ISSN 0976 – 0342

International Journal of Pharmacy & Therapeutics

Journal homepage: www.ijptjournal.com

IJPT

APPLICATIONS AND TECHNIQUES OF NANOLITHOGRAPHY-A TECHNIQUE OF FABRICATION OF NANOMETER- SCALE STRUCTURES: AN OVERVIEW

[*1]Amol P. Pachpute, [1] Shirish J. Sharma, [2]Satyanand Tyagi, [3]Manju Shri, [4] Maheshwari Chaurasia

[*1] Senior Clinical Research Associate, Clinical Department, Macleods Pharmaceuticals Limited, Mumbai, India-400093
[2] K.N.G.D Modi Institute of Pharmaceutical Education & Research, Modinagar, Ghaziabad, Uttar Pradesh, India -201204.
[3] Deptt. of Pharmacy, Raj Kumar Goel Institute of Technology, Ghaziabad, Uttar Pradesh, India -201003.
[4]Oxford College of Pharmacy, Ghaziabad, Uttar Pradesh, India -201001.

ABSRTACT

Nanolithography is the art and science of etching, writing, or printing at the microscopic level, where the dimensions of characters are on the order of nanometers (units of 10^{-9} meter, or millionths of a millimeter). This includes various methods of modifying semiconductor chips at the atom IC level for the purpose of fabricating integrated circuits (ICs). Instruments used in nanolithography include the scanning probe microscope (SPM) and the atomic force microscope (ATM). The SPM allows surface viewing in fine detail without necessarily modifying it. Either the SPM or the ATM can be used to etch, write, or print on a surface in single-atom dimensions. Nanolithography is referred to a technique of printing integrated circuits at a nanometer scale for fabrication of the high end semiconductors and nanoelectromechanical devices. Nanolithography is used in the creation of nanocomputer parts. The Nanolithography can be used for fabrication of the circuits in various devices such as optical devices, displays, data storage, biotech, semiconductor ICs, chemical synthesis materials etc. One of the popular kind of Nanolithography technology is Nanoimprint lithography that conducive to replication neopaterns at the nanometer scale and is characterically simple process with low cost, high throughput and high resolution. Nanonex is a well known nanotechnology enterprise that provides popular Nanolithography tools and engine for the high-throughput, large-area patterning of 3D nanostructures with sub-10 nm resolution and the overlay alignment. This article presents a brief review of nanolithography with an emphasis on its various techniques as well as applications; the article also reveals the concept of nanoimprint lithography in brief.

KEY WORDS: Nanolithography, Integrated Circuits, Nanocircuitry, Nanoelectromechanical Systems (NEMS), Nanotechnology, Nanometer-Scale Structures, Nanoimprint Lithography.

INTRODUCTION

Nanolithography refers to the fabrication of nanometer-scale structures, meaning patterns with at least one lateral dimension between the size of an individual atom and approximately 100 nm. Nanolithography is used during the fabrication of leading-edge semiconductor integrated circuits (nanocircuitry) or nanoelectromechanical systems (NEMS). Nanolithography is that branch of nanotechnology, which deals with the study and application of fabrication of nanoscale structures like semiconductor circuits. As of 2007, nanolithography is a very active area of research in

***Corresponding author**

Amol P Pachpute
E mail: - amolpachpute@gmail.com

academia and in industry. Nanolithography is a term used to describe a number of techniques for creating incredibly small structures. The sizes involved are on the order of tens of nanometers (nm). A nanometer is a billionth of a

One common method of nanolithography, used particularly in the creation of microchips, is known as photolithography. This technique is a parallel method of nanolithography in which the entire surface is drawn on in a single moment. Photolithography is limited in the size it can reduce to, however, because if the wavelength of light used is made too small the lens simply absorbs the light in its entirety. This means that photolithography cannot reach the super-fine sizes of some alternate technologies. A technology that allows for smaller sizes than photolithography is that of electron-beam lithography. Using an electron beam to draw a pattern nanometer by nanometer, incredibly small sizes (on the order of 20nm) may be achieved. Electron-beam lithography is much more expensive and time consuming than photolithography, however, making it a difficult sell for industry applications of nanolithography. Since electron-beam lithography functions more like a dot-matrix printer than a flash-photograph, a job that would take five minutes using photolithography will take upwards of five hours with electron-beam lithography (Pancrazio *et al.*, 1999).

