Hierarchical nano-structuring by combining ion induced self-organization and lithographic pre-patterning

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Guided self-organization processes are currently in focus regarding their potential for hierarchical micro and nano scale structuring. In this regard, self-organized pattern formation due to low-energy ion beam erosion can offer a simple and alternative lower cost-efficient approach to nanolithography, especially for the realization of nanometer ripple or dot patterns on the surface of different materials [1, 2]. However, usually this self-organization process lacks of long range order and positional control of the pattern. One possibility to improve the ordering and lateral positioning of structures is by using pre-patterned substrate. In this way due to spatial limitations and guided by the lateral ordering and the shape of the pre-patterned templates the evolving topography often shows an improved quality. This fabrication principle was applied for the ripple and dot pattern formation on pre-patterned Si surfaces by low energy ion beam erosion. It is demonstrated that by combining conventional lithographic techniques with ion beam induced self-organization a multi-scale patterning is possible. The pre-patterned substrates are fabricated by different top down techniques with main focus on laser ablation of thin films using phase mask projection for sub-micron pattern formation followed by pattern transfer with reactive ion beam etching. In general, it has been observed that the combination of ion beam induced self-organization with conventional lithographic techniques enables, in principle, the formation of new types of patterns, e. g, formation of curved ripples, circular ripples or nearly perfectly square ordered dots on exact positions on the surface). Additionally, an enhanced ordering of nanostructures and the formation of ripples with different directions depending on the local surface orientation has been found. The main parameters determining this pattern formation are identified to be the local incidence angle of the ions, the orientation of the local surface with respect to the ion beam direction, and, the local surface curvature. From future exploration on this topic we also expect to gain new insight in the mechanisms of pattern formation itself and, furthermore potential applications, especially in micro- and nanooptics, e. g., in bio-inspired functional nanooptics. Some of these potential applications will be discussed, shortly.

[1] F. Frost, B. Ziberi. A. Schindler, B. Rauschenbach, Appl. Phys. A **91**, 551 (2008)
[2] B. Ziberi, M. Cornejo, F. Frost, B. Rauschenbach, J. Phys.: Cond. Matter submitted.

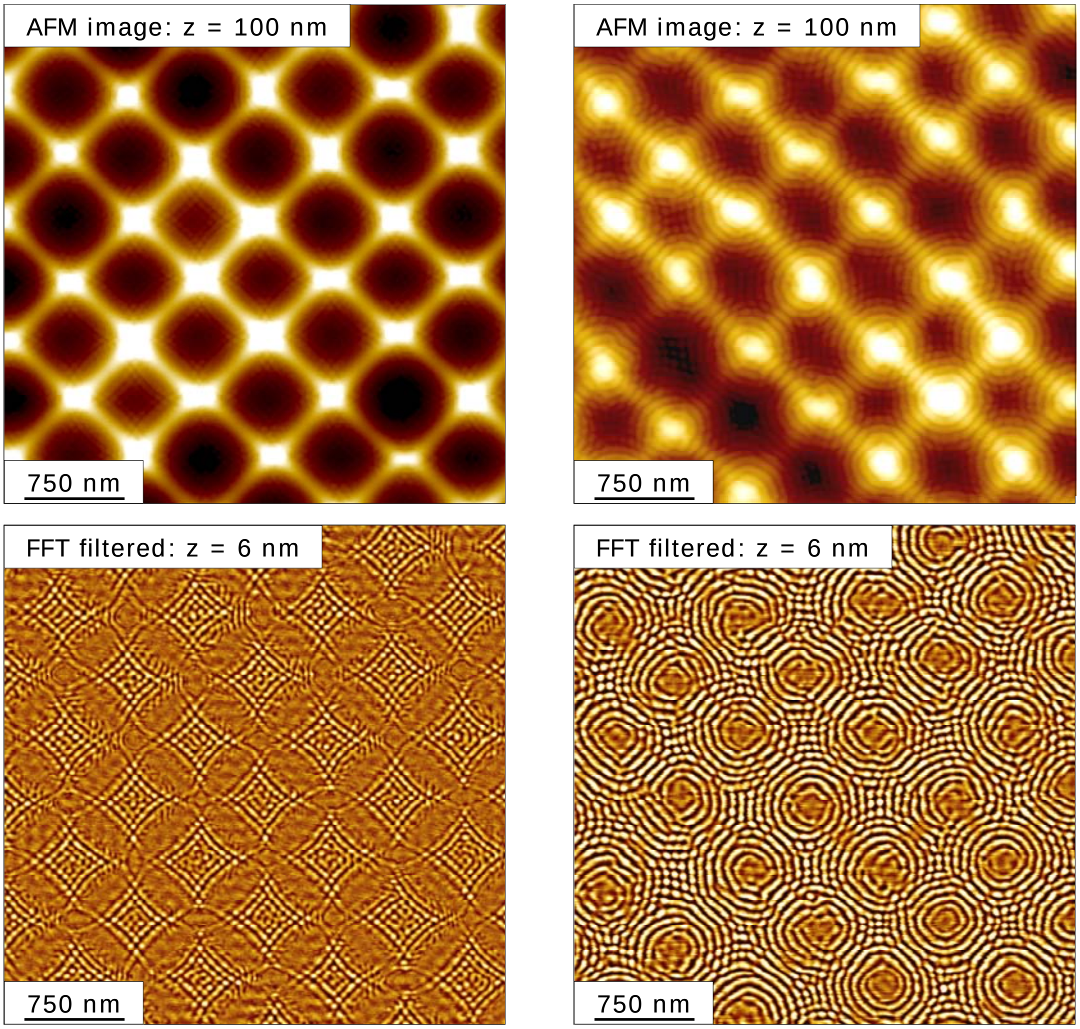

Figure: Top: AFM images of Si surfaces with pre-pattern fabricated by Laser ablation and superimposed with self-organized nanostructures induced by ion beam erosion. Bottom: Fourier filtered images (pre-pattern removed) which enlighten the nano pattern formed by self-organization processes during low-energy ion beam erosion. The differences between the left and the right column are only different ion energies and erosion times, respectively.