MNE 2007 – 33rd International Conference on Micro- and Nano-Engineering 2007, Copenhagen, Denmark

Recent improvements in the integration of field emitters into scanning probe microscopy sensors

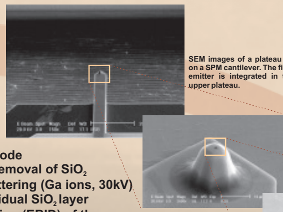
S. Beuer [a], M. Rommel [a], S. Petersen [a], B. Amon [a], Th. Sulzbach [b], W. Engl [b], A. J. Bauer [a], and H. Ryssel [a, c]
[a] Fraunhofer Institute of Integrated Systems and Device Technology (IISB), Schottkystrasse 10, 91058 Erlangen, Germany
[b] NanoWorld Services GmbH, Schottkystrasse 10, 91058 Erlangen, Germany
[c] Chair of Electron Devices, Friedrich-Alexander-University Erlangen-Nuremberg, Cauerstrasse 6, 91058 Erlangen, Germany

Motivation

"Improvement of maskless fabricated field emitters in scanning probe microscopy (SPM) sensors with respect to process yield, process stability and compatibility to semiconductor processes"

Realization of Field Emitter

First approach:



SEM images of a plateau tip on a SPM cantilever. The field emitter is integrated in the upper plateau.

- highly doped Silicon substrate
- 1µm insulating SiO_2 layer
- 0.2µm Pt layer as control electrode
- electrode opening and partial removal of SiO_2 by focused ion beam (FIB) sputtering (Ga ions, 30kV)
- wet etching (HF) to remove residual SiO_2 layer
- electron beam induced deposition (EBID) of the emitter with platinum precursor

SEM image of a C field emitter with a Cr control electrode.

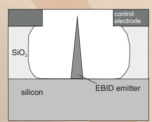
Improved approach:

Change of the control electrode material from Pt to Cr:

- better compatibility to semi-conductor technology

Change of the emitter material from Pt to C:

- suppressed overspray (with Pt precursor, Pt traces at the SiO_2 walls lead to conductive paths between emitter and gate)
- higher stability against bending during emission



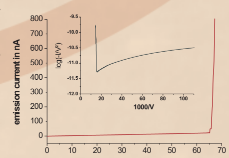
Sketch of the realized field emitter.

Results and Discussion

Electrical Characterization:

- sensor bonded on a TO-5 type mount
- placed into a vacuum chamber (10^{-7}mbar)
- measurement of the IV-curve; voltage between emitter and control electrode is ramped up until emission starts
- emission current is detected between emitter and a target grid facing the sensor at a distance of 5mm

Experimental results:



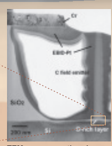
The Fowler-Nordheim plot reveals a linear dependence, indicating that emission of electrons is caused by field emission.

The turn-on voltage is 65V. This is too high for many possible applications and for a simple integration into scanning probe microscopy systems.

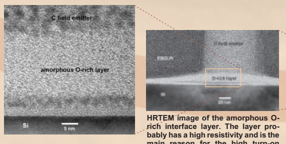
Attempt to decrease the turn-on voltage by reducing the diameter of the control electrode from 1µm to 500nm → no significant change in the turn-on voltage could be obtained.

As for such electrode diameters and similar emitter geometries published values are significantly lower (e.g. 30-40V for Pt tip emitters), a high resistance in the device structure must be the reason for the high turn-on voltage.

TEM, HRTEM and EDX analyses



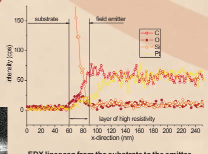
TEM cross section image through the field emitter (the structure was partially filled with EBID-Pt for protection before cross sectioning).



HRTEM image of the amorphous O-rich interface layer. The layer probably has a high resistivity and is the main reason for the high turn-on voltage.

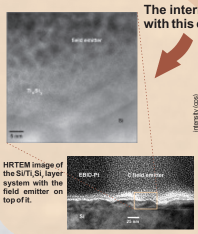
First results clearly identify a 30nm thick intermediate layer between the substrate and the emitter, which contains high amounts of oxygen as shown by EDX. Thus, the layer has a high resistivity and is assumed to be the main reason for the high turn-on voltages.

To avoid this oxygen rich layer, a conductive layer between the emitter and the substrate material can be deposited which prevents the oxidation of the silicon surface. Therefore, a Ti silicide has been formed, with the emitter deposited on top of it.



EDX linescan from the substrate to the emitter.

The intermediate O-rich layer could be completely avoided with this enhanced process as can be seen by HRTEM.



HRTEM image of the Si/Ti_xSi_y layer system with the field emitter on top of it.

Conclusions

- Strategies and processes are presented and discussed which enable the integration of electron beam induced deposited (EBID) emitters into scanning probe microscopy (SPM) sensors.
- The change from a Pt to C emitter precursor material led to improved process stability and electrical performance.
- A Cr control electrode instead of a Pt control electrode improves compatibility to standard silicon semiconductor technology.
- A 30nm thick oxygen rich layer between the emitter and the Si-substrate has a great influence on the turn-on voltage of the field emitter. This was eliminated by advanced processing.
- Further work has to be done in the electrical characterization of the C field emitters with intermediate silicide layer.
- Results of this work significantly ease the use of such field emitter probes for real applications.

Fraunhofer Institut Integrierte Systeme und Bauelementetechnologie

NANO WORLD INNOVATIVE TECHNOLOGIES

LEB

tasnano

Acknowledgement:
This work was partially funded by the European Commission (Contract N° 516865) within the EU-project TASNANO (Tools and Technologies for the Analysis and Synthesis of Nanostructures).
The authors wish to thank Dr. G. Frank from the Institute of Microcharacterisation at the Friedrich-Alexander-University Erlangen-Nuremberg for performing the EDX analysis.

Contact: Fraunhofer Institute of Integrated Systems and Device Technology (IISB)
Schottkystrasse 10
91058 Erlangen, Germany
Telefon: +49 (0)9131 / 761-129
Telefax: +49 (0)9131 / 761-360
Email: Susanne.Beuer@iisb.fraunhofer.de
Internet: www.iisb.fraunhofer.de