New nanolithography technologies are constantly being researched and developed, leading to smaller and smaller possible sizes. Extreme ultraviolet lithography, for example, is capable of using light at wavelengths of 13.5nm. While hurdles still exist in this new field, it promises the possibility of sizes far below those produced by current industry standards. Other nanolithography techniques include dip-pen nanolithography, in which a small tip is used to deposit molecules on a surface. Dip-pen nanolithography can achieve very small sizes, but cannot currently go below 40nm. Nanolithography technologies are likely to play a prominent role in affecting the rate of drug discovery by promoting other technologies such as cell-based sensing (Griscom *et al.*, 2002 and Gross *et al.*, 1977) or cell-based computing (Gross GW *et al.*, 1995 and Morefield *et al.*, 2000). The ability to pattern surfaces, especially electrically active surfaces is critical to the success of these technologies, especially as cells of various phenotypes are employed.

Nanolithography Techniques

1. **Optical Lithography**: Optical lithography has been the predominant patterning technique since the advent of the semiconductor age, is capable of producing sub-100-nm patterns with the use of very short wavelengths (currently 193 nm). Optical lithography will require the use of liquid immersion and a host of resolution enhancement

meter, much smaller than the width of a single human hair. The word lithography is used because the method of pattern generation is essentially the same as writing, only on a much smaller scale (Pancrazio *et al.*, 1998).

technologies (phase-shift masks (PSM), optical proximity correction (OPC)) at the 32 nm node. Most experts feel that traditional optical lithography techniques will not be cost effective below 22 nm. At that point, it may be replaced by a next-generation lithography (NGL) technique. Photolithography (or optical lithography) is a process used in microfabrication to selectively remove parts of a thin film or the bulk of a substrate. It uses light to transfer a geometric pattern from a photo mask to a light-sensitive chemical photo resist, or simply resist, on the substrate. A series of chemical treatments then engraves the exposure pattern into the material underneath the photo resist. In complex integrated circuits, for example a modern CMOS, a wafer will go through the photolithographic cycle up to 50 times (Nalamasu *et al.*, 1991).

Photolithography shares some fundamental principles with photography in that the pattern in the etching resist is created by exposing it to light, either using a projected image or anoptical mask. This procedure is comparable to a high precision version of the method used to make printed circuit boards. Subsequent stages in the process have more in common with etching than to lithographic printing. It is used because it affords exact control over the shape and size of the objects it creates, and because it can create patterns over an entire surface simultaneously. Its main disadvantages are that it requires a flat substrate to start with, it is not very effective at creating shapes that are not flat, and it can require extremely clean operating conditions. Photolithography has been defeating predictions of its demise for many years. For instance, it was predicted that features smaller than 1 micrometre could not be printed optically. Modern techniques already print features with dimensions a fraction of the wavelength of light used - an amazing optical feat. Current research is exploring new tricks in the ultraviolet regime, as well as alternatives to conventional UV, such as electron beam lithography, X-ray lithography, extreme ultraviolet lithography, ion projection lithography, and immersion lithography (Nalamasu *et al.*, 1990).

2. **X-Ray Lithography**: X-ray lithography, is a process used in electronic industry to selectively remove parts of a thin film. It uses X-rays to transfer a geometric pattern from a mask to a light-sensitive chemical photoresist, or simply resist, on the substrate. A series of chemical treatments then engraves the produced pattern into the material underneath the photoresist. It can be extended to an optical resolution of 15 nm by using the short wavelengths of 1 nm for the illumination. This is

implemented by the proximity printing approach. The technique is developed to the extent of batch processing. The extension of the method relies on Near Field X-rays in Fresnel diffraction: a clear mask feature is "demagnified" by proximity to a wafer that is set near to a "Critical Condition". This Condition determines the mask-to-wafer Gap and depends on both the size of the clear mask feature and on the wavelength. The method is simple because it requires no lenses.

Most X-ray lithography demonstrations have been performed by copying with image fidelity (without magnification) on the line of fuzzy contrast. However, with the increasing need for high resolution, X-ray lithography is now performed on what is called the sweet spot, using local demagnification by bias (Vladimirsky *et al*., 1999).

3. **Double Patterning**: Double patterning is a class of technologies developed for photolithography to enhance the feature density. The resolution of a photoresist pattern begins to blur at around 45 nm half-pitch. This technique increases feature density by printing new features in between pre-printed features on the same layer. It is flexible because it can be adapted for any exposure or patterning technique. The feature size is reduced by non-lithographic techniques such as etching or sidewall spacers (Honda *et al*., 2006).

