Designing ultra-sensitive biosensors for early personalised diagnostics

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A new type of high-sensitivity and low-cost sensors, called plasmonic biosensors, could ultimately become a key asset in personalised medicine by helping to diagnose diseases at an early stage.

Personalised medicine is one of the new developments that is deemed to revolutionise health care. A key component is the detection of biomarkers, proteins in blood or saliva, for example, whose presence or abnormal concentration is caused by a disease. Biomarkers can indicate the presence of diseases long before the appearance of symptoms. However, currently the detection of these molecules still requires specialised laboratories and is costly.

Thanks to the EU-funded research project called NANOANTENNA, completed in March 2013, physicists joined forces with chemists, nanotechnologists and biomedical researchers with the aim of developing a so-called plasmonic nanobiosensor for the detection of proteins. It consisted of nanoantennas, tiny gold rods about 100 to 200 nanometres long and 60 to 80 nm wide. By shining light onto such a nanoantenna, the electrons inside start moving back and forth, amplifying the light radiation in hot spots regions of the antenna, explains Pietro Giuseppe Gucciardi, a physicist at the Institute for Chemical-Physical Processes, affiliated with the Italian National Research Council CNR, in Messina, Sicily. "The aim of the project was to deliver a proof of concept," says Gucciardi.

During the 1990s' researchers found that plasmons, tiny waves of

electrons in metallic surfaces that appear when such surfaces are illuminated, also amplify the light in an area close to that surface. In biosensors, protein molecules are identified by irradiating them with infrared light and by analysing the spectrum of the light they emit, known as a Raman spectrum. If these molecules are close to nanoparticles, the plasmons in the nanoparticles enhance the Raman signal coming from the molecules that have to be detected with several orders of magnitude.

The nanoantennas developed in this project only enhance the emitted Raman signal if the biomolecules are close to the hot spots. Therefore, the molecules have to be trapped to be detected. To do so, the researchers attached bioreceptors, fragments of DNA engineered to recognise specific proteins, to the nanoantennas. When the nanoantennas studded with the bioreceptors are incubated in a solution that contains the biomarkers to be detected, the latter become attached to the nanoantennas. When, subsequently, these nanoantennas are illuminated with light, they show the Raman fingerprints of both the bioreceptor and the biomarker, as Gucciardi points out.

One expert comments that health-care programmes are quickly moving to prevention and early detection of diseases, done in point-of-care (POC) or bed-side conditions. "It is important to fund this research because it will be a component of future medicine," says Alexandre Brolo, professor of chemistry specialised in nanotechnology research, who has been developing plasmonic biosensors at the University of Victoria, British Columbia, Canada. He also believes that such approach will make medical care more cost effective. "You want something that is very cheap and is not going to put a big burden on the health care system," says Brolo.

Another expert agrees. "Small, compact and autonomous devices with the same features in terms of sensitivity and robustness as current

commercial instrumentation based on plasmonics are still needed," says Maria Carmen Estévez, a researcher at the Catalan Institute of Nanoscience and Nanotechnology in Bellaterra, Spain. The "end-users" of these biosensors have to understand that the development of these devices by researchers in many disciplines is a long process, notes Estévez. She adds that these biosensors will need to be integrated with optical components, with electronics for reading out the measurements, software to process all data, and rely on the use of microfluidics to prepare and process the sample.

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