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Experimental characterisation of FIB induced lateral damage on silicon carbide samples

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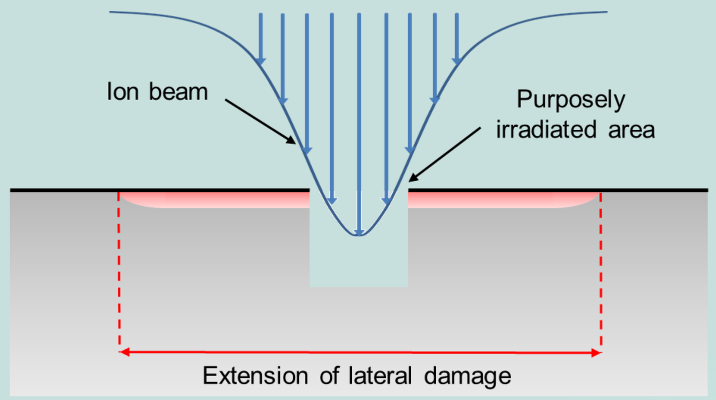
Introduction

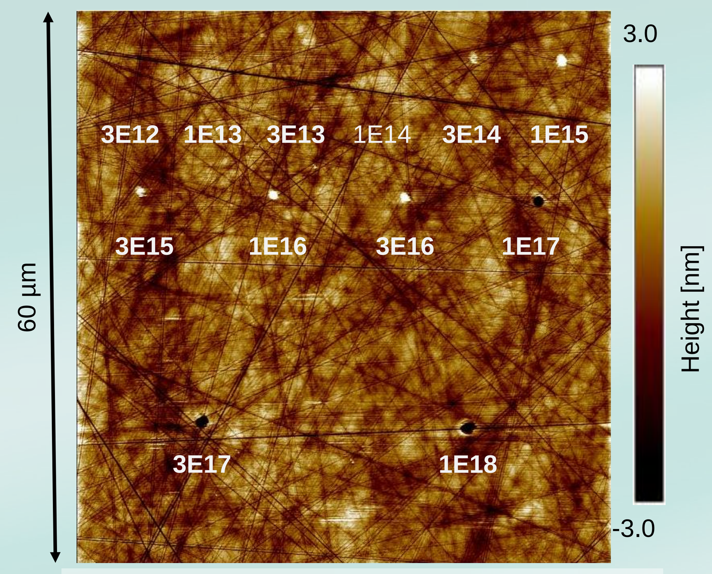
- Focused ion beam (FIB) as flexible tool for prototyping on the nano scale [1]
- Gaussian ion beam shape causes electrical damage outside of purposely irradiated area
- SSRM measurements have shown to be extremely sensitive to irradiation damage on Si [2]
- Silicon carbide (SiC) is a promising material for numerous applications, e.g. power electronics [3]

➡ **Characterisation of ion beam induced damage on SiC of great interest**
➡ **c-AFM measurements for complementary contact behaviour investigations**



Sample preparation and experimental setup

- Measurements performed on n-doped (0.8 – 2.0) · 10^{19} cm^{-3} 4H-SiC substrate
- For comparison with Si, as shown in [2], similar FIB irradiation conditions have been used:
  - FEI Helios Nanolab 600 FIB
  - 1 µm circular patterns of different ion doses ($3.0\cdot10^{12}$ cm^{-2} – $1.0\cdot10^{18}$ cm^{-2})
  - beam current 1.5 pA; beam energy 30 keV
  - chamber pressure 1 - $2\cdot10^{-6}$ mbar
- All AFM measurements performed with Bruker Dimension Icon
  - Electrical measurements (bias applied to sample, Nanoworld AG CDT AFM probes)
    - c-AFM module (voltage ramps: - 5 V to 0 V and 0 V to 5 V ➡ reduced anodic oxidation)
    - SSRM module (voltage bias: -3 V)



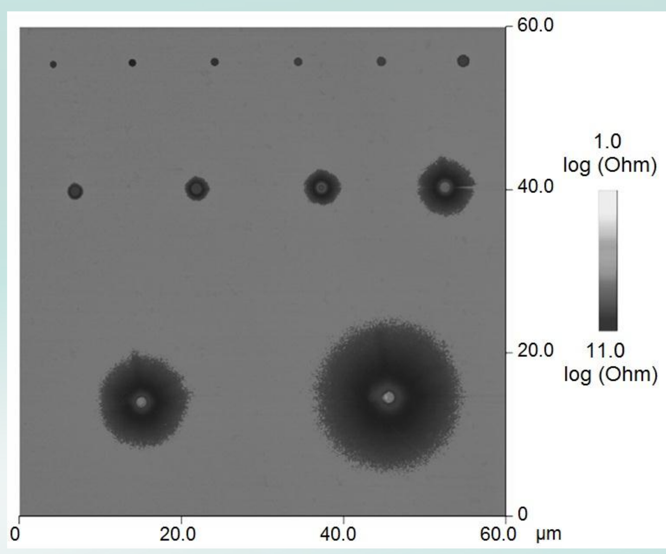
Tapping mode measurement of FIB patterned SiC sample

