UNIVERSITY OF BERGEN

nanoLace

www.nanolace.eu

FET-Open project Mask-based Lithography with 1 nm resolution

Project Coordnator Bodil Holst

Project runs: 01.01.2020-02.01.2023

Total Budget: 3.35 Million Euro, 7 partners

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The European Commission

Future and Emerging Technology Program, Grant Agreement, 863127

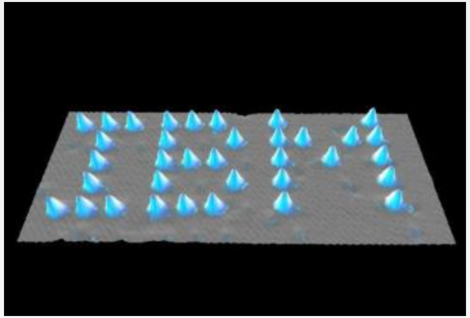
The distance between atoms in materials is roughly 0.5 nm, i.e. lattice spacing in aluminium 0.4 nm

The "fundamental" resolution limit of photolithography

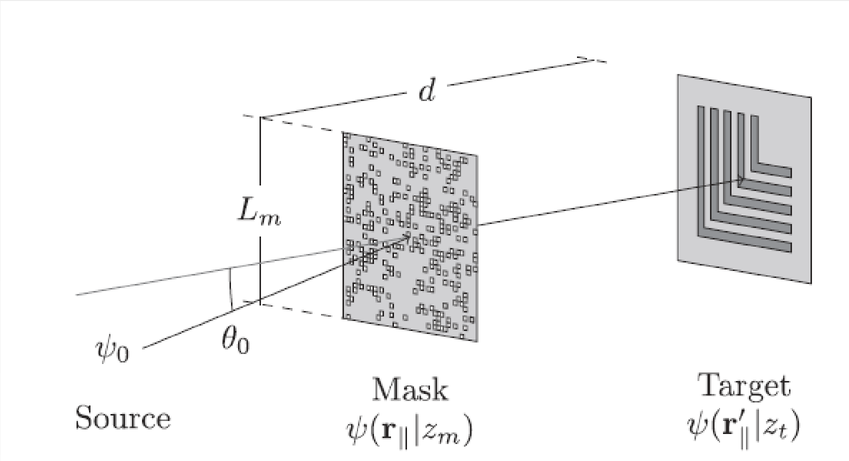
- The resolution limit in photolithography is given by the wavelength of the source as $\lambda/(2n)$. The standard in present industrial photolithography is the immersion skanner using a 193 nm light source. With subtle use of underexposure and overdevelopment features down to 10 nm can be created
  - For high density patterns multiple exposure is required.
- Solution: EUV light, 13.5 nm – BUT the photon energy is very high, 91.8 eV. The high energy means that the minimum feature that can be patterned is determined by the resist response, seems to be stuck at 5-8 nm
  - And the instruments are very expensive..

So how to do pattering at 1 nm resolution?

Lithography Device	Resolution [nm]	Throughput [μm^2/hour]	Instrument price [million €]
193nm immersion photolithography (ASML, Nikon)	45	10^{13}	30 – 40
The above using multiple exposures	16	10^{12}	40 – 50
EUV (ASML, NXE:3400B	13	10^{12}	~100
EBL Multiple beams (Mapper)	10	10^{11}	10 – 30
EBL single beam	5	10^{2}	1 – 2
Ion beam lithography	5	10^{4}	2
FEBID (focused electron beam ion deposition)	2	10^{1}	1– 2
Scanning Probe: Resist	1	10^{1}	1– 2
Nanolace	1	6×10^{8}	~2 (estimated)



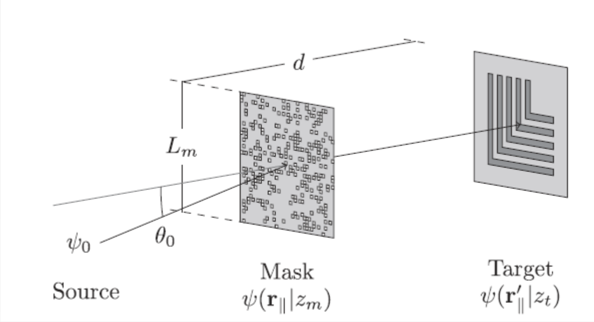
Idea –Binary holography with metastable helium atoms can generate arbitrary patterns.