4. **Maskeless Lithography**: Maskless lithography, the radiation that is used to expose a photosensitive emulsion (or photoresist) is not projected from, or transmitted through, a photo mask. Instead, most commonly, the radiation is focused to a narrow beam. The beam is then used to directly write the image into the photoresist, one or more pixels at a time. An alternative method, developed by Micronic Laser Systems, is to scan a programmable reflective photomask, which is then imaged onto the photoresist. This has the advantage of higher throughput and flexibility. Both methods are used to define patterns on photomasks (Chang *et al.*, 2001).

A key advantage of maskless lithography is the ability to change lithography patterns from one run to the next, without incurring the cost of generating a new photomask. This may prove useful for double patterning. Currently, the main forms of maskless lithography are electron beam and optical. In addition, focused ion beam systems have established an important niche role in failure analysis and defect repair. Finally, systems based on arrays of probe tips have recently been announced. Maskless lithography is already used for the production of photomasks and in limited wafer-level production.

5. **Electron Beam Lithography**: Electron beam lithography (or e-beam lithography) is the practice of scanning a beam of electrons in a patterned fashion across a surface covered with a film (called the resist), (exposing the resist) and of selectively removing either exposed or non-exposed regions of the resist (developing). The purpose, as with photolithography, is to create very small structures in the resist that can subsequently be transferred to the substrate material, often by etching. It was developed for manufacturing integrated circuits, and is also used for creating nanotechnology artifacts (Stoffels *et al.*, 2001).

The primary advantage of electron beam lithography is that it is one of the ways to beat the diffraction limit of light and make features in the nanometer regime. This form of maskless lithography has found wide usage in photomask-making used in photolithography, low-volume production of semiconductor components, and research & development. On the other hand, the key limitation of electron beam lithography is throughput, i.e., the very long time it takes to expose an entire silicon wafer or glass substrate. A long exposure time leaves the user vulnerable to beam drift or instability which may occur during the exposure. Also, the turn-around time for reworking or re-design is lengthened unnecessarily if the pattern is not being changed the second time (Broers *et al.*, 1996).

6. **Extreme ultraviolet lithography** (EUV): EUV is a form of optical lithography using ultra short wavelengths (13.5 nm). *EUV* or *EUVL* is a next-generation lithography technology using a EUVwavelength, currently expected to be 13.5 nm. EUVL has been the subject of ongoing research and development by many groups. The predicted optical resolution capability has been demonstrated in some special cases where the impact of the actual asymmetry of a realistic EUV scanner has been avoided. With the asymmetry considered, the optical resolution limit is not so straightforward to guarantee. However, general optical resolution is not the only limiting factor for EUV.

It is mainly because the EUV community has focused only on optical aspects and not on other physical aspects of EUV radiation that many optimistic forecasts and predictions have not come to pass (Henderson *et al.*, 1999).

7. **Charged-particle lithography**: Charged-particle lithography such as ion- or electron-projection lithography's (PREVAIL, SCALPEL, LEEPL), are also capable of very-high-resolution patterning. Ion beam lithography uses a focused or broad beam of energetic lightweight ions (like He^+) for transferring pattern to a surface. Using Ion Beam Proximity Lithography (IBL) nano-scale features can be transferred on non-planar surfaces (Dhara *et al.*, 2008).

8. **Neutral Particle Lithography** (NPL): This technique uses a broad beam of energetic neutral particle for pattern transfer on a surface.

9. **Nanoimprint lithography**: Nanoimprint lithography (NIL) is a method of fabricating nanometer scale patterns. It is a simple nanolithography process with low cost, high throughput and high resolution. It creates patterns by mechanical deformation of imprint resist and subsequent processes. The imprint resist is typically a monomer or polymer formulation that is cured by heat or UV light during the imprinting. Adhesion between the resist and the template is controlled to allow proper release. Nanoimprint lithography has been used to fabricate devices for electrical, optical, photonic and biological applications. For electronics devices, NIL has been used to fabricate MOSFET, O-TFT, and single electron memory. For optics and photonics, intensive study has been conducted in fabrication of sub wavelength resonant grating filter, polarizers, waveplate, anti-reflective structures, integrated photonics circuit and plasmontic devices by NIL. Sub-10 nm nanofluidic channels had been fabricated using NIL and used in DNA strenching experiment. Currently, NIL is used to shrink the size of biomolecular sorting device an order of magnitude smaller and more efficient. There are many different types of nanoimprint lithography, but two of them are most important: thermoplastic nanoimprint lithography and photo nanoimprint lithography.