➡ Scratches visible on the surface
➡ Typical effect from surface polishing

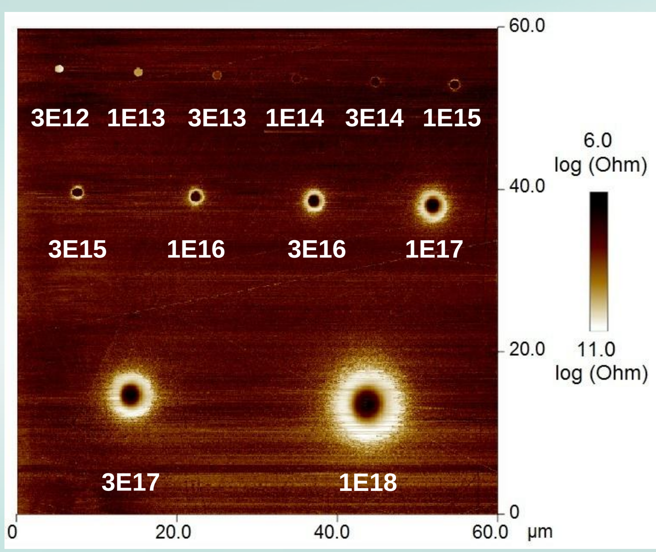
➡ Elevation visible for various doses
➡ Swelling due to the FIB processing

SSRM measurements

- Determination of the resistance change due to the ion beam and its lateral extension

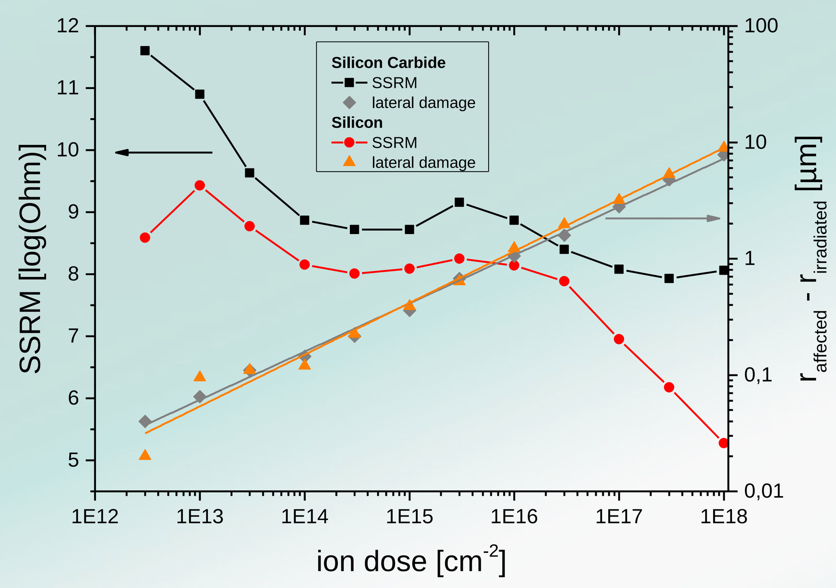


FIB patterned Si sample [2]



FIB patterned SiC sample

➡ Electrically damaged areas vastly exceed irradiated and topographically obversable areas



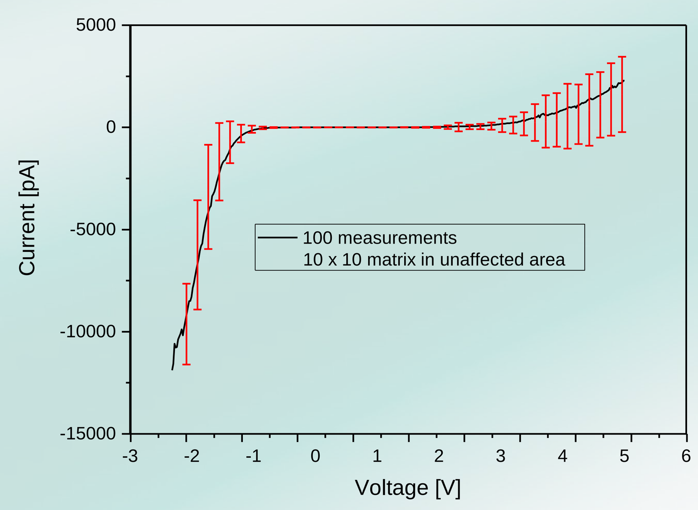
Comparison of the SSRM signal in the irradiated areas and the lateral damage extensions for silicon carbide and silicon

➡ Lateral damage extensions show power law dependency:
   ➡ slope: Si ~ 2.25; SiC ~ 2.45
   ➡ reason: higher dose necessary for amorphization in SiC?

