Abstract

The process of local anodic oxidation, where a positive voltage is applied between a sample and a conductive probe, is well understood. Here, Conducting Atomic Force Microscopy (C-AFM) induced surface modifications of thermally grown Si oxides are investigated for opposite (i.e., negative) sample bias. Also at this polarity, surprisingly the appearance of protrusions is observed. To obtain information on the nature of these protrusions, low energy electron microscopy (LEEM) and x-ray photoelectron spectroscopy (XPS) measurements were performed at the Nanospectroscopy Beamline at the synchrotron radiation source Elettra in Trieste, Italy. With LEEM we find that the protrusions are heavily charged after their formation, but this charge is annihilated after prolonged exposure to light. After extended x-ray exposure, an x-ray induced desorption of the structures as well as a description of the thermal oxide is observed. The spectra obtained from XPEEM images at different photoelectron kinetic energies reveal that the structures formed by C-AFM are chemically homogeneous, and that they are caused by the growth of additional SiO2 on the sample surface.

Experimental

Exposure to X-rays

Short term exposure (few seconds): Photodesorption of parts of the lines and of the thermal oxide.

Long term exposure (several minutes): Annihilation of negative charges deposited in the lines during creation.

Spectroscopy

(a) MEM image obtained after writing lines by C-AFM. Electron energy: 3.0 eV. The image exhibits very strong contrast. This effect could be due to negative charges within the fabricated structures. (b) MEM image at 2.7 eV of the same structures after irradiation with 89.4 eV photons for 2 minutes. The contrast in the image is strongly reduced, and structures and background can be focussed at the same time. (c) Same as in (b) after extended x-ray irradiation at 89.4 eV for 30 minutes. A further contrast reduction is observed. (d) AFM image of the same structures, obtained after writing the lines by C-AFM. z-scale: 15 nm. (e) AFM image of the same sample area, after a total exposure time of 30 minutes to x-rays with a photon energy of 89.4 eV. z-scale: 15 nm. The numbers in (d) and (e) give the average height of individual lines in nanometers before and after exposure as measured with AFM. (f) The height profiles along the lines indicated in (d) and (e).

Time-resolved Spectroscopy

The oxide film thickness d was determined from the intensity ratio between the 2p3/2 component E2p3/2 and the satellite component E1p. According to Rispens et al we have:

\[ E_{\text{satellite}} = 2.64 E_{\text{2p3/2}} - 1 \]

with \( E_{\text{2p3/2}} \) the photoelectron escape depth in SiO2, \( E_{\text{satellite}} \) the photoproduction energy for a base Si substrate, and \( E_{\text{satellite}} \) the photoelectron escape energy for an infinitely thick SiO2 layer.


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