FABRICATION OF NICKEL NANOSTRUCTURES BY TEMPLATE-BASED ELECTRODEPOSITION METHOD AND ANALYSIS

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ABSTRACT

The procedure of creating nickel nanostructures consists in metal deposition through nanoporous alumina template. The width and the density of nanostructures are given by applied template. The length of nanostructures depends on speed of metal deposition. It is possible to create different sorts of nanostructures by altering the parameters which can modify the type of structure.

1 INTRODUCTION

The described technique of forming nanorods (nanowires) or nanotubes is based on using nanoporous non-conductive template (Whatman Anodisc) which is coated with metal layer on one of its sides. During the electrodeposition the nickel metal is growing only on the metal layer (representing cathode) and fills up the nanopores. After dissolving the template (in NaOH or H_3PO_4) nickel nanostructures are obtained. The process is illustrated in Fig. 1.

The length of nanostructures depends on amount of deposited metal, thus according to the Faraday's law (with certain limitation determined by diffusion) the required length of nanostructures can be achieved if the current density and the time of electrodeposition are adequate.

In the case of metal deposition into the template nanopores (the diameter of the pore is smaller then 200 nm) only diffusion as a way of mass transport is effective and a series of two diffusion layers exist. A quasi spherical diffusion layer is added on top of a linear diffusion layer. [1] In order for the plating process to be the most effective the limiting current density has to be determined. If the current exceeds the value of the limiting current a sharp growth of the cathodic current can be observed due to the hydrogen evolution. [2]

The current density has significant impact on the growing structure of the deposited metal. At low current densities, when the discharge of ions happens at a slow rate, crystal nuclei will tend to grow into large crystals. At higher densities the fresh nuclei will tend to be created and deposited metal will consist of small, fine-grained crystals. [3]

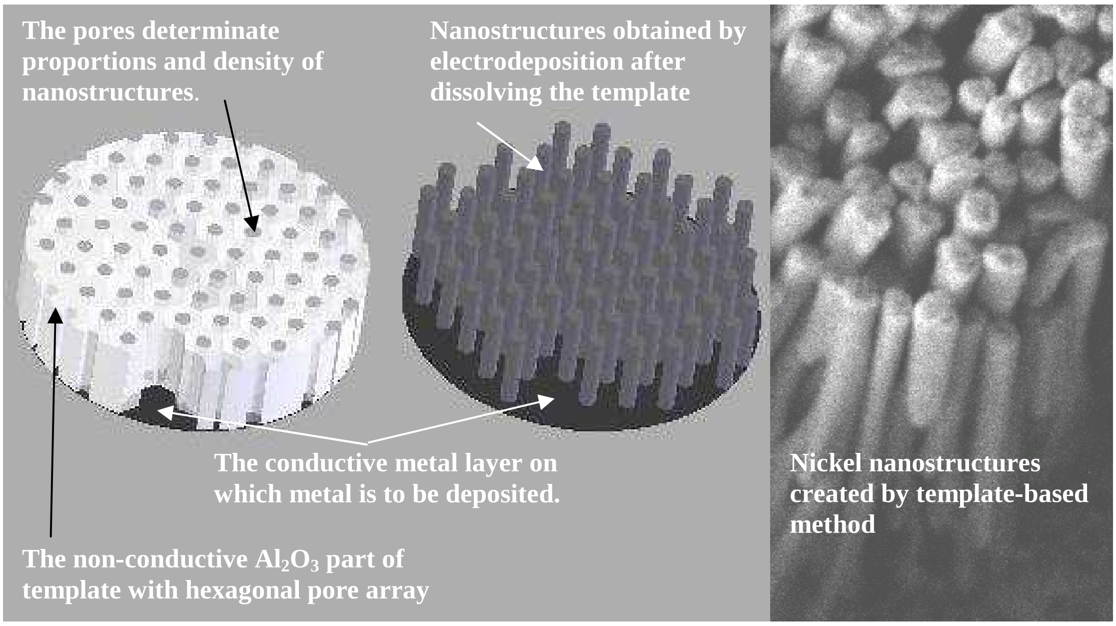

Fig. 1: *Procedure of nanostructures creation*

2 EXPERIMENTS

In order to determine particular length of nanostructures the dependence of amount of the deposited metal on the current density and the time had to be examined. Several preliminary experiments (carried out on copper samples) revealed that the weight of the deposited metal *m [g]* is continually proportional to both current density *I/S [mA/cm²]* and time *t [s]*. According to the examination and the Faraday's law the equation (1) for Ni was derived.

