Fabrication and fluorescence analysis of biofunctionalized gold quantum dots array

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Abstract

The development of new biosensors with the help of micro- and nano-scale technologies allows the improvement of current medicinal diagnostic and therapeutic methods. Optical biosensors represent a broad group of tools based on luminescence, fluorescence, colorimetry or interferometry. These sensors, which are both very sensitive and selective, have found numerous applications, mainly in *in vivo* and *in vitro* imaging [1].

In vitro optical biosensing of proteins and nucleic acids based on fluorescence detection can be easily achieved using quantum dots array. In general, various materials including semiconductor oxide or noble metals are used for the creation of quantum dots strongly fixed on solid substrates [2]. Gold belong to the most studied material due to its attractive fluorescent and plasmonic properties [3]. Self-ordered gold quantum dots array can be readily created via gold pulse galvanic deposition onto pre-patterned surface. This non-lithographic template based process of fabrication is cheap, rapid and well reproducible [4].

The method is based on the formation of nanoporous anodic aluminium oxide (AAO) template on tungsten nanolayer, which is transformed into tungsten oxide nanostructures (see Figure 1 a-e). In the following step, these WO_3 nanostructures are selectively removed from AAO template in chemical etching process which results in the creation of nanodimpled surface. Finally, gold is electrodeposited trough AAO template into self-ordered dimples. After AAO template selective dissolving, gold quantum dots with tunable size and strong adhesion to substrate are formed.

The complex of fabrication conditions, such as current density, electrolyte composition, concentration, and temperature, and duration and number of deposition pulses as well as a period between each pulse significantly influence the final QDs dimensions and ordering. All these parameters have to be taken into account regarding the achievement of homogenous coverage of surface with QDs having uniform size distribution.

The surface roughness of pure metal layers before anodization process is measured using profilometer. Ordering and size of Au QDs are analyzed using SEM (see Figure 2). The influence of vacuum annealing on Au QDs crystallinity is also studied. The chemical composition of Au QDs is characterized using EDX and XPS. The fluorescence correlation spectroscopy and stationary polarized fluorescence were used for the study of Au QDs array optical properties before and after biofunctionalization. Two biomolecules, namely glutathione (GSH) tripeptide and bovine serum albumin (BSA) protein, were chosen as model compounds for Au QDs modification. The surface immobilization of these biocomponents is done by means of physical adsorption. These ligands can further serve as binding partner for detected analyte in the solution.

References

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[3] Ng V. W. K., Berti R., Lesage F., Kakkar A., Journal of Materials Chemistry B, **1** (2013) 9.
[4] Calavia R., Mozalev A., Vazquez R., Gracia I., Cane C., Ionescu R., Llobet E., Sensors and Actuators B-Chemical, **149** (2010) 352.

Figures

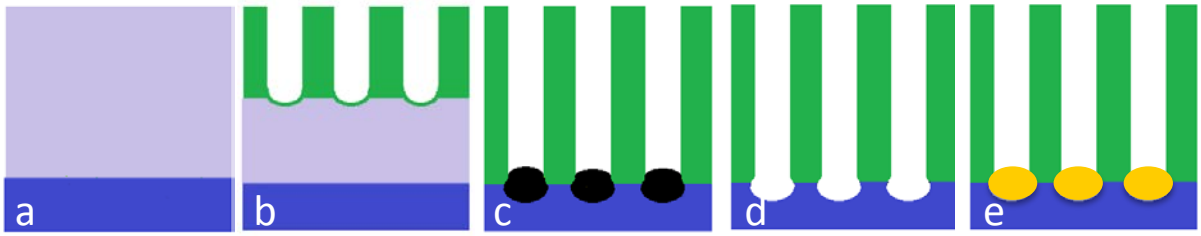

Figure 1 Fabrication of self-ordered Au QDs array: a) thermal-evaporated aluminium layer (light blue) on sputter-deposited tungsten layer (blue) on silicon wafer; b) anodic oxidation of aluminium layer into alumina nanoporous template (green); c) anodic oxidation of tungsten layer into tungsten trioxide forming ordered nanodots on the pores bottom (black); d) self-ordered nanodimples after tungsten trioxide nanodots removing; e) gold nanodots galvanically deposited into the dimples through alumina template.

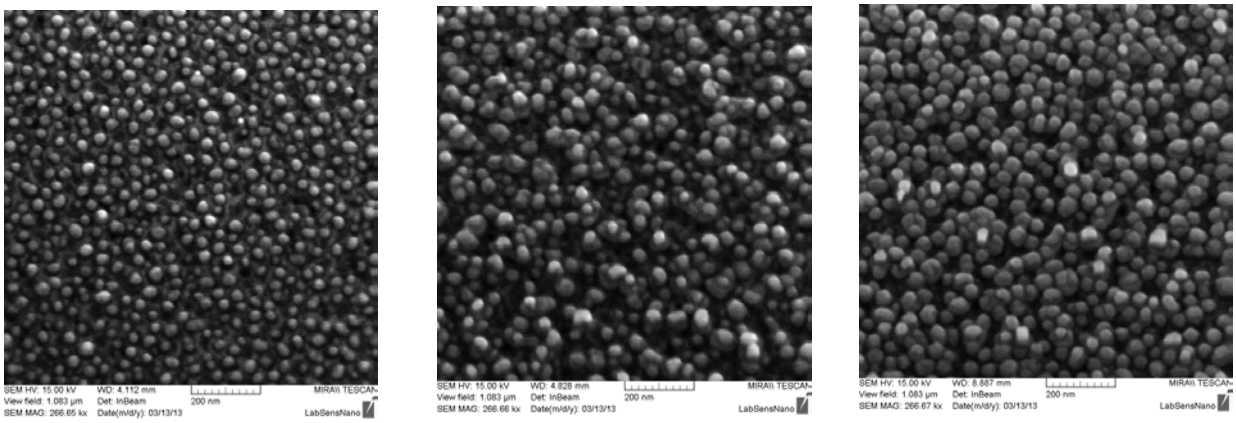

Figure 2 SEM figures of self-ordered Au QDs array prepared under 5 pulses and deposition time of 250 ms (left); 15 pulses and deposition time of 100 ms (center); and 15 pulses and deposition time of 200 ms (right). The estimated size of Au QDs varies from 10 to 30 nm depending on the preparation conditions.