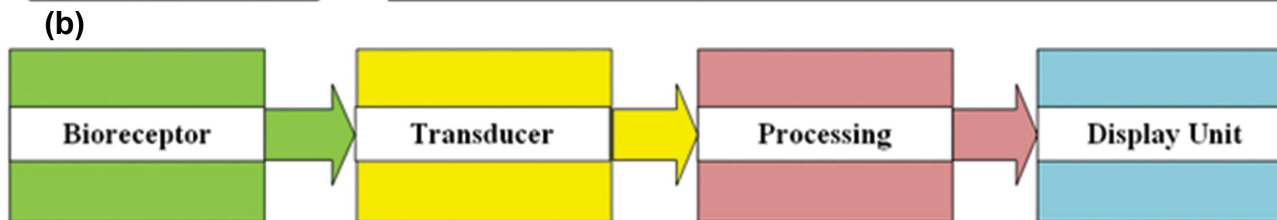
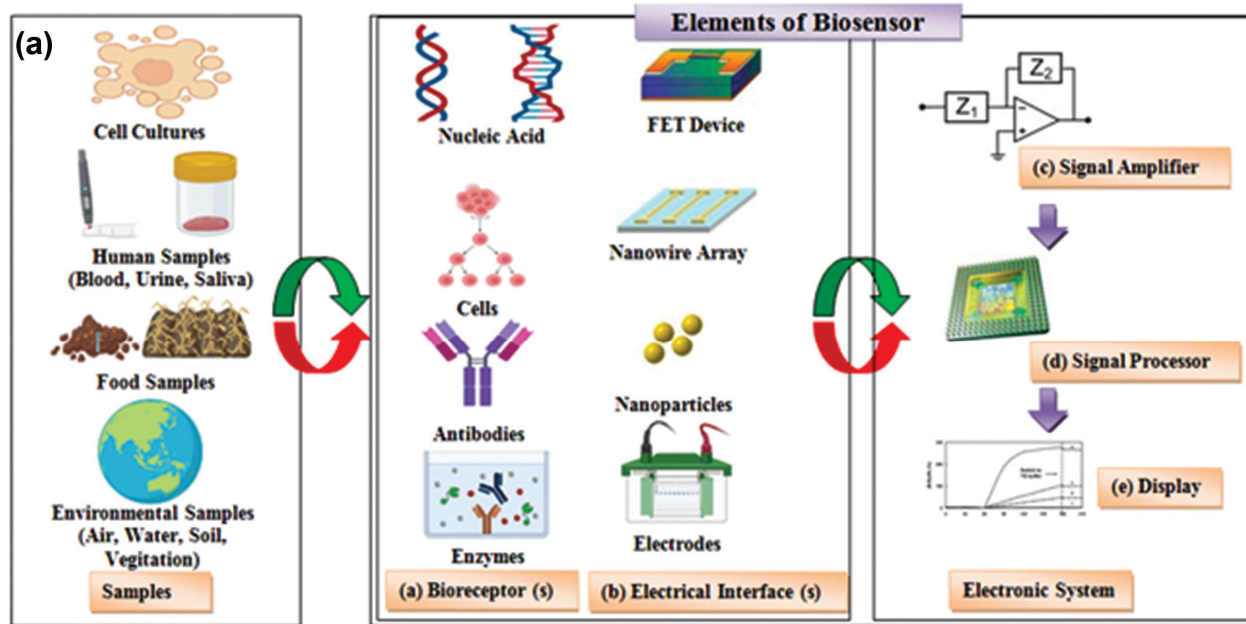


