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Nickel Nanoparticle Arrays Prepared Using Nanosphere Lithography

Nirupama M.P[1], Amarnath Bheemaraju[2], O. S. Panwar[3], B. S.Satyanarayana[4]
[1]*Dept. of Electronics & Communication Engineering,*
[2]*Research Scholar, Jain University, Bengaluru & BML Munjal University, Gurgaon, Haryana, India*
[3]*BML Munjal University, Gurgaon, Haryana, India*

Abstract*: The localized surface Plasmons (LSPs), supported by metal nanostructures find applications in wide range of sensors, vacuum nanoelectronic devices and for enhancing the efficiency of solar cells. The plasmonic properties solely rely on the size, shape and local environment of the metal nanostructures. For the production of nanometre scale periodic particle array (PPA), the nanosphere lithography (NSL) is demonstrated and presented in this article. Nanosphere Lithography (NSL) is simple, offers high throughput, cost-effective self-assembly nanofabrication technique capable of producing large variety of nanostructures and ordered nanoparticle arrays on any given substrates. The paper focuses on the synthesis of Nickel (Ni) nanoparticle arrays by nanosphere lithography technique. The characteristics of these nanoarrays are analysed using NSOM (ALPHA 100RAS) for AFM (atomic force microscopy) measurements. It is proposed to use this Self-Assembled Mask less Nanoparticle arrays to create nanocarbon emitter arrays by Cathodic Arc Deposition system. This nanocarbon emitter arrays are good field emitters and can be used for the development of Field emission electrical propulsion (FEEP) system for Nano satellites.
***Keywords*: Nanosphere Lithography (NSL), Nanocarbon, nanoparticles, Field Emission Electrical Propulsion (FEEP)**

I. INTRODUCTION

Nanosphere lithography (NSL) is simple, low cost, high-throughput nanofabrication technique used to produce well-ordered periodic nanoparticle arrays. These nanostructures find applications in sensors, photonics, light emitting diodes and solar cells. To synthesise, assemble these nanoarrays and control them for a specific application is a challenge. The size, shape, orientation and spacing of these nanopatterns can be controlled to yield a high throughput with low cost. There are various methods for depositing colloidal crystal on a flat surface. For the creation of arrays on various substrates different methods are adopted like self-assembly, template based process, electron beam lithography and Nano imprinting. Based on the cost, requirements, application and complex procedures involved to develop nanopatterns the above mentioned methods can be adopted accordingly [1-3].

To synthesize periodic nanoparticle arrays of Nickel (Ni) on plain glass, TCO-coated glass and silicon substrates, Nanosphere lithography (NSL) technique is used. A monolayer self-assembled mask were generated from polystyrene sphere (PS). Polystyrene sphere (PS) are hexagonally closely packed and of various diameters were used in the process, contributing in creating a different arrays of Ni nanoparticles. The created patterns were investigated using Atomic force microscopy (AFM). It is revealed from the AFM analysis that nanoparticles were circular in shape with consistent array dimensions. In this study Polystyrene spheres (PS) of various diameters – 100 nm, 200 nm and 500 nm diameter were used. A monolayer masks yielded Nickel (Ni) nanoparticle array of various diameters.

The best suitable and easy way to deposit an ordered colloidal layer on substrate is demonstrated. For fabricating self-assembled, well ordered nanoarrays the polystyrene spheres have been used. The array patterns can be changed under different experimental conditions and by varying diameter of the polystyrene spheres. The size and shape of the sputtered Nickel (Ni) mask depends on the number of colloidal layers and size of the polystyrene spheres. The size and shape of the nanocarbon emitter arrays depends on the mask developed and the experimental conditions such as gas used, bias voltage and other deposition parameters. The developed nanocarbon emitter arrays can used as filed emitters to demonstrate the feasibility of developing FEEP system [4-8].

The study focus on investigating the patterned growth of a monolayer nanospheres for the deposition of ultrathin layer of Nickel (Ni) by DC sputtering. After removing the spheres a periodic arrays of Ni were obtained by ultrasonic agitation. It is well know that nanocarbon possess high aspect ratio, low work function of electron tunnelling, thermal stability and chemical inertness compared with other field emitters such as silicon field emitter arrays [4-8]. They can be used in various applications, in this study it is proposed to use it as field emitter array for demonstrating the feasibility for the development of field emission electrical propulsion system for Nano satellite [9-10].