➡ SSRM signals behave similarly for the medium range of ion doses, i. e. $3\cdot10^{13}$ cm^{-2} – $3\cdot10^{16}$ cm^{-2}

➡ At high doses a Gallium layer forms close to the surface for Si [2]
   ➡ decrease of the SSRM signal

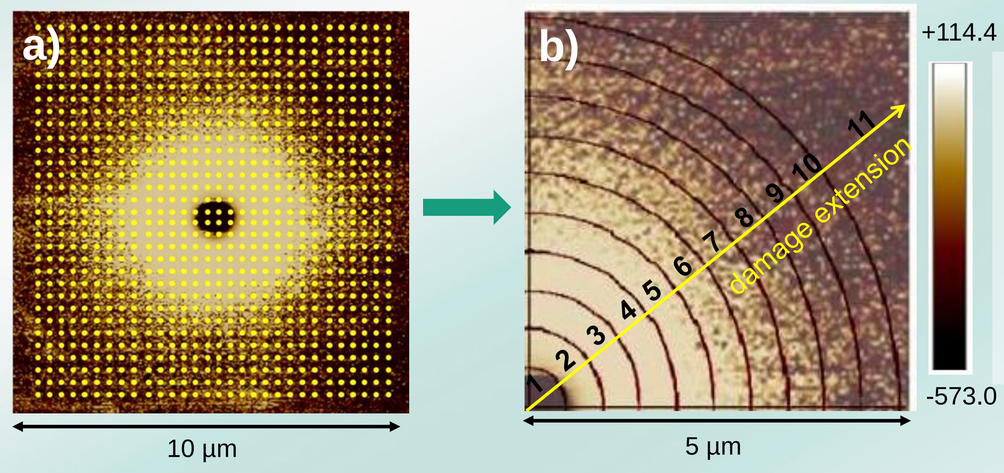
c-AFM measurements



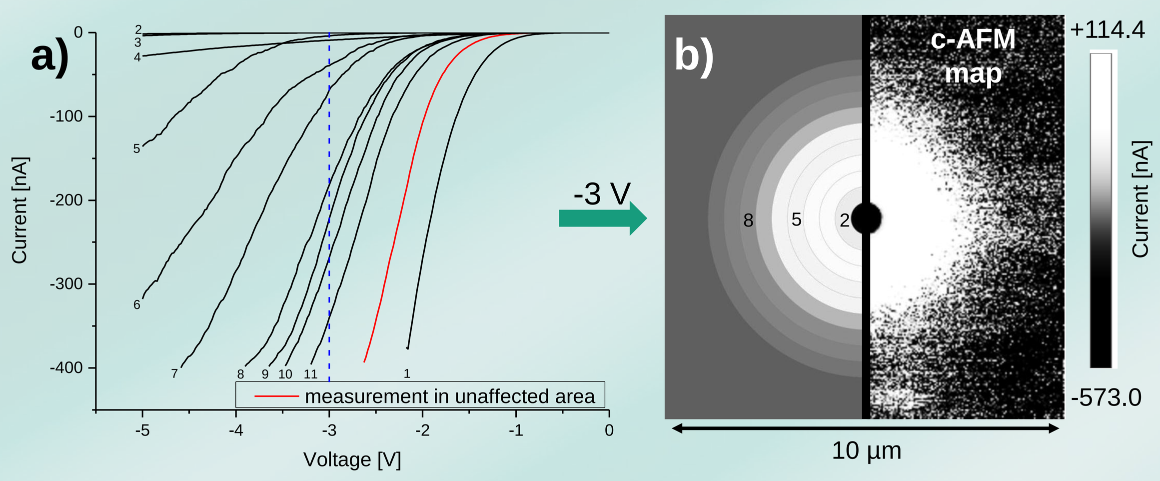
- Schottky contact clearly visible
- Forward behaviour at negative sample bias
- Reverse behaviour at positive sample bias

➡ n-doped substrate confirmed

- I-V-ramps on a 30 x 30 matrix covering the affected and unaffected areas to determine the radial dependency of forward direction



a) Overview of the 30 x 30 matrix on the measured irradiation with an ion dose of $1\cdot10^{17}$ cm^{-2}
b) Splitting of the damaged area into smaller radial areas to perform more detailed analysis



a) Mean values of the I-V-curves in radial areas as defined above
b) Comparison of c-AFM map and results from a) at -3 V

➡ Radial influence of the electrical damage on the I-V-ramps clearly visible

➡ Possibility to determine radial dependency of ion doses due to beam tails?

Summary

In conclusion, this work investigates the FIB induced electrical damage on silicon carbide in comparison with the previously published work on Si

- Electrically damaged areas exceed the irradiated and topographically observable areas in lateral dimensions, comparably to the results on Si
- Resistances in the irradiated areas show comparable dependence on the FIB irradiation dose for Si and SiC, especially for the medium range of ion doses
- Schottky contact behaviour of silicon carbide has been shown and its changes due to the radial distance from the purposely irradiated area

[1] L. Frey, C. Lehrer, H. Ryssel, Appl. Phys. A **76**, 1017-1023 (2003)
[2] M. Rommel, G. Spoldi, V. Yanev, S. Beuer, B. Amon, J. Jambreck, S. Petersen, A.J. Bauer, and L. Frey, J. Vac. Sci. Technol. B **28**, 595 (2010)
[3] N.G. Wright, A.B. Horsfall, K. Vassilevski, Mater. Today **11**, 16-21 (2008)

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