Nano Part I: Improving Sensitivity via Selection of Nanomaterial

Recap: Biosensor

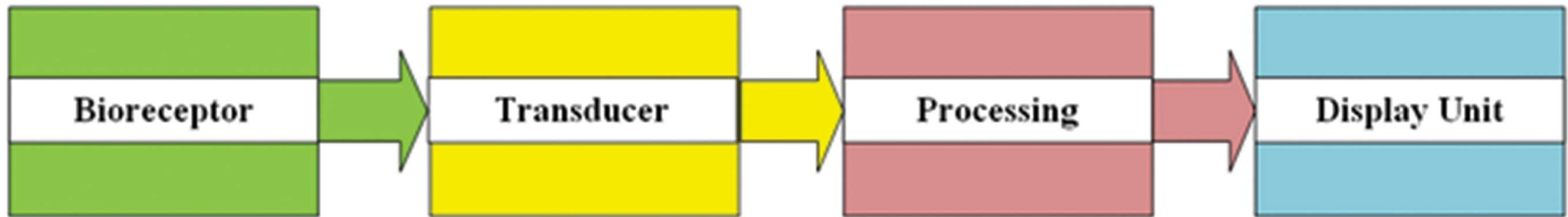
Key components



[1] Kumari, S. et al. Introduction to Biosensors: An Overview. <https://doi.org/10.1039/9781837673230-00001> (2024) doi:10.1039/9781837673230-00001.

Recap: Biosensor

Key components



Key Performance Index:

- ✓ Sensitivity
- ✓ Selectivity
- ✓ Response time
- ✓ Reproducibility
- ✓ Stability

- ✓ Sensitivity
- ✓ Linearity
- ✓ Response time
- ✓ Reproducibility
- ✓ Stability

- ✓ Response time
- ✓ (Size)

- ✓ Ease-of-use
- ✓ Comprehensibility

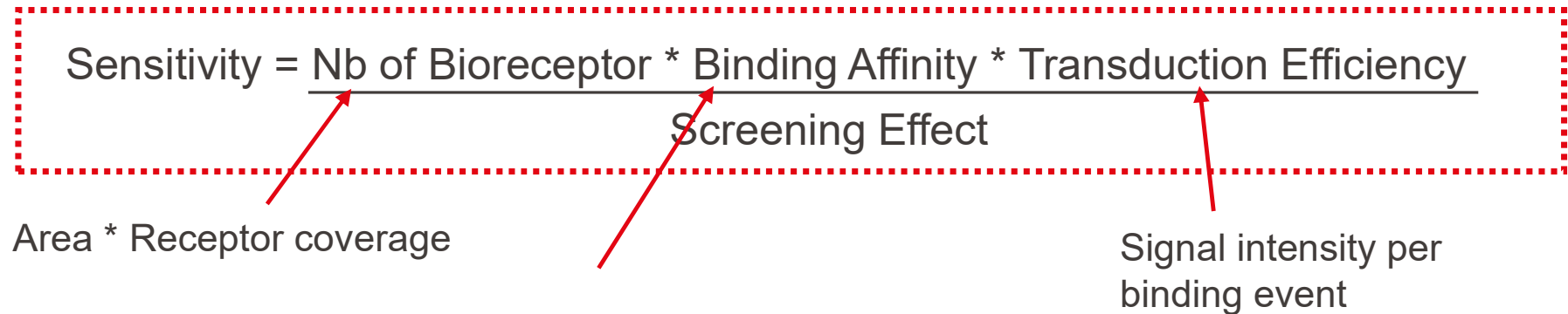
[1] Kumari, S. et al. Introduction to Biosensors: An Overview. <https://doi.org/10.1039/9781837673230-00001> (2024) doi:10.1039/9781837673230-00001.

Sensitivity

Definition

$$S = \frac{\Delta Y}{\Delta C}$$

Difference of Signal Intensity
Difference of Analyte Concentration



Langmuir's
absorption model:

$$\theta_{\text{binding}} = \frac{C}{K_d + C}$$

Sensitivity

Strategies of increasing sensitivity using nanomaterial

$$\text{Sensitivity} = \frac{\text{Nb of Bioreceptor} * \text{Binding Affinity} * \text{Transduction Efficiency}}{\text{Screening Effect}}$$