This is one of the first work reported and considerable efforts has been put to optimize the synthesis of Nickel (Ni) Nanoparticle Arrays created using Nanosphere Lithography (NSL). Further more systematic material growth, electron emitter array development, characterization of nanocarbon emitter arrays and packing for use in actual Nano satellite is required.

II. EXPERIMENTAL

For Nanosphere Lithography (NSL) mask creation, dip coating method was used. The cleaned substrates were immersed in a colloidal suspension and pulled out. A colloid consists of finely divided particles varying in size from nanometres to micrometres, usually dispersed in another substance. It could be solid, liquid or in gaseous form. In this study powdered polystyrene spheres were used. It exhibits spontaneous property of forming self-assembled periodic arrays. For good quality colloidal crystal lattice polystyrene spheres of various diameters are used in the study. It is used as lithographic mask for creating nanosphere arrays and this technique is termed as nanosphere lithography [2].

It is possible to create a monolayer of a uniformly distributed colloidal particles on the substrate such as silicon, TCO-coated glass and plain glass. For the self-organization of colloidal suspension, capillary force and controlled evaporation is used in the dip coating technique. The ordered arrays depends on the evaporation rate and it is controlled just by pulling out the substrate in slow pace by hand from the colloidal suspension. For producing regular and homogeneous arrays of nanoparticles, Nanosphere lithography (NSL) is a promising fabrication tool. The polystyrene nanospheres of various diameters – 100 nm, 200 nm and 500 nm diameter – in the form of aqueous suspension are dispersed at air/water interface by dip and dry process. The process is optimized by determining various parameters such as nanospheres at the interface, the water level on the capillary tip, surfactant concentration and height of water on the substrate surface to attain hexagonally close packed polystyrene monolayer. The process of NSL is optimized by varying the colloidal suspension composition for various diameters of polystyrene spheres.

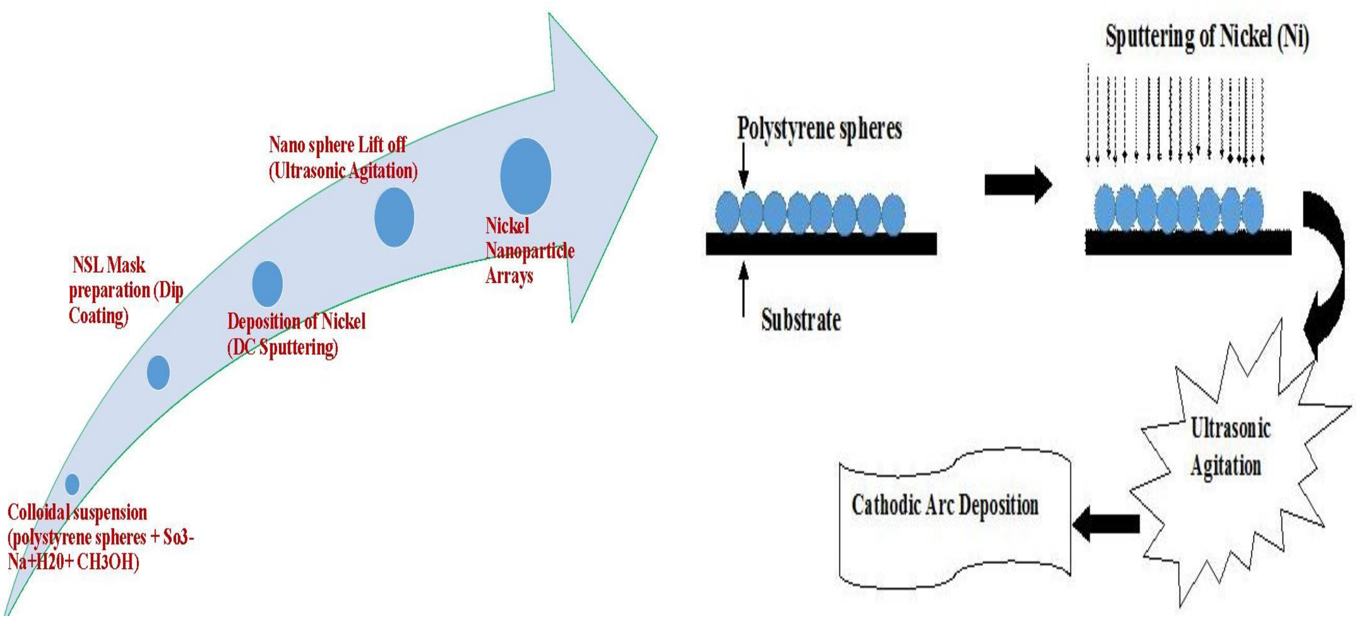

Figure 1.a) Figure 1.b)

