Spatially resolved materials modification using Helium Ion Microscopy

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Helium Ion Microscopy (HIM) [1, 2] is best known for its high resolution imaging capabilities of both conductive as well as insulating samples. However, since the introduction of Ne as a source gas for the gas field ion source (GFIS) an increasing number of nano-fabrication applications are realized. While the use of Neon as an imaging gas results in a somewhat lower lateral resolution (1.8 nm for 25 keV Ne^+ compared to 0.5 nm for 30 keV He^+) the user usually benefits from the much higher cross section for nuclear stopping. The latter results in a larger number of sputtered atoms and bonds broken directly by small impact parameter collisions.

After a brief introduction of the technique I will present results obtained using direct write milling, low fluence ion beam irradiation and ion beam based mixing. In all three cases the electronic or magnetic properties of the target material will be altered at the nano-scale in a controlled way to achieve new functionality. The examples comprise

- The fabrication of semiconducting graphene nano-ribbons by direct milling [3]
- The fabrication of a lateral spin valve and other magnetic structures using low fluence focused ion beam irradiation [4]
- The formation of individual 3 nm Si clusters for a room temperature single electron transistor [5]

For all presented examples the critical length scale of the nanostructure is smaller or in the range of collision cascade. This size regime can not easily be accessed with traditional broad beam based ion irradiation and holds many promises but also challenges that need to be overcome to enable new device concepts and new functional materials on the nano-scale.

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References

[1] Gregor Hlawacek and Armin Gölzhäuser, editors. *Helium Ion Microscopy*. NanoScience and Technology. Springer International Publishing, Switzerland, 2016.

[2] Gregor Hlawacek, Vasilisa Veligura, Raoul van Gastel, and Bene Poelsema. Helium ion microscopy. *Journal of Vacuum Science and Technology B*, 32(2):020801, March 2014.

[3] Gaurav Nanda, Gregor Hlawacek, Srijit Goswami, Kenji Watanabe, Takashi Taniguchi, and Paul F. A. Alkemade. Electronic transport in helium-ion-beam etched encapsulated graphene nanoribbons. *Carbon*, 119:419–425, August 2017.

[4] Falk Röder, Gregor Hlawacek, Sebastian Wintz, René Hübner, Lothar Bischoff, Hannes Lichte, Kay Potzger, Jürgen Lindner, Jürgen Fassbender, and Rantej Bali. Direct Depth- and Lateral- Imaging of Nanoscale Magnets Generated by Ion Impact. *Scientific Reports*, 5:16786, November 2015.

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[5] Xiaomo Xu, Thomas Prüfer, Daniel Wolf, Hans-Jürgen Engelmann, Lothar Bischoff, Rene Hübner, Karl-Heinz Heinig, Wolfgang Möller, Stefan Facsko, J. von Borany, and Gregor Hlawacek. Site-controled formation of single Si nanocrystals in a buried SiO_2 matrix using ion beam mixing. *Beilstein Journal of Nanotechnology*, 9:2883–2892, November 2018.