1. Increase receptor/signal density
2. Smaller transducer
3. Both

Example

Increasing sensitivity via MOF

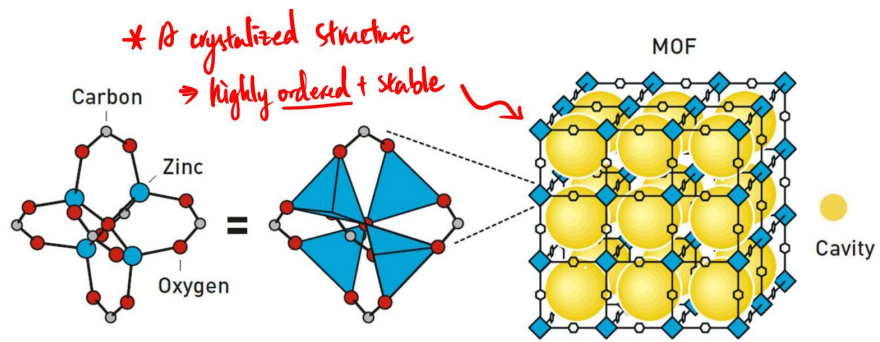


Figure 5. In 1999, Yaghi constructed a very stable material, MOF-5, which has cubic spaces. Just a couple of grams can hold an area as big as a football pitch.

* By modifying the molecular links, the pore size can be changed. → Highly versatile.

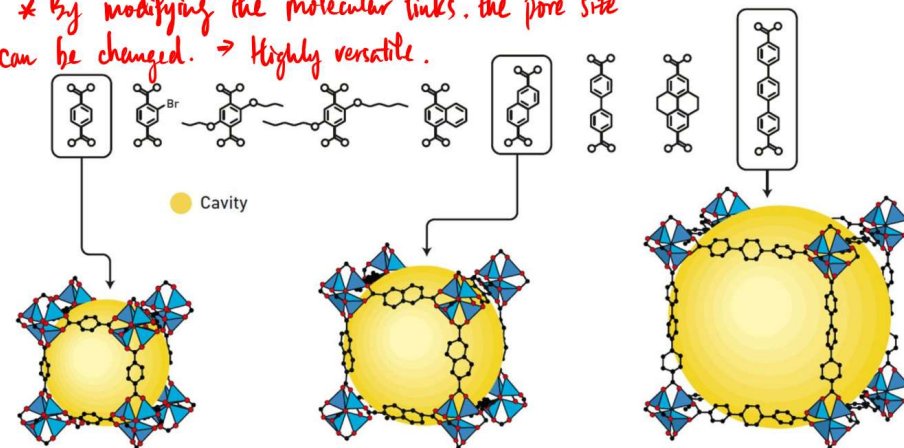
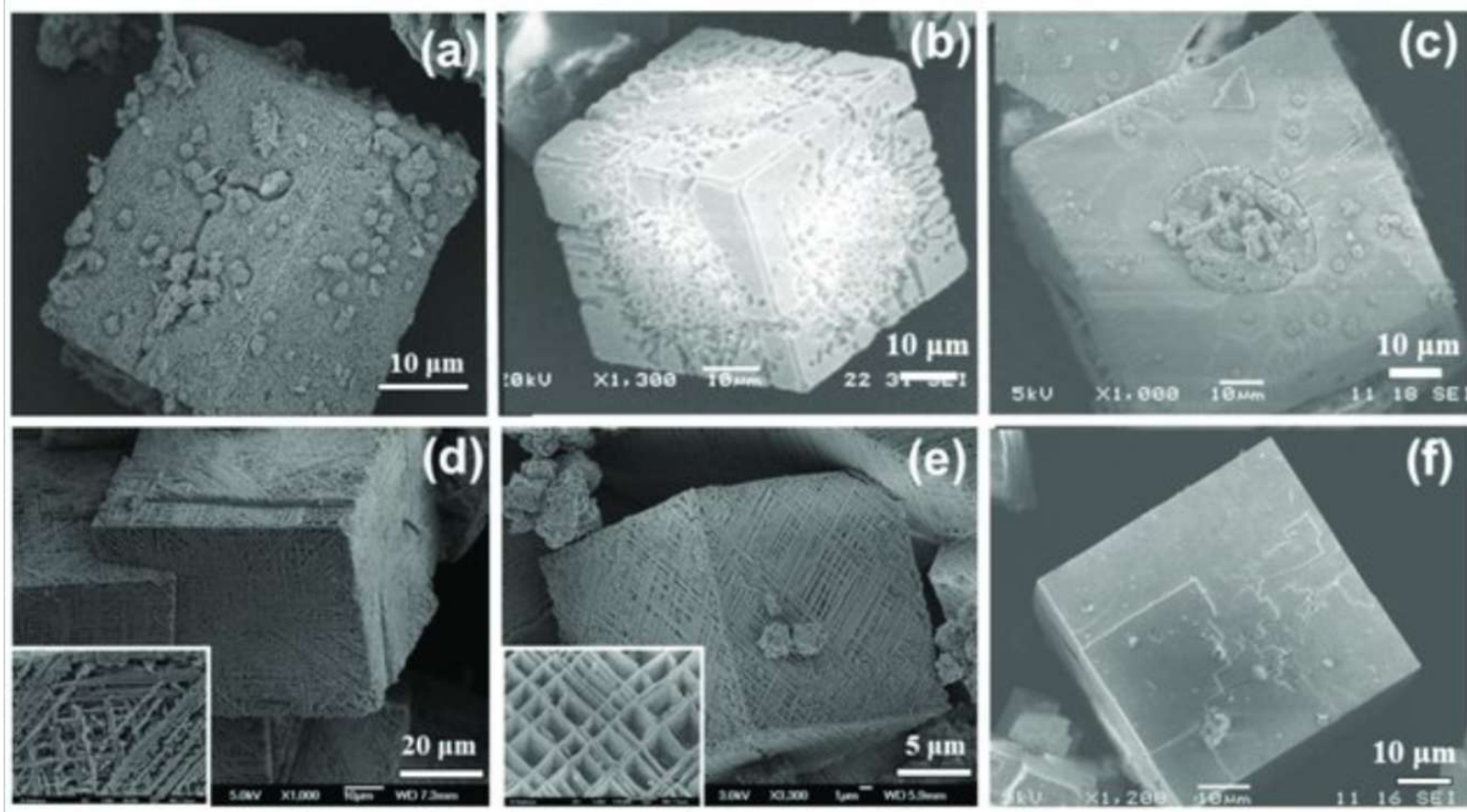