Figure 1(a, b): Schematic representation of the synthesis procedure in creating Nickel (Ni) Nanoparticle Arrays using Nanosphere Lithography

Metallization was carried out using DC sputtering and the polystyrene balls were removed by ultrasonic agitation. Uniform distribution has been achieved. The developed patterns were considered for depositing Carbon nanotube (CNT) and room temperature nanocluster carbon using cathodic arc and Plasma CVD process under various optimized parameters. Figure.1 (a, b) shows the steps involved in the development of self-aligned Nickel (Ni) nanoparticle arrays using Nano sphere Lithography. It is proposed to use this nanoparticle arrays to grow Self-Assembled Mask less Nano carbon field assisted electron emitters for the development of Field Emission Electrical Propulsion (FEEP) system for Nano satellite.

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III.RESULTS AND DISCUSSION

A. Atomic Force Microscopy (AFM)

To understand the feasibility of Nanosphere lithography process for fabricating Nickel(Ni) periodic patterns for the growth of Self-Assembled Mask less Nanocarbon Emitter Arrays, Polystyrene spheres(PS) of various diameters – 100 nm, 200 nm and 500 nm diameter are used. This various range of PS were selected to develop nanocarbon emitter arrays of different size and shape which depends on the Ni mask developed.

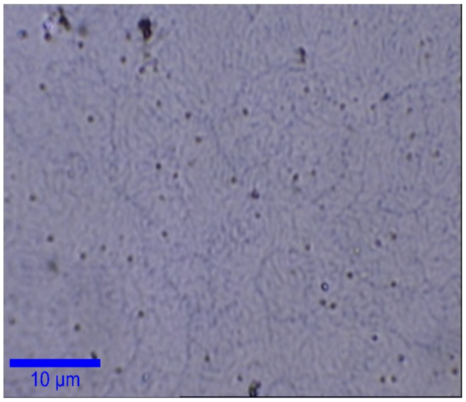

Figure 2.a)

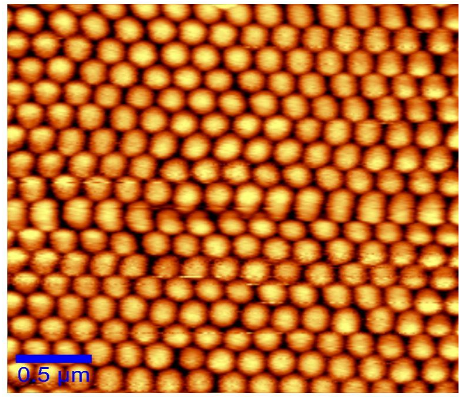

Figure 2.b)

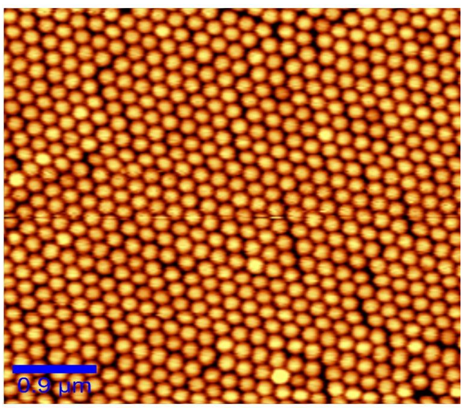

Figure 2.c)

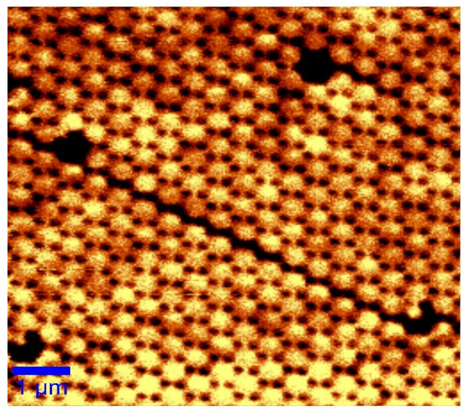

Figure 2.d)

