

**INTEGRATED SYSTEM FOR MANUFACTURE OF SUB-MICRON 3D STRUCTURES
USING 2-D PHOTON LITHOGRAPHY
AND NANOIMPRINTING AND PROCESS THEREOF**

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FIELD OF INVENTION

The present invention relates to a system and process which integrates 2-photon lithography and nanoimprinting to manufacture high-throughput and low cost sub-
10 micron 3D structures.

BACKGROUND

Two-photon lithography is a very powerful, yet simple technique to produce complex,
15 three-dimensional structure from a liquid, photosensitive material. Two-photon polymerization (TPP) is based on the simultaneous absorption of two photons, which induce chemical reactions between starter molecules and monomers within a transparent matrix. The absorption of 2 photons requires extremely high peak intensities, thus an ultra-short pulse laser is needed to provide the high intensity. Previously, the most
20 common application of two-photon absorption (TPA) has been two-photon confocal microscope where the fluorescence of a dye molecule is observed after being excited by the means of TPA. Single-photon absorption used in standard photo- and stereolithographic techniques is inherently two-dimensional, since ultra-violet light is absorbed by the resin within the first few micrometers. Since the photosensitive resins are
25 transparent in the near-infrared (NIR) region, NIR laser pulses can be focused into the volume of the resin. As the laser focus is moved three-dimensionally through the volume of the resin, the polymerization process is initiated along the path allowing the fabrication of any 3D microstructure.

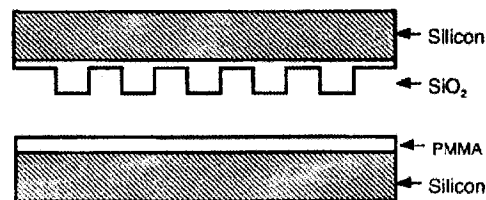
30 The rate of TPA is non-linear or quadratic dependent on incident intensity, therefore making it possible to achieve lateral resolutions better than 100nm in the polymerized structures. Since implants, tissue engineering scaffolds require features in the micrometer regime, the TPP process offer a fast and simple way to achieve the desired resolutions.

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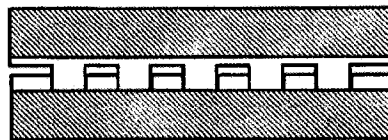
Nanoimprint Technology

The principle of nanoimprint is straightforward. A schematic of the process developed in the original NIL process [4] is shown in the “Schematic of nanoimprint lithography process steps” below. A hard mold that contains micron – nanoscale surface relief features is pressed into a polymeric material cast on a substrate at a controlled temperature and pressure, thereby creating a thickness contrast in the polymeric material. A thin residual layer of polymeric material is left underneath the mold protrusions and acts as a soft cushioning layer that prevents direct impact of the hard mold on the substrate and effectively protects the delicate nanoscale features on the mold surface. For most applications, this residual layer needs to be removed by an anisotropic O₂ plasma-etching process to complete the pattern definition.