Figure 6. In the early 2000s, Yaghi showed that it is possible to produce entire families of MOF materials. He varied the molecular links, which resulted in materials with different properties. These include 16 variants of MOF-5, with cavities of various sizes.

Example

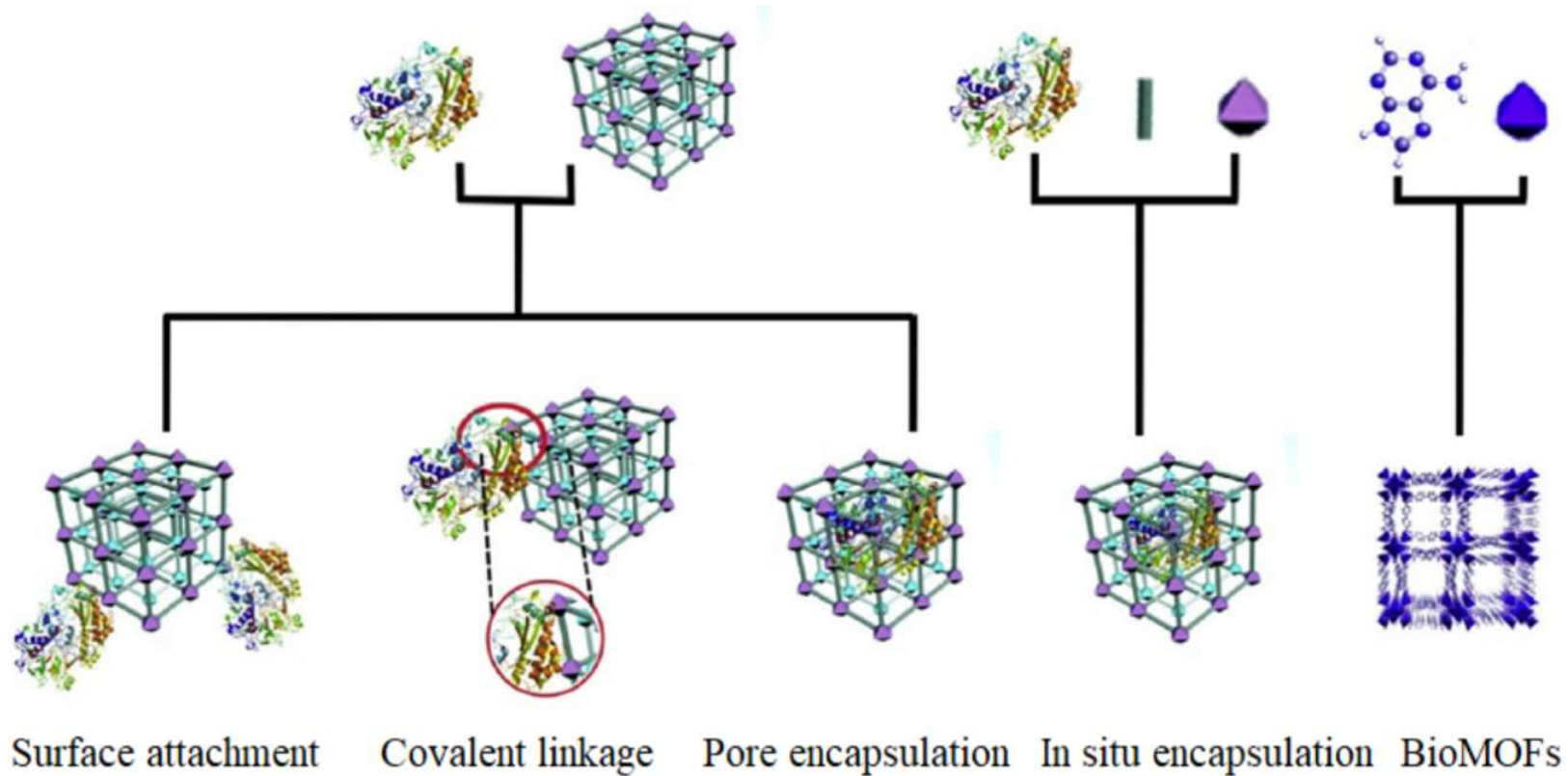
Increasing sensitivity via MOF



[3] https://www.researchgate.net/publication/329899482_Reversed_Crystal_Growth/figures

Example

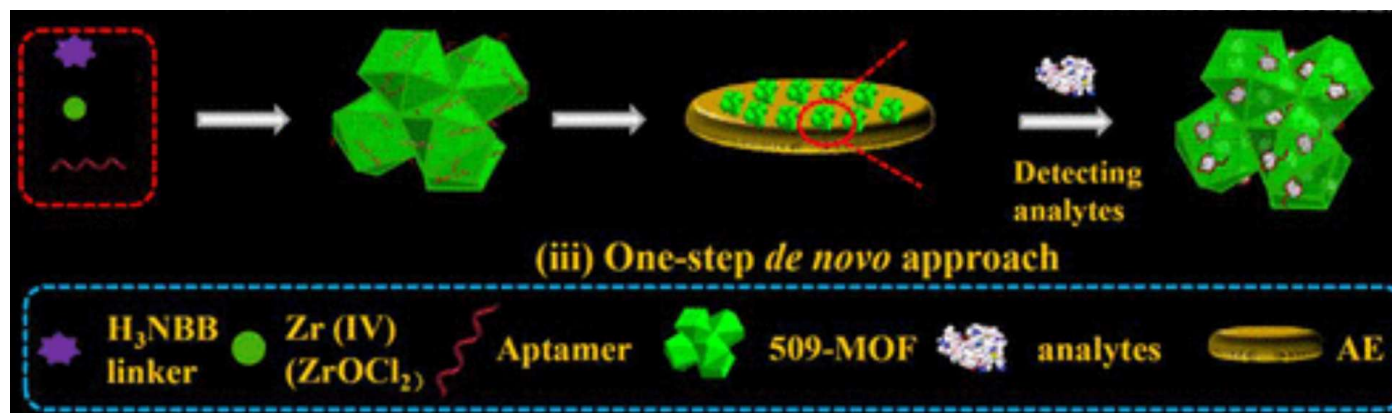
Increasing sensitivity via MOF



[4] An, H.; Li, M.; Gao, J.; Zhang, Z.; Ma, S.; Chen, Y. Incorporation of biomolecules in Metal-Organic Frameworks for advanced applications. *Coord. Chem. Rev.* 2019, 384, 90–106

