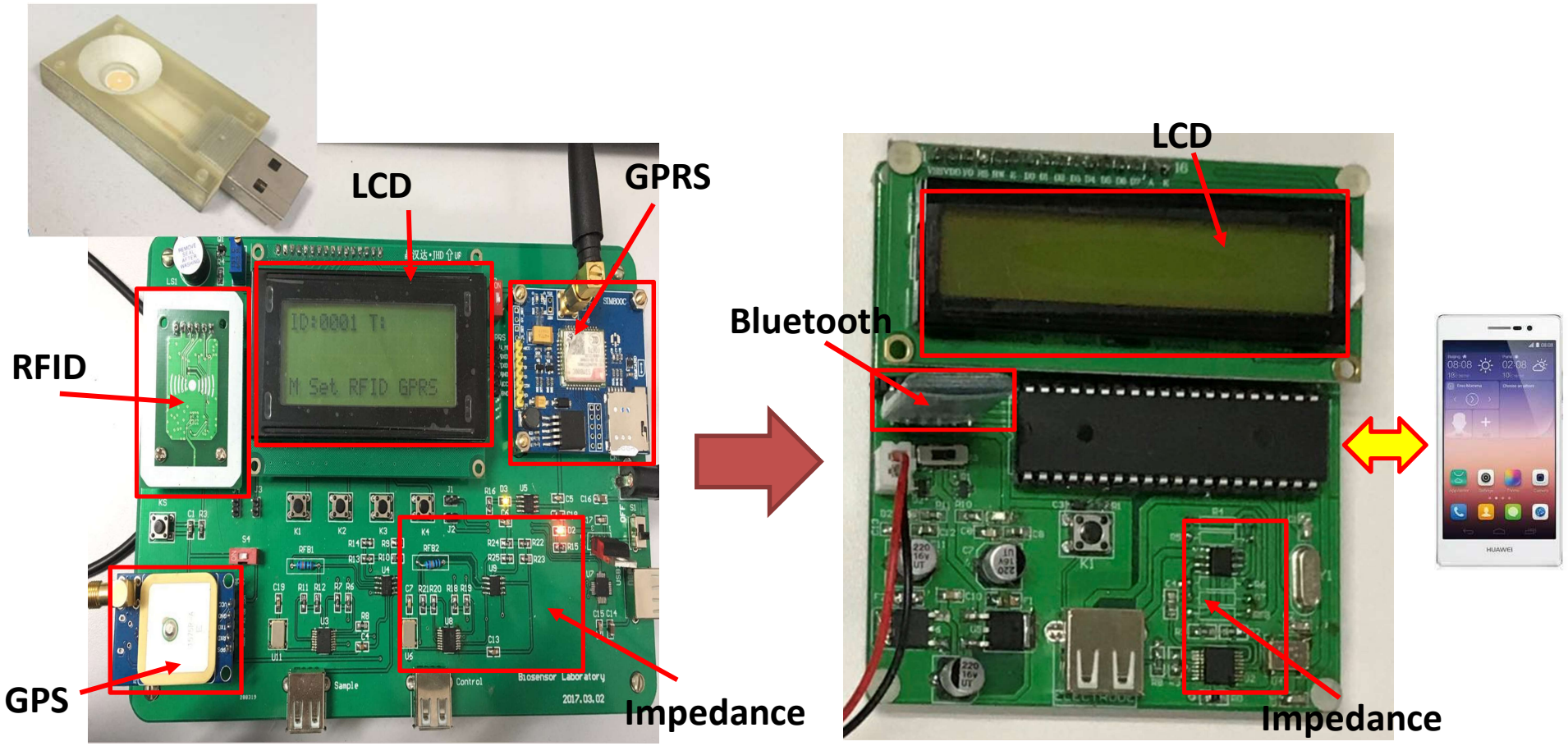
II. Impedance biosensing: one-piece-of-electrode strategy



- Limit of detection (avian influenza virus H5N1): 8×10^{-4} HAU in 200 μL sample (**The best so far**)
- One piece of electrode for more than 200 samples
- Simplify instrument and reduce cost