1. Initial Setup



2. Nanoimprinting

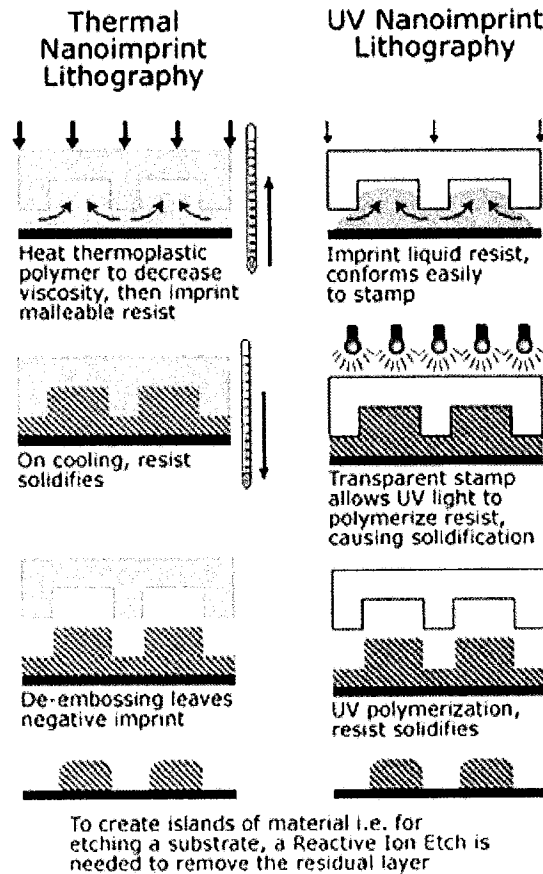


3. Mold Removal



15 *Schematic of nanoimprint lithography process steps*

A variation of nanoimprint has also been developed known as Step and Flash Imprint Lithography (SFIL) or UV nanoimprint lithography. In this technique, a transparent mold and UV-curable precursor liquid to define the pattern is used, allowing the process to be carried out in room temperature, as shown in the “Side by side comparison of the difference between thermal Nil and UVNIL” below.



Side by side comparison of the difference between thermal NIL and UVNIL

5 DISCUSSION OF PRIOR ART

Use of 2-photon lithography in the fabrication of 3D template/mold for nanoimprint

Current NIL technologies rely on e-beam lithography, laser writers and optical lithography technologies to write the device designs onto the NIL templates. Unfortunately these technologies are inherent 2D writing technologies and are unable to fabricate 3D structures required by many NIL applications. Although current investigators get around this problem by a multi-layer processing, this is not an effective long term manufacturing solution to cheap, 3D, nanostructures. The steps or effects of grayscale produced by multi-layer process are not acceptable in many applications.

The proposed use of 2-photon lithography in nanoimprint template fabrication is novel. For application with simple 3D requirements, such as hemispherical structures, the stamping process could be performed in a single step, eliminating the need for a multi-stamping overlay process.

2-photon lithography has an extremely high write resolution (~100nm) compared to conventional laser writer (~600nm). However, similar to conventional laser writers, 2-photon lithography has comparatively high writing speed compared to e-beam writers, making this technology ideal for most write applications except those that require resolutions less than 100nm.

Use of 3D nanoimprint in tissue engineering

Currently, there are no known groups working on the development of organ/tissue scaffolds using 3D nanoimprint technologies. By stacking layers of imprinted structures onto each other would make this rapid prototyping technique with the highest resolution and with comparatively high throughputs. This process does not suffer as much material constraints compared to other rapid prototyping processes, as it relies on a physical stamping process to define its features.

Although the NIL approaches have been designed to provide a solution to lithography in the next generation semiconductor wafer fabrication, scientist and engineers have been working on numerous applications in hybrid plastic electronics, organic electronics, novel Silicon devices, novel Gallium Arsenide devices, organic lasers, photonics, non-linear optical polymer structures, high resolution organic light-emitting diode (OLED pixels), diffractive optical elements, broadband polarizer, hard disk drive, DNA manipulation, nanoscale protein patterning and cell culture. Currently, the NIL technology is used by the hard drive industry in the fabrication of disk media.

The critical technical steps in NIL are separated into 1) mold fabrication, 2) resist, and 3) processes.

OBJECTIVE OF THE INVENTION

The inventor has proposed a high-throughput sub-micron 3D structure technology which integrates multiple state of the art technologies, nanoimprint [1], 2-photon lithography [2] and roll-to-roll nanoimprint [3]. By leveraging on the advantages of each technology it is possible to produce sub-micron 3D structures at a low cost. This approach is similar to the approach the semiconductor wafer manufacturing industry, where the integrated circuit on a silicon wafer is manufactured, using many expensive

capital equipment for high volume production while reducing the cost of each individual component.

The inventor's proposed technology deviates from conventional NIL technology right
5 from the mold fabrication step. Conventional NIL templates are patterned using e-beam lithography or optical lithography, fundamentally these patterning technologies are 2D in nature. However, the inventor proposes 2-photon lithography, a 3D write technology, to pattern the template. The patterned mold could be 3D as well.

10 SUMMARY OF THE INVENTION

A first object of the Invention is a system to manufacture high-throughput and low cost sub-micron 3D structure products, the said system integrating 2-photon lithography and nanoimprinting.

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A second object of the Invention is a process to manufacture high-throughput and low cost sub-micron 3D structure products, the said process integrating 2-photon lithography and nanoimprinting.