● Thermoplastic nanoimprint lithography

Thermoplastic nanoimprint lithography (T-NIL) is the earliest nanoimprint lithography developed by Prof. Stephen Chou's group. In a standard T-NIL process, a thin layer of imprint resist (thermoplastic polymer) is spin coated onto the sample substrate. Then the mold, which has predefined topological patterns, is brought into contact with the sample and they are pressed together under certain pressure.

When heated up above the glass transition temperature of the polymer, the pattern on the mold is pressed into the softened polymer film. After being cooled down, the mold is separated from the sample and the pattern resist is left on the substrate. A pattern transfer process (reactive ion etching, normally) can be used to transfer the pattern in the resist to the underneath substrate (Chou *et al.*, 1996).

● Photo nanoimprint lithography

In photo nanoimprint lithography (P-NIL), a photo (UV) curable liquid resist is applied to the sample substrate and the mold is normally made of transparent material like fused silica. After the mold and the substrate are pressed together, the resist is cured in UV light and becomes solid. After mold separation, a similar pattern transfer process can be used to transfer the pattern in resist onto the underneath material. The use of a UV-transparent mold is difficult in a vacuum, because a vacuum chuck to hold the mold would not be possible.

10. **Scanning probe lithography:** Scanning probe lithography (SPL) is a promising tool for patterning at the deep nanometer-scale. For example, individual atoms may be manipulated using the tip of a scanning tunneling microscope (STM). Dip-Pen Nanolithography (DPN) is the first commercially available SPL technology based on atomic force microscopy. Scanning probe lithography describes a set of lithographic methods, in which a microscopic or nanoscopic stylus is moved mechanically across a surface to form a pattern.

This type of method can be split in two different groups:

● Constructive - In which the patterning is done by directly transferring chemical species to the surface (Dip Pen Nanolithography).

● Destructive - In which the patterning is done by providing the substrate with energy (mechanical, or thermal, photonic, ionic, electronic, X-rays, and so on and so forth) to physically, chemically, electronically deform the substrate's surface. Examples include nanoimprint lithography and local oxidation nanolithography.

11. **Atomic Force Microscopic Nanolithography:** Atomic Force Microscopic Nanolithography (AFM) is a chemo-mechanical surface patterning technique that uses an atomic force microscope (Davis *et al.*, 2003).

12. **Magnetolithography**: Magnetolithography (ML) is based on applying a magnetic field on the substrate using paramagnetic metal masks call "magnetic mask". Magnetic mask which is analog to photo mask define the spatial distribution and shape of the applied magnetic field. The second component is ferromagnetic nanoparticles (analog to the photoresist) that are assembled onto the substrate according to the field induced by the magnetic mask.

13. **Nanosphere lithography**: It uses self-assembled monolayers of spheres (typically made of polystyrene) as evaporation masks. This method has been used to fabricate arrays of gold nanodots with precisely controlled spacings (Hatzor *et al*., 2007).

Nanolithography –A Valuable Technology

A recent patent entitled “Method and apparatus for mesoscale deposition of biological materials and biomaterials,” invented by Gregory Marquez, and Michael J. Renn (Marquez *et al.*, 2007) , describes a method for deposition of an aerosolized biomaterial consisting of an aerosol stream using a carrier gas that deposits material onto a target surface in a digitized pattern. Aerodynamic focusing of the aerosol stream attached to a print head deposits patterns with feature sizes ranging from 5 - 200µm, onto flat or featured targets. This method has the advantage of avoiding the use of masks, but its limited feature size places it in a category of devices similar to the Nano eNablerTM, available commercially from BioForce Nanosciences Inc. Potential deposition materials are numerous and are listed in the disclosure to include: conductive metal precursors, nanoparticle metal inks, dielectric and resistor pastes, biocompatible polymers, and a range of biomolecules including peptides, viruses, proteinaceous enzymes, extracellular matrix biomolecules, as well as whole bacterial, yeast, and mammalian-cell suspensions. This type of application is especially valuable for technologies such as biosensor rapid prototyping and microfabrication, lab-on-chip manufacturing, biocompatible electroactive polymer development, hybrid BioMEMS, biooptics, and microfabrication of biomedical devices.