Anal. Chem., 2014, 86, 1965; Biosens. Bioelectron. 2015, 74, 504

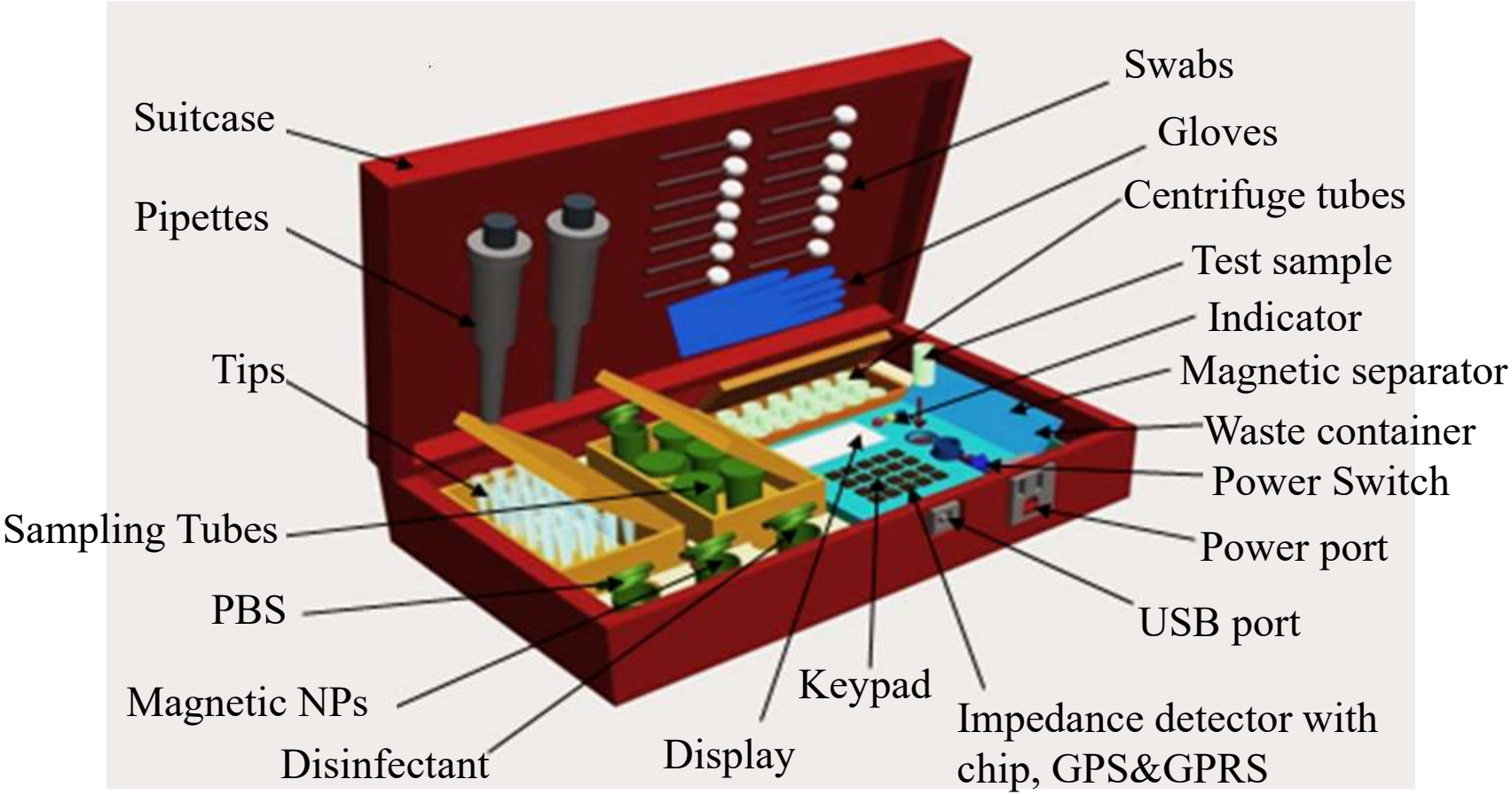
II. Impedance biosensing: analyzer for bacteria



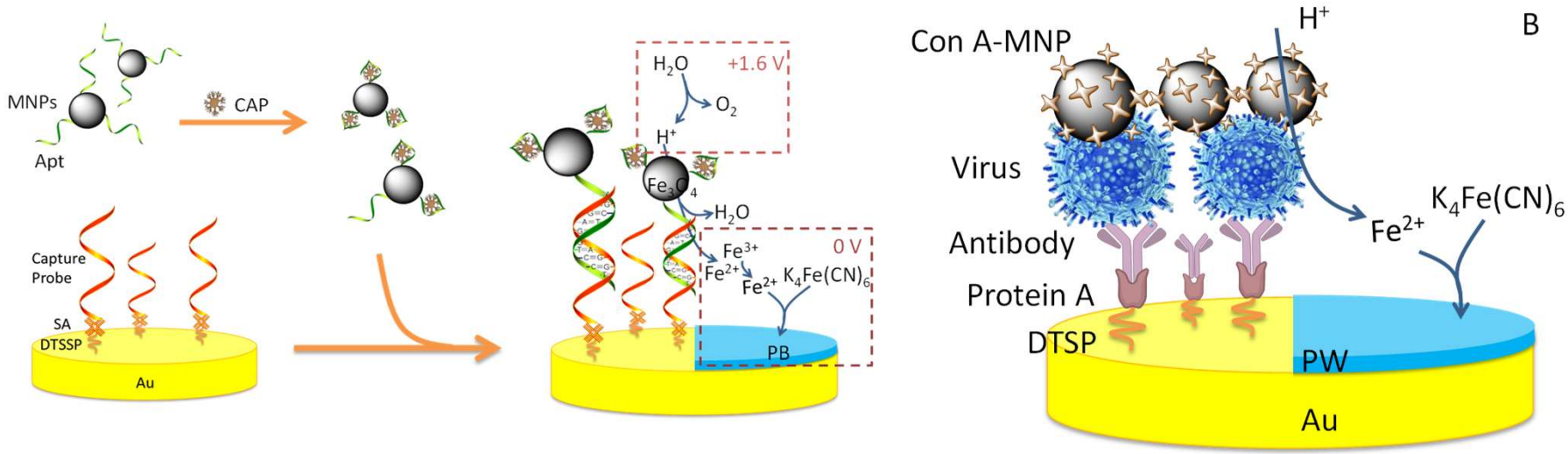
impedance measurement, GPS positioning, and wireless transmission

II. Impedance biosensing: Ongoing work

Impedance biosensor prototype development



III. Electrochemical biosensing: one-in-all strategy



- Multi-role of magnetic nanoparticles: magnetic separation/collection + signal generation
- No requirement of signal labels, comparable performance with analogues (antibiotics and avian influenza virus H5N1)

Anal. Chem., 2017, 89, 12145; Electroanalysis, 2018, in press

Conclusions

- Food safety urgently requires efficient detection methods and instruments

- Exploring more functions and more composites of advanced bio-molecules and nanomaterials to generate integrated systems is promising to provide solutions for food safety detection

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Dr. Jianhan Lin
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NSFC

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State Key Laboratory of Chemo/Biosensing and Chemometrics, Hunan University

浙江大学
Zhejiang University

Thank you

Welcome to visit Hangzhou