Gold-seeded lithium niobate nanoparticles as NanoZyme biosensors

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The need for a versatile, simple, fast and sensitive biosensor is crucial for environmental and health applications. Nowadays, enzyme-based assays in biosensing such as ELISA are one of the most used methods due to their high sensitivity and their selectivity. This sensing method basic principle relies on antigen-antibody interaction and the detection is carried out by an enzyme label, which generates a measurable colour product from a chromogenic substrate.[1] Initially, antibodies are fixed onto a solid surface support and they are incubated with the sample which contains the antigen. Subsequently, the antigen is bonded to an enzyme labelled antibody. The last step is the addition of the chromogenic substrate.[2] This method is simple as it is based on a colour change and presents high specificity. However, antibodies and enzymes are expensive and unstable in non-physiological conditions, and the experimental set up requires various steps.[3,4] To overcome these drawbacks, extensive research has been done to replace antibodies and enzymes for other recognition and detection elements.

Aptamers are molecular recognition elements based on single stranded DNA or RNA molecules which are generated by Systematic Evolution of Ligands by Exponential enrichment (SELEX).[5] Among the most remarkable advantages of aptamers over antibodies one can find, the cost reduction which is caused by the *in vitro* synthesis, the unlimited shelf-live, the ease of chemical modification and the relative stability in non-physiological conditions. Additionally, they present little or inexistent batch variation and reversible thermal denaturation.[6–10] SELEX method allows to diversify the targets of aptamer-based biosensors. Aptamers have successfully permitted the detection of a vast range of environmental and biological targets from metal ions to cells and bacteria and the development of various types of sensors.[8,10]

Nanoparticles which mimics enzyme activity are called NanoZymes. The high performance is achieved thanks to the high surface to volume ratio. Among them metal nanoparticles might be a solution. However unspecific aggregation remains a drawback. The immobilization of the metal nanoparticles on the oxide reduces the loss of performance related to this problem. This strategy allow one to to mimic the catalytic performance of enzymes.[11,12]

In addition, it produces a synergetic effect motivated by two complementary processes: a charge transfer between the materials and the creation of defects. This generates a hotspot for catalysis.[13,14] Since the pioneer work of Haruta et al.[15] gold nanoparticles deposited onto an oxide support has attracted lots of attention in catalysis in volatile organic compounds oxidation.

One can deposit directly metal nanoparticles onto the surface of the metal oxide, but the stability of the junction is not guaranteed. In addition, there is a lack of control on how the metal nanoparticles are distributed over the surface. Thus, to maximize the catalytic surface available, a link between the metal and the metal oxide can be introduced. Layer-by-layer method is a simple and rapid method to link the two types of nanoparticles.[16]

Exploiting this feature in peroxidase-mimics has already been investigated in hybrid nanoparticles composed of iron oxide-gold or cobalt oxide-gold.[17,18]

$LiNbO_3$ (LN) is one of the most versatile materials. Its non-centrosymmetric structure confers outstanding nonlinear optics, pyroelectric and piezoelectric properties which make it ideal for numerous applications in optics, batteries and optical communications.[19–21] At the nanoscale, LN NPs present low toxicity and lack of phase-matching conditions which makes it an excellent candidate for bio-imaging and photo-triggered drug delivery.[22,23]. Other features are the semiconducting properties and ferroelectricity which enhances catalysis and photocatalysis, especially in redox reactions. These properties favour charge separation and polarization-induced facile adsorption of the species.[24]

We synthesized gold-coated lithium niobate nanoparticles with branched-polyethyleneimine as an intermediate linker between these two components.[25] We showed that the intrinsic peroxidase-mimic NanoZyme activity of gold nanoparticles is upgraded when they are deposited onto lithium niobate nanoparticles. We also probed that the presence of a link between the two nanomaterials was necessary to ensure maximum efficiency. In addition, we optimized the conditions to maximize the colorimetric response (pH, temperature, quantity and surface coverage). The subsequent addition of aptamers, which bind to the gold nanoparticles, quenches the enzyme-mimics which is restored in the presence of the target. We managed to successfully attach the aptamer and the optimization of the biosensing of antibiotics is being carried out.

References

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Figures

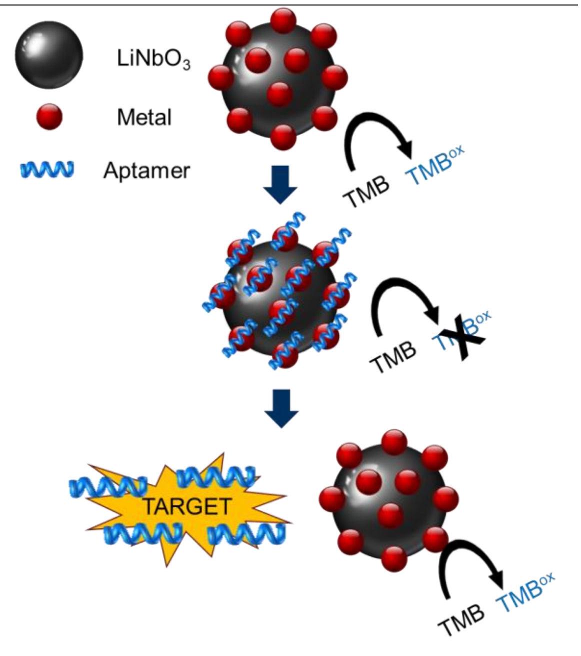

Figure 1: Gold-seeded lithium niobate based aptasensor. Mechanism of action.