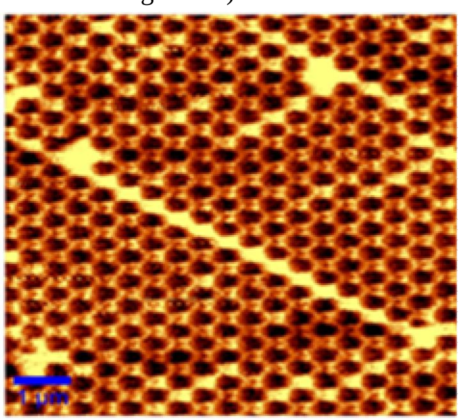

Figure 2.e)

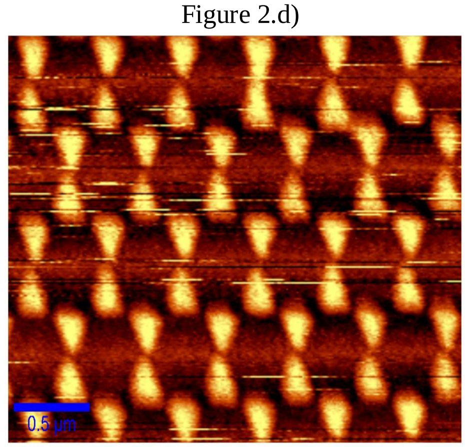

Figure 2.f)

Figure 2. AFM images depicting the fabrication steps with PS particles of diameter 200nm (a) The PS array in 50µm area on the silicon substrate under 20X objective (b) AFM image of closely packed self-aligned PS in 2.5µm area (c) AFM image of closely packed self-aligned PS in 4.5µm area (d) Shows the array of highly hexagonally packed nanoparticle crystal. (e) Shows the hexagonal array of holes after removal of the polystyrene sphere with some defects in 5µm area (f) AFM image of Ni nanoparticle in triangular prism array after lift-off.

Near-field Scanning Optical Microscope (NSOM), model ALPHA 300RAS is from (WI Tec) company used in characterizing the samples. It is a combinational equipment with three imaging techniques in a single instrument: Raman, Atomic Force Microscopy (AFM) and Scanning Near field Optical Microscopy (SNOM).

To study the surface morphology, the Atomic Force Microscopy (AFM) was used. The resolution of the AFM images depends on the tip used. The cantilever with 42N/m & 285 KHz, AC Tapping mode (Non-contact Mode) was used for the measurements. The non-contact mode was deliberately considered for the measurements to avoid possible damage to the sample like dragging particles across the surface of the sample [11, 12].

The advantage of using dip coating technique is the time required for preparing the colloidal masks. It approximately took 2-3min of preparation time and allowed a controlled formation of monolayer of Polystyrene Spheres. However some defects were also observed in the surface morphology study of the films.

Figure 2(a-f) shows the AFM images depicting the fabrication steps with PS particles of diameter 300nm. It also reveals the defects in these arrays: missing particles, overlapping of spheres, cracks in the array, variations in the particle size and dislocation. These defects can be due to PS concentration, even with optimal concentration these defects may occur. It is observed that with high concentration particle scatters and with too low concentration holes are formed. The fabrication technique decides the size of the particles. The possibility of dislocation, is the result of disturbance during the dip coating of the monolayer of PS on to the substrate. With optimization of NSL process these defects were well controlled.

The AFM images using tapping mode confirms the well-defined periodic patterns of Ni-coated nanospheres. For the removal of polystyrene spheres and retaining the Nickel (Ni) nanopatterns on the substrate, the patterned substrates were subjected to ultrasonic agitation process after deposition. Figure 2.a) shows the Polystyrene spheres in 50µm area on the silicon substrate under optical microscope 20X objective. The AFM image of closely packed self-aligned PS in 2.5µm and 4.5µm area is shown in figure 2.b) and c). Figure 2.d) shows the array of highly hexagonally packed nanoparticle crystal. Figure 2.e) shows the hexagonal array of holes after removal of the polystyrene sphere with some defects in 5µm area. Figure 2.f) depicts the AFM image of Ni nanoparticle in triangular prism array after evaporation and lift off. The periodic particle array (PPA) surface particle matrix can be defined from the mask geometry. The inter particle (ip) spacing for a monolayer (ML) on a given mask geometry can be defined as $d_{ip} = D/\sqrt{3} = 0.577D$, where D is the diameter of the PS used [13]. Further the developed patterns are used for the growth of CNT and room temperature nanocluster carbon using cathodic arc and Plasma CVD process under various optimized parameters. These films has enhanced field assisted electron emission properties and can be used as field assisted electron emitter arrays (FEA) to demonstrate the feasibility of development of Field Emission Electrical Propulsion (FEEP) for Nana/Pico satellite. A simple and economical technique is demonstrated for generating arrays of Nickel (Ni) metal nanoparticles on various substrates. Further the process can be tuned for the more controlled growth of particle arrays in terms of diameter, height and spacing.

