TEM Characterization of Etched Si Nanopillars Prepared by Small Angle Cleavage Technique

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Introduction

Silicon nanowires are promising candidates for future device applications, e.g. in single-electron devices. Shrinkage of nanopillars by subsequent dry thermal oxidation enables the fabrication of silicon nanostructures in the sub-10 nm regime. Such structure sizes are required for semiconductor devices, and make use of quantization effects. The properties of these nanostructures are strongly affected by etching-created defects and by their surface.

Fabrication of Silicon nanopillars

Silicon nanopillars were fabricated by an CF based highly anisotropic reactive ion etching (RIE) process. This process uses a lithography technique utilizing gold colloidal particles (or citrate Au sol [1]) with 50 nm diameter as mask. Silicon nanopillars were fabricated by an CF based highly anisotropic reactive ion etching (RIE) process. This process uses a lithography technique utilizing gold colloidal particles (or citrate Au sol [1]) with 50 nm diameter as mask.

Experimental

TEM sample preparation by the Small Angle Cleavage Technique

5 Steps to prepare a T-XTEM sample by SACT (described in detail in [5],[6],[7]):

1) Mount sample surface down on a platin and polish at a small angle to the edge of the sample or to a cleavage plane.

2) Scribe the sample along polising induced grooves and remove from the platin.

3) Take one of the cleaved strips with a smooth fracture edge and place it on a glass slide. Scribe parallel to the normal cleaving direction of sample and cleave a little wedge (Fig. 4).

4) Get a good TEM sample it is necessary to preinvestigate the wedge using a light microscope. The sharper the apex of the wedge, the better the sample (Fig. 5).

5) Mount the wedge on a 30 μm thick copper ring. Because of the difficult use of these thin rings the ring is stabilized by small pieces of silicon (100 μm thickness) and another copper ring which are stick to the ring with epoxy glue. The sample is fixed between the silicon pieces, the surface in vertical direction. The second copper ring is cut as seen in Fig. 5.

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Results

S A C T

Overview of a cross-section of Si nanopillars. Below Si substrate, in the middle the etched Si nanopillars with gold colloids on top. Note the wide range of electron transparency.

S A C T t o T r a d i t i o n a l C r o s s - S e c t i o n T E M ( T - X T E M ) S a m p l e P r e p a r a t i o n

Using the T-XTEM sample preparation method, artefacts mainly by argon ion beam thinning and face to face gluing are generated.

C O M P A R I S O N

S A C T T - X T E M

Conclusions

It was found:

Using the traditional cross-sectional sample preparation method, a number of artefacts were produced, which unable a structural investigation of the nanopillars.

The small angle cleavage technique was found to be an excellent and fast method to prepare cross-sectional TEM samples of nanopillars without artefacts. It was found that the nanopillars are crystalline. The interface between nanopillar and Au particle was resolved. An amorphous layer with a thickness of 2 nm to 4 nm around the nanopillars could be clearly identified.

We already applied the method to GaAs substrates successfully.