$$m = 0{,}163\overline{6} \cdot 10^{-6} \cdot t \cdot {}^{I}\!/_{S} \tag{1}$$

As an electrolyte, Watts Bath (250g/l $NiSO_4$, 50g/l $NiCl_2$, 34g/l H_3BO_3) was used. The boric acid served as buffer agent, which adjust the pH close to the cathodic film. The pH was ranging between 3 and 3,5 and the temperature of the solution was 55°C.

3 RESULTS

Fabricated nanostructures were examined by scanning electron microscopy (SEM), which revealed that various types of nanostructures were obtained. (Although it is never certain that the identification of nanotubes is correct because of resemblance to insufficiently dissolved alumina template. An example of not fully dissolved template is in Fig. 2a.) Interesting thin-walled nanotubes (Fig. 2b) were obtained at low concentrated (5%) electrolyte and this type of nanostructures is often created when the template with wide pores (0,1μm and 0,2μm) is employed. The nanostructures shown in Fig. 2c were created at very similar conditions but at higher electrolyte concentration. However in such case it is not sure if the nanotubes are not a remainder of the template or unfinished nanotubes. The thin-walled nanotubes with thin hollow (Fig. 2d) were achieved from experiments with 100%

concentrated electrolytes. There is also uncertainty that the structure is made from nickel metal. Sometimes even a kind of structure which is something between nanotubes and nanorods was created (Fig. 2e). The nanostructures which were desired to create above all are nanorods (Fig. 2f). They are sometimes formed in strange clusters (the reason of it is not known yet) but on samples where the nanorods cover the surface uniformly, the length of nanorods corresponds with derived equation (1).

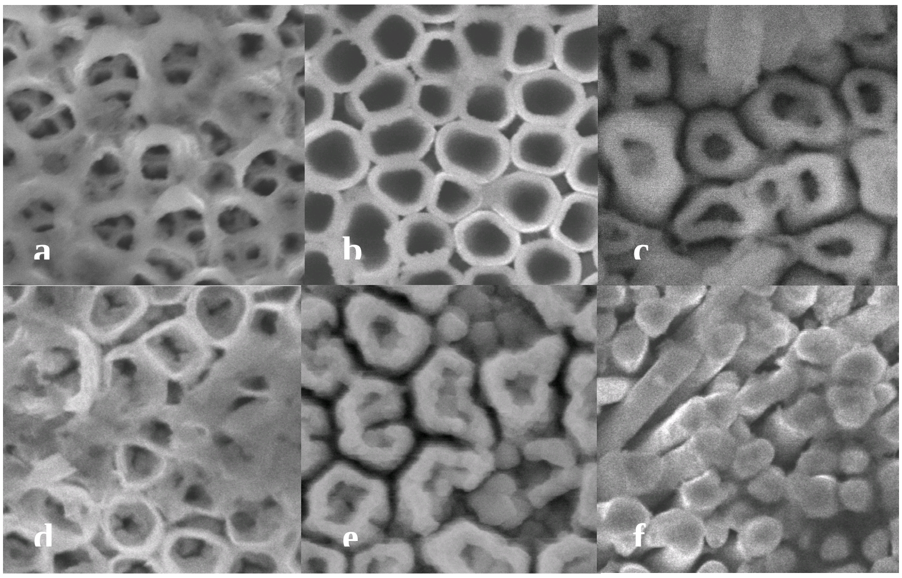

Fig. 2: *SEM analysis of created nanostructures*

4 CONCLUSION

The nanorods of required proportions and other different nanostructures were created. They can be applied where it is essential to create intended surface on the small area, like in sensor technology.

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