IV. CONCLUSIONS

Nanosphere Lithography is economical and simple process for preparation of Nickel (Ni) Nanoparticle Arrays on plain glass, TCO-coated glass and silicon substrates. The process, growth and its characterization is demonstrated in this work. A simple dip and dry method is used to create periodic nanoarrays on various substrates by immersing in a colloidal suspension.

The size of the metal patterns vary with the size of polystyrene balls and number of layers of polystyrene balls. To study the inter-particle distance between the nanospheres, various polystyrene nanosphere of different diameters were used in the experiments. The films were characterized using NSOM (WI Tec Germany, GmbH) for AFM measurements. The polystyrene balls were uniformly distributed and further metallization was carried out using sputtering process with nickel and ultrasonic agitation was performed to remove polystyrene balls after deposition. To have the enhanced field assisted electron emission properties from nanocarbons, these patterns are to be used for the growth of CNT and room temperature nanocluster carbon using cathodic arc and Plasma CVD process under various optimized parameters. Further these Field assisted electron emitter arrays (FEA) are proposed to be used in demonstrating the feasibility of development of Field Emission Electrical Propulsion (FEEP) for Nano satellite.

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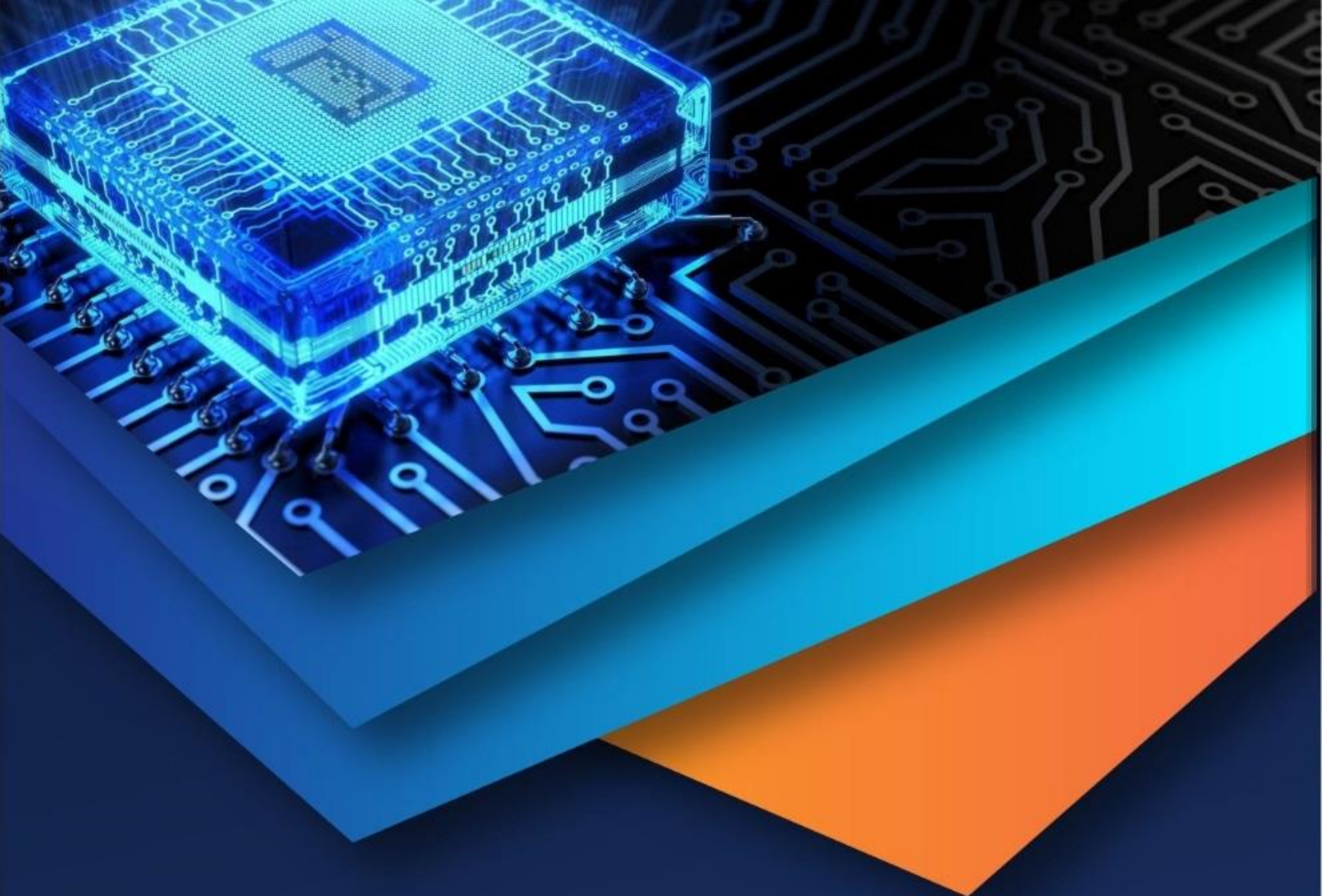
REFERENCES