Example

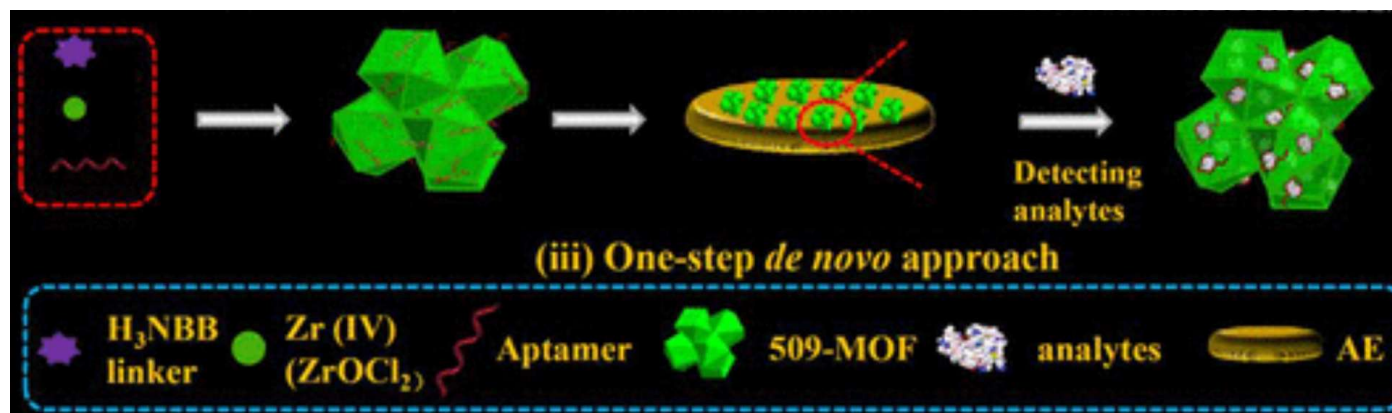
Increasing sensitivity via receptor density



The typical improvement of sensitivity using MOF for hosting the receptor is $\sim 50\times$
 Since the effective surface of MOF is 10,000 larger, why can the sensitivity be increased for 10,000 times?

Example

Increasing sensitivity via receptor density



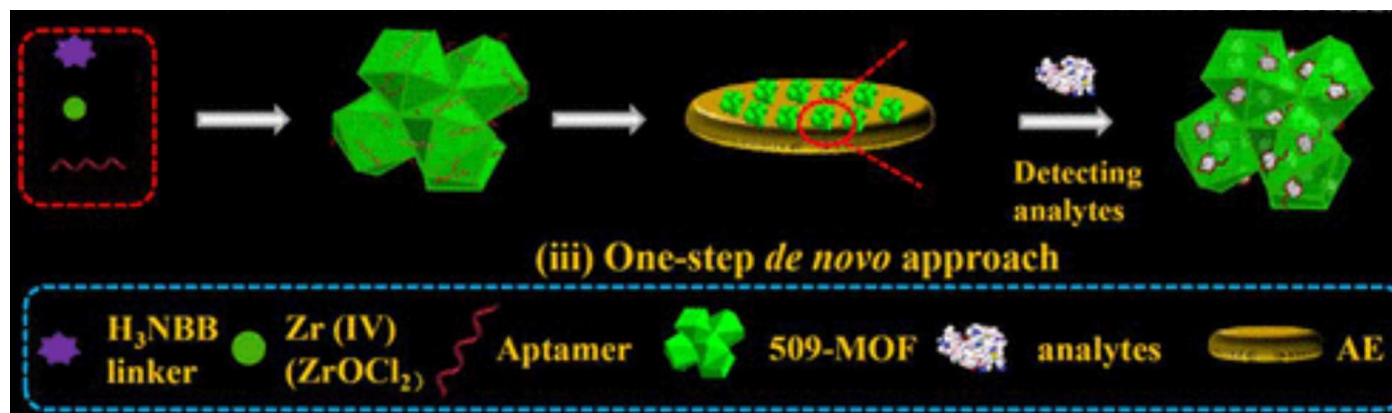
The typical improvement of sensitivity using MOF for hosting the receptor is $\sim 50\times$
 Since the effective surface of MOF is 10,000 larger, why can the sensitivity be increased for 10,000 times?

