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Hybrid nanosensors made of gold and aluminium for enhanced detection of individual biomolecules

Researchers present, in an article published in the ACS Nano cover, a new type of biosensor that uses plasmonic nanoantennas made of gold and aluminum for highly sensitive single-molecule detection, even in the presence of strong background signals.

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Understanding how biomolecules interact between them allows us to have a deeper knowledge of how biological processes work. But, to be able to monitor individual biomolecules in their native environment, one has to manipulate light on very small scales. Traditional techniques to observe single biomolecules in a non-invasive way include methods based on fluorescence detection. In fluorescence, specific molecules - so-called fluorescent labels - are attached to the biomolecules of interest, absorbing light of a particular color and emitting it at a color slightly redder. The emitted light of the fluorescent labels can then be detected, indirectly revealing the biomolecules they are attached to. This indirect detection of the biomolecules helps researchers to better understand the interaction of specific biomolecules in cells and tissues.

Biosensors based on metallic nanostructures are particularly useful for detecting fluorescent labels with high sensitivity because they can enhance their fluorescence emission, making them shine more brightly. However, when trying to detect individual biomolecules in environments with many surrounding molecules, the fluorescence background generated by these fluorescent labels can decrease the fluorescence detection sensitivity. To address this issue, researchers already developed a type of nanostructure called "antenna-in-box" made of gold, that not only enhances the emission of a target fluorescent label but also reduces the excitation of surrounding labels through a tiny hole in a metal film, known as a nanoaperture. This makes it easier to detect individual biomolecules. However, gold is not an efficient material to screen background, ultimately jeopardizing the potential of antenna-in-box nanosensors.

Improving the detection of individual molecules

In an article featured on the cover of ACS Nano, a team of researchers propose a new antenna-in-box design using a hybrid material system made of gold and aluminum, to improve the single-molecule detection sensitivity through better background reduction and higher fluorescence emission of the fluorescent label. ICFO researchers **Ediz Herkert** and **Domenica Romina Bermeo,** led by **ICREA Prof. at ICFO Maria Garcia-Parajo**, in collaboration with Martina Recchia, Wolfgang Langbein and Paola Borri from Cardiff University, report on the fabrication and optical characterization of hybrid antenna-in-box nanostructures made of gold and aluminum, which they optimize to improve the signal-to-background ratio, fluorescence excitation enhancement, and fluorescence emission enhancement provided by the nanostructures.

The team demonstrates that biosensors based on hybrid antenna-in-box nanostructures can improve the sensitivity of fluorescence-based biosensing applications. In their paper, they show that using hybrid materials and controlling the nanoaperture diameter lead to improved signal-to-background ratios. Most importantly, the team discovered that these finely-tuned hybrid nanostructures also provide additional excitation intensity and fluorescence enhancements. As a result, a major gain in the sensitivity for the detection of single biomolecules is achieved in the presence of strong background signals, which is the common scenario of biological samples.

However, despite their advantages, fabricating these hybrid nanosensors is technologically very challenging. Thus, the team also established a two-step electron beam lithography process, a technique used to create patterns on a substrate, for the reproducible fabrication of the hybrid material antenna-in-box arrays, demonstrating improved detection sensitivity compared to conventional fluorescence biosensing methods. ?

These results demonstrate that using alternative material combinations can further improv the sensitivity of biosensors of single-molecule biosensing applications. By combining gol and aluminum, the hybrid nanostructures can achieve a better performance than the one purely made of gold, which has been, until now, commonly considered the ideal material fo the wavelength under study.