CONCLUSION

It may be concluded that Nanolithography is a valuable technique used in the creation of nanocomputer parts. The Nanolithography can be used for fabrication of the circuits in various devices such as optical devices, displays, data storage, biotech, semiconductor ICs, chemical synthesis materials etc. One of the popular kinds of Nanolithography technology is Nanoimprint lithography that conducive to replication neopaterns at the nanometer scale and is characterically simple process with low cost, high throughput and high resolution. There are different techniques of nanolithography and each technique has got important applications. In the upcoming years, we are likely to see nanotechnology and nanolithography maintaining the momentum of the recent biology revolution.

ACKNOWLEDGEMENT

The authors are thankful to all the seniors of Macleods Pharmaceuticals Limited, for their valuable guidance and co-operation. One of the co-author Mr. Satyanand Tyagi is highly thankful to Dr. D.K.Modi honourable President and Mr. Meghraj, Administrator of K.N.G.D Modi Institute of Pharmaceutical education and Research for their valuable guidance, co-operation and help in providing facilities to utilize the library and internet in the college.

REFERENCES

Broers AN et al. Electron beam lithography—Resolution limits. *Microelectronic Engineering*, 32, 1996, 131-142.

Chang THP et al. Maskeless lithography: A general Introduction. *Microelectronic Engineering*, 7, 2001, 57-58.

Chou SY, Krauss PR, Renstrom PJ. Imprint Lithography with 25-Nanometer Resolution. *Science*, 272(5258), 1996, 85-87.

Davis RC et al. Chemomechanical surface patterning and fictionalization of silicon surfaces using an atomic force microscope. *Appl. Phys. Lett*, 82(5), 2003, 808-810.

Dhara Parikh, Barry Craver, Hatem N. Nounu, Fu-On Fong, John C. Wolfe. Nanoscale Pattern Definition on Nonplanar Surfaces Using Ion Beam Proximity Lithography and Conformal Plasma-Deposited Resist. *Journal of Microelectromechanical Systems*, 17(3), 2008, 560-568.

Griscom L, Degenaar P, LePioufle B, Tamiya E, Fujita H. Techniques for patterning and guidance of primary culture neurons on micro-electrode arrays. *Sensors Actuators B-Chem*, 83(1-3), 2002, 15-21.

Gross G, Rieske E, Kreutzberg G, Meyer A. A new fixed-array multi-microelectrode system designed for long-term monitoring of extracellular single unit neuronal activity *in vitro. Neurosci Lett*, 6, 1977, 101-106.

Gross GW, Rhoades BK, Azzazy HME, Wu MC. The use of neuronal networks on multielectrode arrays as biosensors. *Biosens Bioelectron*, 10, 1995, 553-567.

Hatzor-de Picciotto A, Wissner-Gross AD, Lavallee G, Weiss PS. Arrays of Cu (2+)-complexed organic clusters grown on gold nano dots. *Journal of Experimental Nanoscience*, 2, 2007, 3-11.

Henderson PT et al. EUV: A Form of Lithography. *Proc. Natl. Acad. Sci. USA*, 96, 1999, 8353-8358.

Honda T et al. Double Pattern Technique. *J. Microlith. Microfab. Microsyst*, 5, 2006, 430-34.

Morefield SI, Keefer EW, Chapman KD, Gross GW. Drug evaluations using neuronal networks cultured on microelectrode arrays. *Biosens Bioelectron*, 15, 2000, 383-396.

Nalamasu O, Cheng M, Kometani JM, Vaidya S, Reichmanis E, Thompson LF. Photolithography: Principles and Techniques. *Proc. SPIE,* 32, 1990, 1262.

Nalamasu, Omkaram et al. An Overview of Resist Processing for DUV Photolithography. *Journal of Photopolymer Science and Technology*, 4(3), 1991, 299-318.

Pancrazio JJ, Bey Jr PP, Cuttino DS et al. Portable cell-based biosensor system for toxin detection. *Sensors Actuators B – Chem*, 53, 1998, 179-185.

Pancrazio JJ, Whelan JP, Borkholder DA, Ma W, Stenger DA. Development and application of cell-based biosensors. *Ann Biomed Eng*, 27(6), 1999, 697-711.

Stoffels E, Stoffels W, Kroesen GMW. Concept of electron beam lithography. *Plasma Sources Science and Technology*, 10, 2001, 311.

Vladimirsky Yuli, Bourdillon Antony, Vladimirsky et al. Physics parameters in X-rays lithography. *Journal of Physics D: Applied Physics*, 32, 1999, 114.