New Concept of integrating Nanowires in Technical Devices by Anodization of Aluminium

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Abstract

Nanowires are of great interest for technical devices, because of their special electric and magnetic behaviour. The main challenge in micro production technology is to realize a reproducible process for handling these nanowires. Otherwise it leads to a high rejection rate depending on failures in critical process steps. To avoid this, new production methods for nanowires-containing devices have to be found. The chosen way deals with the idea of using an anodized Al mask. The aim is to integrate the nanostructures into a MEMS technology to enhance its application field.

1 Introduction

Nanowires are of great interest due to their huge capabilities in technical applications. In 2008 e.g. electrical engineers of the University of California, San Diego created solar cells spiked with Indium phosphide nanowires that boost its efficiency [1]. ZnO is also known for its superior properties. Wang et al. were able to create ZnO nanowires with controlled dimensions and morphology to be used in electronic and optical nanodevices [2].

For creating nanowires, different methods were evaluated over the years. The fabrication by either vapour-liquid-solid growth or vapour-solid growth was tested and the optical and electronic properties of single nanowires were studied [3]. Several other groups tried to get defined nanowires through liquid phase reaction [4]. Usually all these methods lead to nanowire mixtures featuring different properties. These have to be characterised before further processing. Nevertheless, a more reproducible process is still required.

The process of aluminum anodization is known for decades. Over the last years it became more important due to the fact that it is a controllable self-organizing process. Former studies showed that it is possible to get porous alumina membranes with self-

organized 100 nm interpore distance [5]. A wide range of anodization processes were tested to optimize the self-organization and to manipulate the porous structures afterwards [6, 7].The fabrication concept proposed in this paper is to combine the well-known and ordered structures of the anodized Al with an electroplating process to generate the mask for growing nanowires. The anodized Al is used as a template (mask) for the plating process to grow nanowires. The first step to generate a mask was to get more information about the anodization process. Pure Al is known for well-structured anodization results. Figure 1 shows the model of a pure Al block which surface was treated with phosphoric acid and a voltage of 120 V [8].

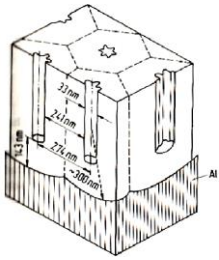

Figure 1: Model of anodized Al [8].

The proposed process is shown in Figure 2. Step A shows a wafer layout with typical microstructures. These structures are exemplary for a structure used in microsensors which should be contacted by the nanowires. A layer of aluminum is e.g. vacuum evaporated over the microstructures (step B). Afterwards, this layer is anodized to create the mask holes (step C). Finally, the holes are galvanically filled to grow the nanowires (step D). Furthermore, the anodization of aluminum on different substrates is executed to evaluate a flexibility of an approach.

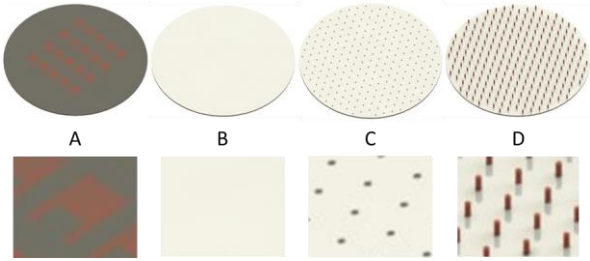

Figure 2: The different process steps (A-D).

2 Experimental

Our general procedure was related to the experiments by Li [9] and Sousa [10]. The samples are pre-treated with isopropanol and acetone. The anodization is performed from several minutes up to an hour to evaluate the process. Oxalic acid is used during the anodization. Several anodization steps are performed after another. For each step the samples are cleaned, so the Al oxide layer is removed to generate a prestructured substrate. This prestructure is the so called barrier layer which consists of Al oxide. It is meant to channel the following anodization to a more ordered porous layer.

3 Results

Tests with aluminum and silicium substrates were performed. The results are distinct and promising. The Al substrate shown in Figure 3 is vacuum evaporated (1) with a pure layer of aluminum. After the first anodization step (2) a hardly ordered layer of aluminum oxide is formed on the surface. This layer is removed (3) for further treatment.

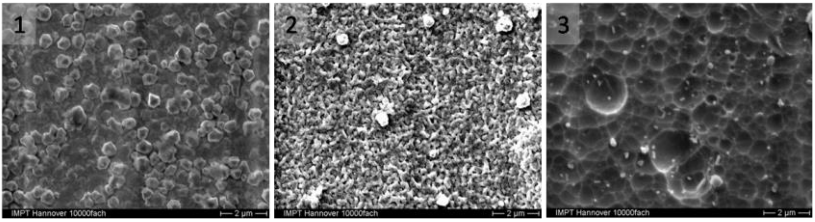

Figure 3: The substrate through the first three steps of the anodization process.

The achieved roughness (Ra) of Si averages 5 µm. The used Al substrate featured a 10 times higher Ra compared to the Si substrate. The influence of the surface roughness on the forming of the layer during the anodization process is shown in Figure 4. Therefore, the Si substrate (4) was additionally planarized by chemical mechanical polishing. A pore size of 200 nm could be reached.

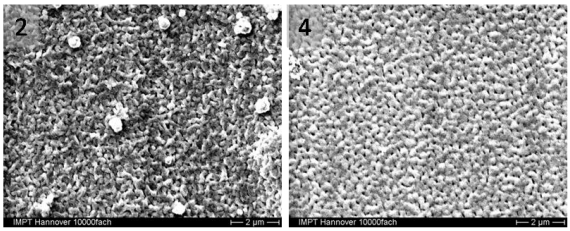

Figure 4: Comparison between an Al (2) and a Si (4) substrate.

4 Conclusion and Outlook

The parameters of the process were studied and first tests with different samples of Al and Si were done. In fact, the influence of the bulk material used can lead to several disorders in the final mask structure. In order to avoid disorders caused by roughness or missing adhesion of the Al, detailed tests are planned. The chemical mechanical polishing showed good results and will be further investigated. The comparison of these results to the state of the art opens new perspectives for the use of anodization as a flexible mask fabrication process. The combination of a mask to build the nanowires, which is also used to increase the stability of the whole sensor system afterwards, seems promising.

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