INTEGRATION OF PLASMONIC NANOPARTICLES IN 3D PRINTING

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The new generation of sensors can be designed to work in conjunction with smartphones exploiting the detection and optical illumination capabilities of handheld devices. Plasmonic nanostructures have a significant potential to become the new element of the optical sensing devices. A recent study showed that with 3D printing it is possible to create new functional materials using additive assembly nanomaterials[1]. Depending on the deposition parameters, it was possible to obtain functional 3D-printed plasmonic structures with either graded or sharp interfaces. We propose to produce plasmonic/polymer structures by 3D printing based on filament precursor containing nanoparticles made of noble metals.

The technology for integration of plasmonic nanoparticles into 3D structures is the main objective of this study. It consists of several stages. First, we need to determine which polymer will be used. The polymer should be transparent and have a smooth surface in order to act as efficient optical elements. Given the thermal sensitivity of the plasmonic nanoparticles, we investigate the printing temperature of different polymers to minimize particle melting and aggregation that result in degradation of the plasmonic activity.

Two ways for introducing the nanoparticles into the 3D polymer ink will be investigated. The first method consists of mixing the nanoparticles with the dissolved polymer, and then making the mixture completely homogeneous using chemical methods. In this approach, polylactic acid (PLA) a biodegradable polymer with relatively low melting temperature is used. This material is advantageous for this study since it is widely employed in 3D printing and can be chemically functionalized with the nanoparticles. The finished mixture is melted in an extruder to obtain the filaments used in the 3D printing process.

The second method for introducing the nanoparticles in 3D printing involves the use of polyethylene terephthalate (PET). Because it is soluble only in chemically hazardous reagents, purely physical methods of mixing of nanoparticles and PET will be used. It will be mixed directly in the extruder at relatively high temperatures than those used for PLA. The main risk is that nanoparticles can fuse together during the polymer melting process.

The polymer filaments with nanoparticles will be optically analyzed, and the rationality of its future uses and the methods of parameter optimization will be discussed. Ultimately, we aim at determining the best method of preparation of the mixture of polymer nanoparticles, including the choice of polymer.

The sensor that will be created based on the plasmonic structure will be used as a portable device for chemical detection in different media such as blood, urine, and other liquids[2]. The devices will be developed based on numerical simulations and prototyping based on the finite element method.

Figure 1 presents a scheme of the sensor. Here, the camera acts as the optical detector, and the light from the display as the light source. The light falls directly on the structure, which contains the analyte flow, after it is refracted by the prism and focused on the front camera of the smartphone. The physical principle of detection is based on the phenomenon of Localized Surface Plasmon Resonance (LSPR). Due to the LSPR, the local electromagnetic field around the metallic nanoparticles will be enhanced dramatically, with the resonant wavelength being sensitive to the variation of the local dielectric environment. Noble metal nanoparticles, such as gold and silver, exhibit a strong optical extinction at visible and near-infrared (NIR) wavelengths and generate LSPR phenomenon which is sensitive to the surrounding medium. Accordingly, the camera will show the image in which the color of the absorbed wavelengths will be missing. Such selective decrease in intensity will be correlated with the presence of the analyte to be detected[2].

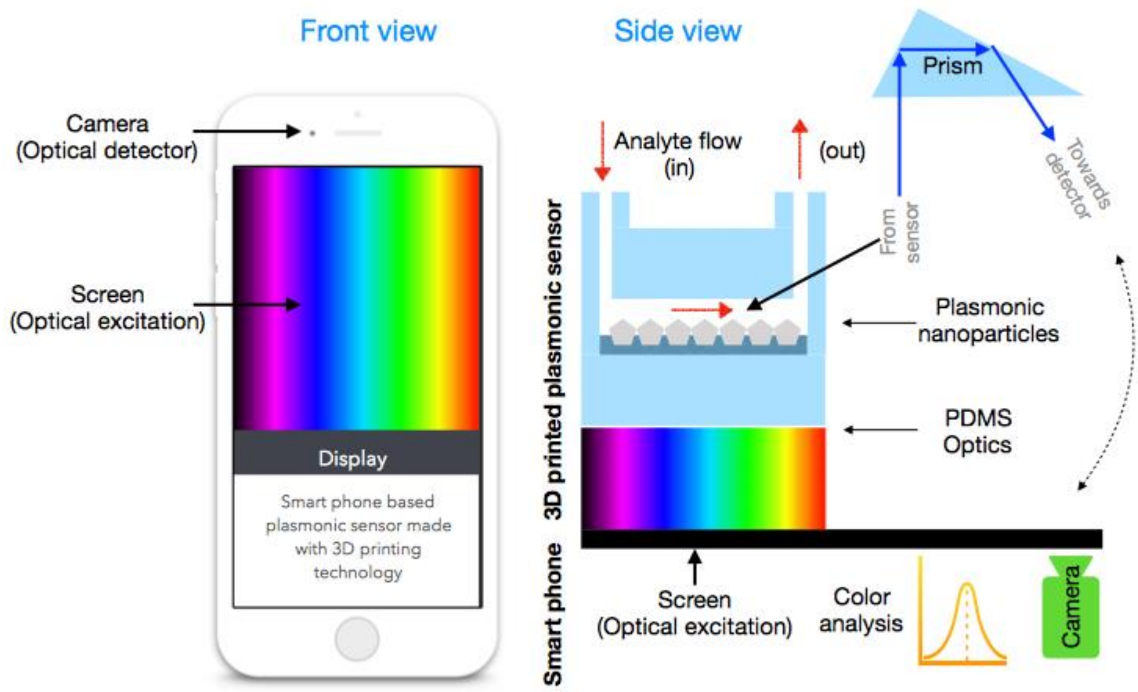

Figure 1. 3D-printed plasmon sensor based on a smartphone

We expect that our technology will make an innovative contribution for the inexpensive fabrication of portable optoelectronic devices that can compete with conventional sensor technologies. It will be a very simple way to implement biomedical chemical detection and for other applications where the only extra part required is a device that most people from both developed and under developed countries already have access to.

References

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