20 A third object of the Invention is a mold making process for manufacture high-throughput and low cost sub-micron 3D structure products using a system integrating 2-photon lithography and nanoimprinting wherein the 2-photon lithography using proprietary software can fabricate 3D molds of any shape and molds of different shapes can be combined to form complex molds.

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A fourth object of the Invention is a system to manufacture high-throughput and low cost sub-micron 3D structure products as claimed in Claim 2, using 3D write technology to pattern a template for the 3D mold.

30 A fifth object of the Invention is a process to manufacture high-throughput and low cost sub-micron 3D structure products as claimed in Claim 2, using 3D write technology to pattern a template for the 3D mold.

A sixth object of the Invention is a system integrating 2-photon lithography and
35 nanoimprinting to manufacture high-throughput and low cost sub-micron 3D structure products, wherein nanoimprinting is by Thermal NIL thermal or UV NIL or Roll-to-Roll nanoimprinting..

A seventh object of the Invention is a process integrating 2-photon lithography and nanoimprinting to manufacture high-throughput and low cost sub-micron 3D structure products, wherein nanoimprinting is by Thermal NIL thermal or UV NIL.

- 5 The inventive technology is the enabling technology for organ/tissue engineering and key innovations and are listed below.

A process for writing 3D templates for nanoimprint, through the use of 2-photon lithography wherein the initial template is 3D in shape (hemispherical or other shape with
10 curved side walls) compared to typical grayscale structures, which has vertical or sloping side walls.

A process for writing 3D templates for nanoimprint wherein the process follows the NIL process flow, including:-

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improved designs in mold manufacturing with library of shapes to establish design rules for mass manufacturing of 3D devices;

making molds with these 3D templates;

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use of the stamp on NIL thermal, UV, stamping and roll-to-roll technology.

A method for fabrication of organ/tissue scaffolds using 2-photon lithography to create any type of 3D structures and nanoimprint to create whole organ scaffolds of complex
25 organ such as kidney or liver, including the following:-

- a. organ/tissue scaffolds fabricated by slicing a 3D CAD design of the scaffold into multiple layers. Each layer is individually fabricated using nanoimprint and overlay and bonded forming the final scaffolds. With this
30 technique scaffolds that are anatomically similar to in vivo physical environment is created;
- b. tissue engineering scaffolds;
- c. fabrication of medical implantable devices.

35 A method for fabrication of simple 3D structures such as sinusoidal structures and hemispheres in a single pass, for use in photonics, LCD industry, holographic tags, micro lens for focusing, bandages.

A method for fabricating of simple 3D structures wherein the material used in the NIL process could be either synthetic or biological material.

5 A process to manufacture scaffolds for tissue engineering using a system integrating 2-photon lithography and nanoimprinting comprising the following steps:-

- a. creating a 3D template using 2-photon lithography;
- b. transferring the image onto a mold by electroforming or any type of forming techniques, such as e-beam lithography or optical lithograph, depending on the type of molds (flexible, hard, size, surface properties, and resolution) needed for the processing;
- c. designing the structures with a computer aided design program (CAD);
- d. using proprietary software with the 3D CAD drawing as input to automatically sliced the said structures into multiple layers;
- e. eliminating layers with repeated patterns;
- f. fabricating templates for mold making;
- g. fabricating a master mold for each layer to produce a hard/flexible mold for a stamping/roll-to-roll nanoimprint tool;
- h. sandwiching each layer produced onto each other to form a complete organ scaffold with physical dimensions close to an actual natural scaffold.

A process to manufacture medical devices such as bridges for nerves and bones requiring physical cues to guide growth of nerves and bones, using a system integrating 2-photon lithography and nanoimprinting comprising the following steps:-

- a. creating a 3D template using 2-photon lithography;
- b. transferring the image onto a mold by electroforming or any type of forming techniques, such as e-beam lithography or optical lithograph depending on the type of molds (flexible, hard, size, surface properties, and resolution) needed for the processing;
- c. designing the structures with a computer aided design program (CAD);
- d. using proprietary software with the 3D CAD drawing as input to automatically sliced the said structures into multiple layers;
- e. eliminating layers with repeated patterns;
- f. fabricating templates for mold making;

- g. fabricating a master mold for each layer to produce a hard/flexible mold for a stamping/roll-to-roll nanoimprint tool;
- h. sandwiching each layer produced onto each other to form a complete organ scaffold with physical dimensions closes to an actual natural scaffold.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a process flow of the manufacturing method proposed for the invention.

