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Short Communication

Secondary Electron Imaging by Means of a Microfabricated Electron Column

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PACS.41.90.+e – Other topics in electromagnetism; electron and ion optics

PACS.41.85.Ne – Electrostatic lenses

Abstract. — This letter reports about the application of a miniaturized electron microscope for generating scanning secondary-electron images. The employed electrostatic lens-system was fabricated using silicon microfabrication techniques and a scanning tunneling microscope, operated in the field emission mode, was used as electron source. A resolution of better than 100 nm at a beam energy of 200 eV was achieved.

Introduction

The concept of microfabricating an electron column was introduced by Chang and co-workers in 1989 [1]. These instruments are designed for low energy e-beam writing, for example on Self Assembled Monolayers (SAM) [2, 3], and, up to now, have been applied mainly for imaging perforated samples. For that purpose, the beam is raster scanned across the sample and when it hits a hole, the electrons pass through the sample and are collected with a conventional detector further down stream. A resolution of 10 nm at 1 keV beam energy has been achieved [4].

Here we report about secondary-electron images generated with 200 eV electrons on opaque samples. The reason for choosing a low beam energy is twofold: firstly, the range of electrons has a minimum around 100 eV irrespective of the material. This appears to be attractive for e-beam writing, where proximity effects and critical exposure dose are expected to be minimized. Secondly, the low energy will cause less radiation defects in underlaying, delicate substrates. The energy range below 1 keV is of additional interest since here many materials have a secondary-electron yield of one. This could allow to image also non-conductive materials without charging effects. Non-contact potentiometry in electronic-circuit testing would be yet another application.

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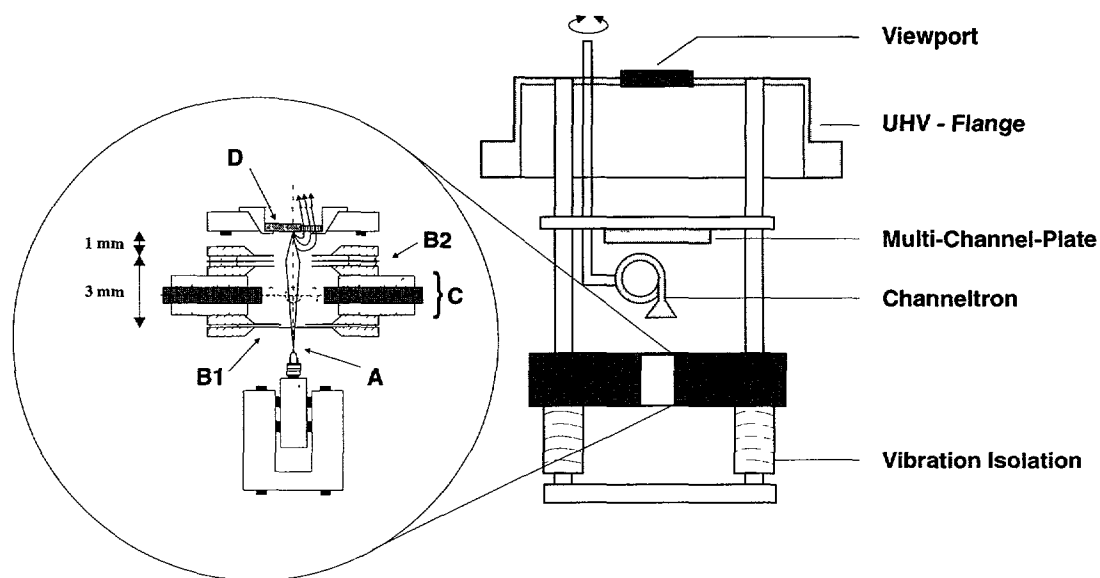
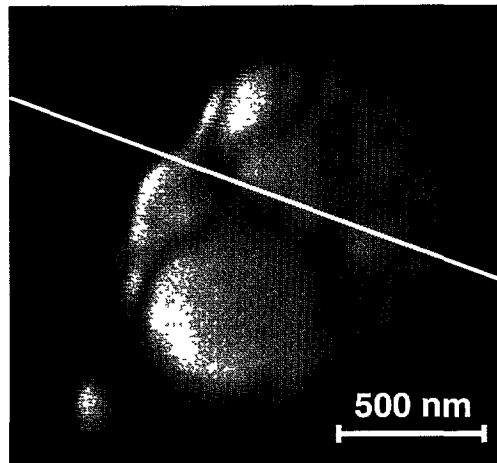


Fig. 1. — Schematic drawing of the experimental set-up. The in-set depicts the arrangements of the STM field-emission tip (A), the electron lenses (B1, B2), the beam-deflection unit (C), and the sample (D).

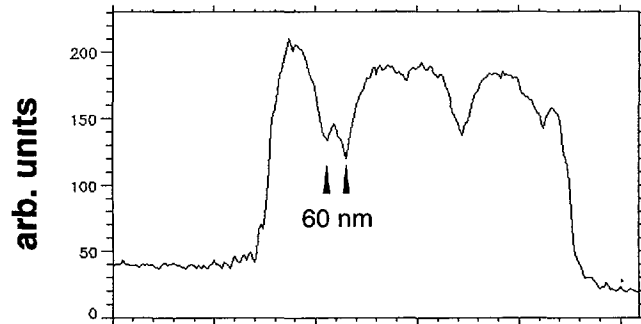
Experiments and Results

In Figure 1 a schematics of the currently used experimental set-up is shown. The instrument consists of a Scanning Tunneling Microscope (STM) which has been supplemented with a miniaturized electron-lens-system. This will allow to form a focused electron beam when operating the STM in field emission mode. The electrostatic lenses were fabricated from silicon membranes by electron-beam lithography, reactive ion etching and anodic bonding. The sample can be positioned *in situ* by means of an inertial walker. A channeltron is used for detecting electrons which have passed the sample. Details about the instrument and its fabrication have been published elsewhere [3,5-8].