[1] Li L, Zhai T, Zeng H, Fang X, Bando Y, et al. (2011) Polystyrene sphere-assisted one-dimensional nanostructure arrays: synthesis and applications. Royal Society of Chemistry 1: 40-56.

[2] Oshima H (2013) Nanosphere Lithography for High-Density Nanopatterning in Vistas in Nanofabrication, Singapore. Stanford Publishing Pt. Ltd 1-26.

[3] Toyin Jibowu* University of Western Ontario, Faculty of Engineering, Chemical and Biochemical Engineering, Canada "Nano-spherical lithography for nanopatterning" Frontiers in Nanoscience and Nanotechnology.
[4] B. S. Satyanarayana, A. Hart, W. I. Milne, and J. Robertson, Appl. Phys. Lett. 71, 1997, 1430 -1432
[5] B.S.Satyanarayana, Robertson, J. and Milne, W.I., J. Appl. Phys.., 87(6), pp. 3126–3131 (2000)
[6] B.S.Satyanarayana 2005."IEEE, 18th International Vacuum Nanoelectronics ConferenceTechnical Digest, Oxford, P219.
[7] Niranjana S, B.S. Satyanaryana, U.C. Niranjan & Shounak De, IJRRAS 4 (1), July 2010
[8] Shounak De, S. Niranajana, B. S. Satyanarayana, Mohan Rao, Optoelectronics and Advanced Materials – Rapid Comm Vol. 3, No. 12, 2009, p. 1365 - 1367
[9] M.P. Nirupama1&2, Ashok Bhattacharya1&2, Shounak De3, B. S.Satyanarayana1 1R.V.College of Engineering, Mysore Road, Bengaluru, India, 2Jain University, Bengaluru, India. 3Manipal Institute of Technology, Manipal University, Manipal India "Nano-Carbon Based Vacuum Nano-Electronic Emitters For Nano-Satellite Propulsion" Technical Digest, 2015 28th International Vacuum Nanoelectronics Confererncе, 13-17 July, Guangzhou, China
[10] Nirupama M.P.1,2&3, Ashok Bhattacharya2, B.S. Satyanarayana2, 1Jain University, Bengaluru, India 2R.V. College of Engineering, Mysore Road, Bengaluru, India 3BML Munjal University, Gurgaon, Haryana, India "Field Assisted Electron Emission for Electrical Propulsion of Nano Satellites" International Journal of Enhanced Research in Science, Technology & Engineering ISSN: 2319-7463, Vol. 6 Issue 2, February-2017
[11] Morita, S., Wiesendanger, R., Meyer, E. (eds.): Noncontact Atomic Force Microscopy. Springer, Berlin (2002)
[12] Morita, S., Giessibl, F.J., Wiesendanger, R. (eds.): Noncontact Atomic Force Microscopy, vol. 2. Springer, Berlin (2009)
[13] Hulteen, J. C., & Van Duvne, R. P. (1995). Nanosphere lithography: A materials general fabrication process for periodic particle array surfaces. Journal of Vacuum Science and Technology A: Vacuum, Surfaces and Films, 13(3), 1553-1558.



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