10 DETAILED DESCRIPTION OF THE INVENTION

The process flow of the manufacturing method is shown in Figure 1 and summarized as follows:-.

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Designing the 3D structures;

Fabricating 3D mold template using 2-photon lithography;

Transferring the features of the 3D structure onto the mold;

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(Depending on the application, the mold could be flexible, hard, metal or transparent.)

Using a master mold to fabricate more molds, if required;

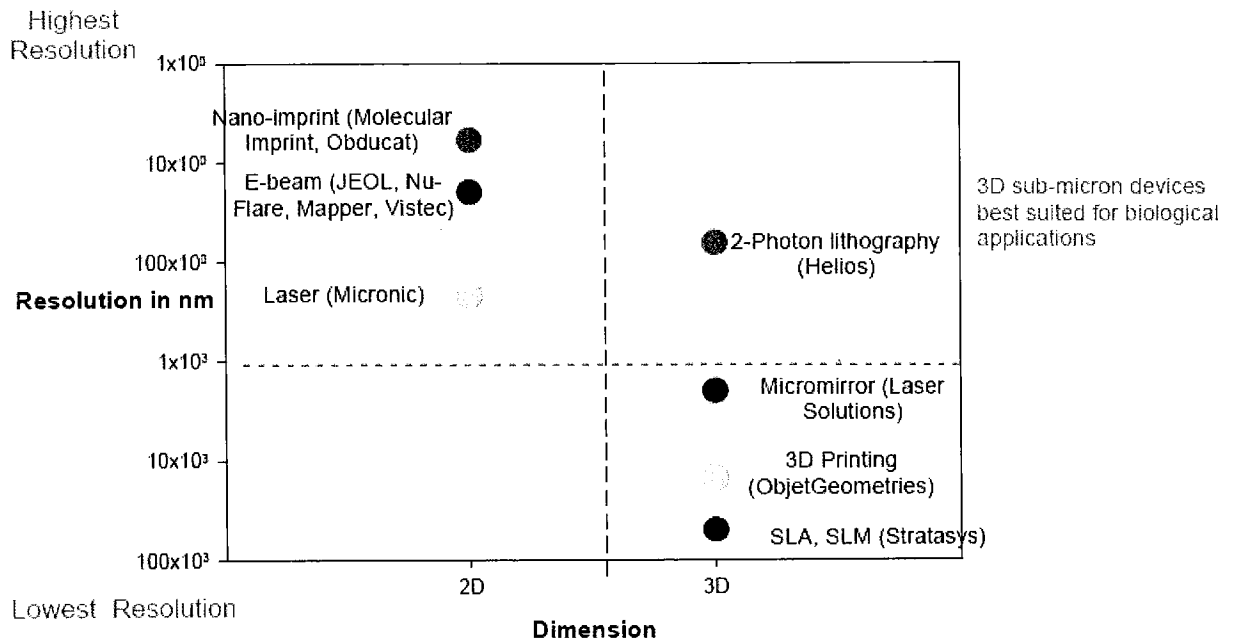
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Using the mold in nanoimprinting process such as Thermal NIL or UV NIL or Roll-to-roll NIL;

Stamping more layers and creating multiple layers of the nanostructure, assembling the 3D structure, layer by layer, in the case of larger objects.

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A comparative advantages of the different fabrication technologies is shown in the matrix below. By combining 2-photon lithography and nanoimprint, the invention will enable mass-manufacture of devices at a very low cost compared to all the competing manufacturing technologies.



The approach using the invention is fairly similar to clinical approaches to organ transplantation and existing grafting techniques. Instead of using biomaterial scavenged from cadavers, a totally synthetic scaffold is manufactured to minimize issues of disease transmission, shortage of suitable cadavers and lower cost.