When operating the instrument at an energy of 200 eV and using perforated carbon-films as samples, a resolution of better than 60 nm in transmission has been achieved (see Fig. 2). In the cross-section shown in Figure 2b, two fibers separated by 60 nm can still be resolved. The restriction to perforated samples, however, is quite a sever one. Especially for registration in lithography it would be desirable to have means for forming also secondary- or backscattered-electron pictures. For that purpose, a detector would needed to be mounted above the sample. Unfortunately, this is hindered by the short working distance of only 1 mm and the lateral size of the lenses, which amounts to 6 mm × 6 mm. Nor does the low energy of the primary-electrons permit to "suck" the secondaries to one side as it is frequently done in a conventional arrangement. Ideally, the detector should be mounted directly to the final lens and have a rotational symmetry. The beam would then be least affected. We found, however, that for again perforated samples or for images close to the samples edge also another approach is feasible. By applying a voltage of about +100 V to the entrance electrode of the channeltron on the backside of the sample, secondary-electrons were sucked through the holes or around the edge to the detector (see Fig. 1). Areas up to 100 μm away from an edge or from a hole could



a)



b)

Fig. 2. — a) Two carbon fibers are stretched across a hole in a carbon foil. The fibers are 60 nm apart and can still be resolved as it can be seen in the cross-section depicted in b).

still be imaged. Figure 3 shows as an illustrative example the frame of a copper-mesh with some residual silver-paint on it. A clear material contrast between copper and silver is observable. A similar difference between exposed and un-exposed SAM or PMMA was detected. In Figure 4, the edge of a silicon wafer is depicted. The resolution is somewhat worse compared to the pure transmission mode. The distance between two features that can still be separated is about 100 nm.

Summary

We have shown that the microcolumn can also be used for generating secondary-electron images which is important *e.g.* for registration in e-beam lithography. At an energy of 200 eV, a resolution of 100 nm was achieved. We believe that these results can still be improved. One possible path is to mount a miniaturized secondary-electron detector directly to the objective lens.

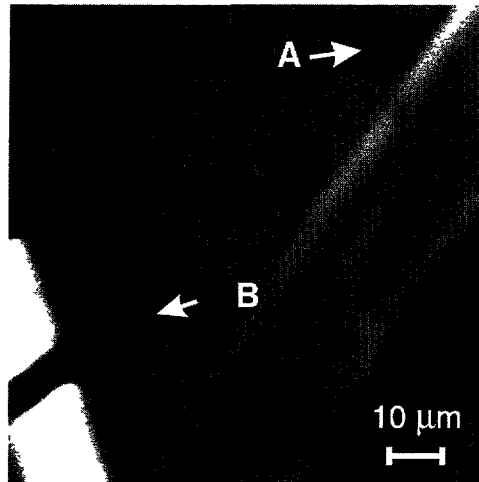
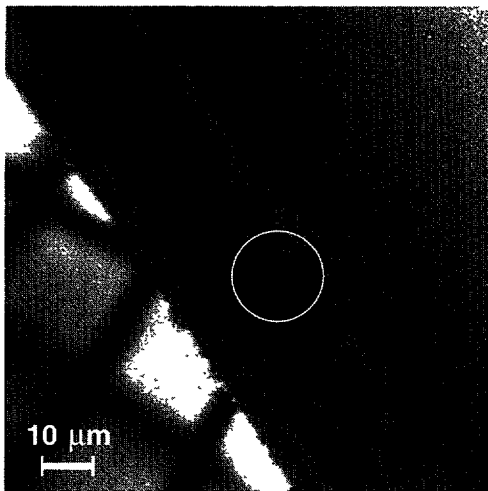
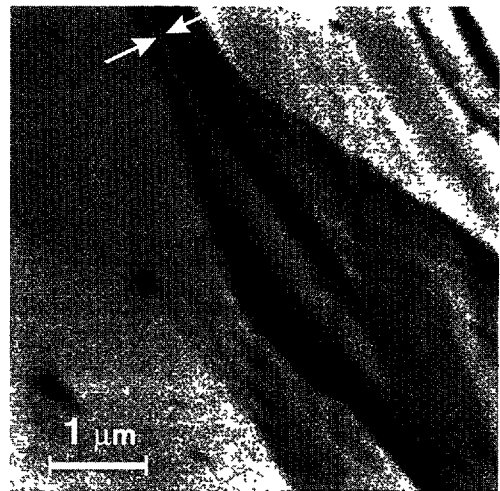


Fig. 3. — This picture shows the frame of a copper 1000-mesh, which was used for calibrating the scanning field. Marker A points to an area on the copper surface. The bright structures (indicated by B) on the frame of the mesh are residues of silver-paint which has been applied for mounting the mesh to the sample holder.



a.)



b.)

Fig. 4. — These two pictures were taken from an edge of a cleaved silicon wafer. The picture on the left hand is a close-up of the encircled area of the first picture. It gives an indication of the achieved resolution. The two marked structures are separated by 100 nm.

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