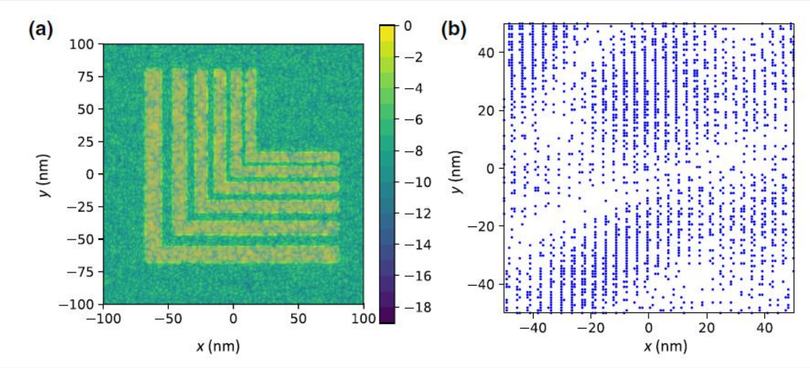


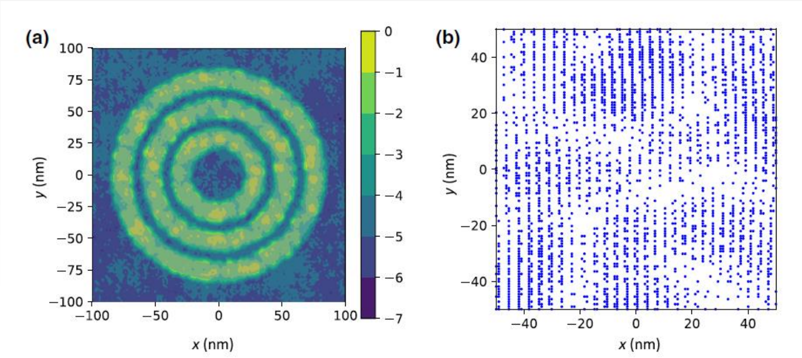
Advantage: Wavelength 0.1 nm, means patterns to the nanoscale can in principle be easily made. Energy of metastable state – 20 eV – Directly depositied on resist – A nano-grenade – More efficient energy dissipation

J. Fujita, M. Morinaga, T. Kishimoto, M. Yasuda, S. Matsui, F. Shimizu, Manipulation of an atomic beam by a computer-generated hologram, Nature 380, 691 (1996) – FRAUNHOFER DIFFRACTION

Our new idea – take it to the near field.



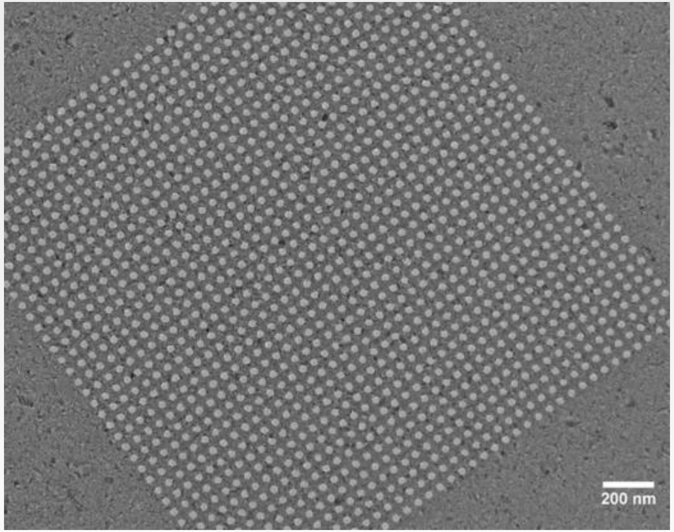




T. Nesse, I. Simonse, B. Holst
Nanometer-resolution Mask Lithography With Matter Waves: Near-Field Binary Holography, Phys. Rev. Applied 11, 024009 (2019)

How do we make the masks?

Lithography Techniques



Nanostructured-membran electron phase plates,
https://arxiv.org/ftp/arxiv/papers/2001/2001.01144.pdf
Y. Yang, C-S Kim, **Richard G. Hobbs**, P. D. Keathley, K. K. Berggren

The nanolace team

UNIVERSITAS BERGENSIS

UNIVERSITY OF BIRMINGHAM

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

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Disclaimer

- Before we start it is important to remember that FET is a very big call, covering many different disciplines. What I give you are my honest impressions, but there is no guarantee that different referees may not interpret the rules differently in some cases.

The key(s) to success:

- You MUST have a very good idea (that is not so easy)
- Very important – you must have a «radical vision of a science enabled technology».
- SO this is not «blue skye research» (The ERC is place for that) – A clear technology vision is VERY important.
- You will need to convey your vision using sound scientific arguments that your idea will revolutionize the world.
  - Revolution can mean not just a big market, but also "save the world", "save world heritage cultur" – BUT IT MUST BE REALLY NEW
- Remember that people who are not absolute experts in the filed, might find it hard to distinguish high-risk from "insane". Substantiate the feasibility of the project with calculations and numbers as much as possible.
- You don´t need a business plan but also the non-experts will need to understand the potential impact of your idea
- The concept might be well know to your field, but might disrupt another field. THIS IS OK! E.g. Acoustics methods used in fishery applied in a new radical way in medicine (or the other way round).
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The key(s) to success, continued:

- Success rates are much better now than previously (around 12%)
  - I have seen many bad proposals as an evaluator so «real» success rate is higer than 12% (it is difficult to get good ideas)
- It is no shame to resubmit. We did! and we used the comments from our first submission in the resubmission.
- You do not need a fantastic CV (as you do in the ERC), you just need a fantastic idea.
- Pick the right partners, which means the partners who are best suited to do the tasks. If you can, include:
  - Small companies
  - Young, promising researchers
- Include a good risk assessment, this is supposed to be high-risk, so OK to have risks and OK to fail
- Include lots of scientific citations (with titles) and also references to patens if relevant
- Get Help – We got support from NFR to use a consultancy company. They were REALLY helpful.

Good luck!