- Small pore size ($\sim 10\text{nm}$), while antibody is $\sim 20\text{nm}$
 OK, what about aptamers ($\sim 5\text{nm}$)

[4] Li, J.; Liu, L.; Ai, Y.; Liu, Y.; Sun, H.; Liang, Q. Self-Polymerized Dopamine-Decorated Au NPs and Coordinated with Fe-MOF as a Dual Binding Sites and Dual Signal-Amplifying Electrochemical Aptasensor for the Detection of CEA. *ACS Appl. Mater. Interfaces* 2020, 12, 5500–5510.

Example

Increasing sensitivity via receptor density



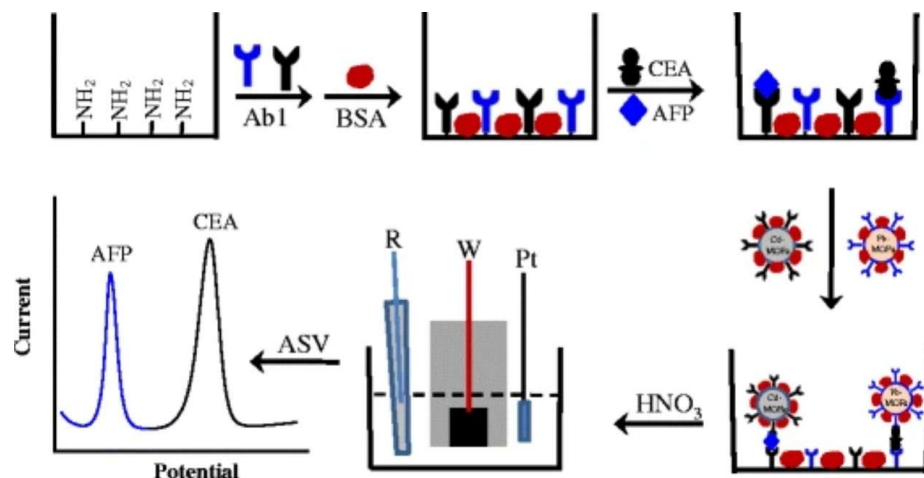
The typical improvement of sensitivity using MOF for hosting the receptor is $\sim 50\times$. Since the effective surface of MOF is 10,000 larger, why can the sensitivity be increased for 10,000 times?

- Small pore size ($\sim 10\text{nm}$), while antibody is $\sim 20\text{nm}$.
- Orientation of the receptors.
- Steric hinderness.

[4] Li, J.; Liu, L.; Ai, Y.; Liu, Y.; Sun, H.; Liang, Q. Self-Polymerized Dopamine-Decorated Au NPs and Coordinated with Fe-MOF as a Dual Binding Sites and Dual Signal-Amplifying Electrochemical Aptasensor for the Detection of CEA. *ACS Appl. Mater. Interfaces* 2020, 12, 5500–5510.

Example

Increasing sensitivity via signal density



Optic sensor: Fluorophores
 Electrochemical: Electroactive molecule
 Si-NW FET: Charged molecules

The typical improvement of sensitivity using MOF for hosting the signal enhancing molecules is ~500 to 1000x. What's the limitation of this method?

- Steric hinderness.
- Debye's length screening.

[5] Zhang, P.; Huang, H.; Wang, N.; Li, H.; Shen, D.; Ma, H. Duplex voltammetric immunoassay for the cancer biomarkers carcinoembryonic antigen and alpha-fetoprotein by using metal-organic framework probes and a glassy carbon electrode modified with thiolated polyaniline nanofibers. *Mikrochim. Acta* 2017, 184, 4037–4045