Top-down approaches for the fabrication of titanium nanostructures

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Titanium nanostructures are already used in devices and circuits that show a great potential for the future of microelectronics[1]: MEMRISTORs[2], and SETs[3]. However, very few results have been reported on the fabrication of those types of devices using electron-beam lithography (EBL) combined with plasma etching[4], or chemical mechanical planarization (CMP). This paper presents two approaches for the fabrication of top-down titanium nanostructures. The advantages and limitations of each process will be discussed, and the results will be compared with titanium structures obtained with a PMMA two layer lift-off process.

The first process involves an EBL followed by a tailored titanium plasma etching. The two main challenges lie in the optimization of the negative tone MaN electroresist resolution, and in the definition of a controlled titanium etching process. Figure 1 illustrates a less than 20nm wide and 40nm thick MaN line that has been obtained with a diluted resist and an agitated development solution. The titanium dry etching is very sensitive to the native and process dependent titanium oxide grown on the surface. In this work, the etching has been achieved at 5mT using a Cl2, BCl3 based chemistry and very low platen and coil RF power. The patterns have been successfully transferred to the material at about 70nm/min using positive ZEP (Figure 2) or negative MaN electroresists.

The second approach is a damascene process where the titanium nanostructures are buried in the oxide. Very shallow and narrow (20nm x 30nm) trenches are first patterned in the oxide[5], while the nanostructures are achieved by planarization of the evaporated titanium film. The dimensions of the structures are defined by the EBL resolution and the etching recipe. The third dimension, the titanium or any other metal thickness, can be controlled down to few nanometers thanks to the CMP. The titanium removal rate (RR) is adapted by adding an oxidizer, H_2O_2, to the slurry solution and a 1:1 $Ti:SiO_2$ selectivity is obtained by diluting the 50nm silica slurry with DI water or isopropyl alcohol (IPA). IPA allows a better control of the within wafer non uniformity (WWNU), and dishing, without appearance of titanium agglomerates surface scratches due to DI water addition. Figure 3 shows a fabricated titanium nanostructure with a line width of less than 40nm.

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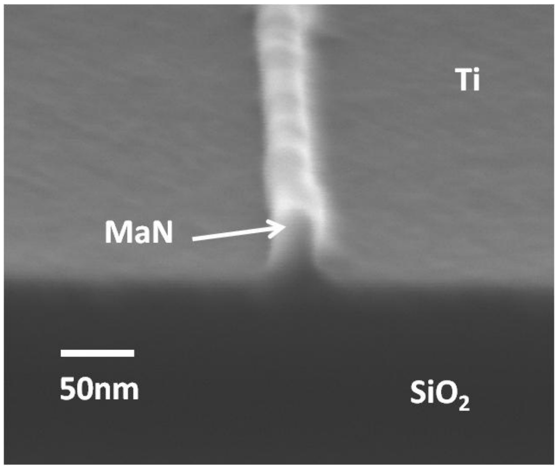

Figure 1: Cross-section SEM micrograph of a 40nm thick and 18nm wide MaN electroresist line on top of a 20nm titanium layer.

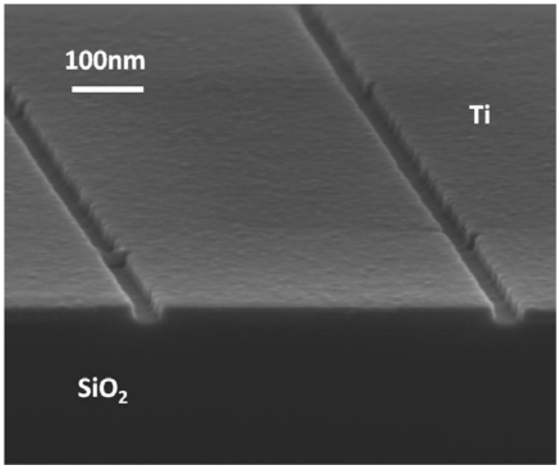

Figure 2: Cross-section SEM micrograph of 20nm thick etched titanium. The 30nm wide trenches have been patterned using ZEP electroresist.

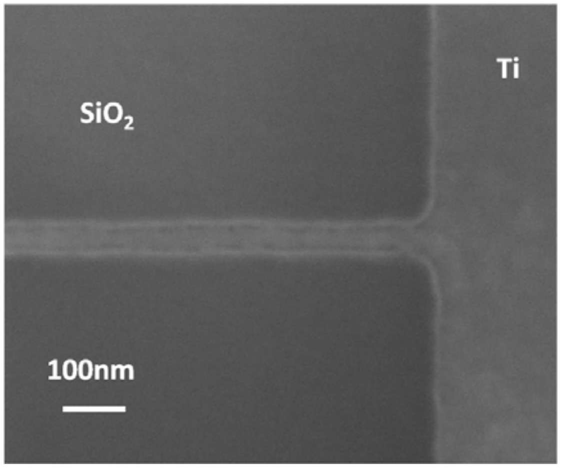

Figure 3: Top-view SEM micrograph of a buried titanium nanostructure showing a line width of 36nm.