First a 3D template that is created using 2-photon lithography or other types of rapid prototyping technology (determined by the resolution of final device) is created. Next the image is transferred onto a mold by electroforming or any type of forming techniques, depending on the type of molds (flexible, hard, size, surface properties, and resolution) needed for the processing. Products that only require a single stamping process could be then produced by either standard roll-to-roll technology or through standard NIL or UV NIL technologies.

The structures are designed with a computer aided design program (CAD). Next this 3D CAD drawing is input into proprietary software used for the invention and automatically sliced into multiple layers. Layers with repeated patterns are eliminated and templates for mold making are fabricated. With this template, a master mold for each layer is fabricated to produce a hard/flexible mold for a stamping/roll-to-roll nanoimprint tool.

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For applications where a single imprint step is sufficient, such as holographic tags, micro lens for focusing, LCD, bandages, the final product is packaged for sale. Other application that require more complex 3D structures could have each layers bonded onto

each other to form a larger device such as a tissue scaffold, organ scaffold. With this inventive technology it is possible to produce an organ scaffold at a rate of 4/hour.

The manufacturing method includes a process for writing 3D templates for nanoimprint, through the use of 2-photon lithography. The initial template is 3D in shape (hemispherical or other shape with curved side walls) compared to typical grayscale structures, which has vertical or sloping side walls.

The process for writing 3D templates for nanoimprint which is based on the NIL process flow, includes:-

improved designs in mold manufacturing using library of shapes to establish design rules for mass manufacturing of 3D devices;

making molds with these 3D templates;

use of the stamp on NIL thermal, UV, stamping and roll-to-roll technology.

The method for fabrication of organ/tissue scaffolds using 2-photon lithography to create any type of 3D structures and nanoimprint to create whole organ scaffolds of complex organ such as kidney or liver, including the following:-

a. organ/tissue scaffolds fabricated by slicing a 3D CAD design of the scaffold into multiple layers. Each layer is individually fabricated using nanoimprint and overlay and bonded forming the final scaffolds. With this technique scaffolds that are anatomically similar to in vivo physical environment is created;

b. tissue engineering scaffolds;

c. fabrication of medical implantable devices.

The method for fabricating simple 3D structures, such as sinusoidal structures and hemispheres, in a single pass, can be used in photonics, LCD industry, holographic tags, micro lens for focusing, bandages.

The method for fabricating simple 3 D structures wherein the material used in the NIL process could be either synthetic or biological material.

This manufacturing technology can be used for organ/tissue engineering scaffold
5 fabrication.

The inventive technology is the enabling technology for organ/tissue engineering and key innovations which are listed below.

10 **Fabrication of organ/tissue scaffolds with 3D nanoimprint technology**

Conventional scaffolds methods for scaffold fabrication include techniques such as solvent casting and particulate leaching, gas foaming, fiber meshes and fiber bonding, phase separation, melt molding, emulsion freeze drying, solution casting and freeze
15 drying. There are several limitations involving these processing techniques such as lack of precise control of pore sizes, pore geometry, pore interconnectivity, spatial distribution of pore, and construction of internal channels within the scaffolds. In addition many of these techniques exploit organic solvents, like chloroform or methylene chloride as a part of the process to dissolve synthetic polymers. The presence of organic solvent residues is
20 a significant problem of conventional fabrication methods due to toxins and carcinogens to which cells are exposed if residual solvent exists.

An alternative approach to scaffold fabrication is through the use of advance manufacturing technologies/rapid prototyping (RP) technologies such stereolithography
25 (SLA) selective laser sintering (SLS), 3D printing, fused deposition modeling (FDA) and 3D bioplotter. So far only a few research groups have demonstrated the exploitation of RP technologies in clinical applications. Within bone tissue engineering the SLS has proven its usefulness to fabricate polycaprolactone scaffolds. Also 3D printing has been used to create negative molds into which a polyactide solution can be poured and
30 thermally phase separate to create nanofibrous scaffolds. The results of all biological studies show that microporosity and very fine surface features improve bone growth into scaffolds by increasing surface area for protein adsorption, increasing ionic solubility in the micro environment and providing attachment points for osteoblasts. All mentioned RP approaches have not yet lead to the construction of harmonically organized complex
35 tissues. This is due to the lack of print resolution of current RP technologies, difficulty in embedding various cell types within intricate designs. The only technology capable of doing that right now is organ printing, some structures have been printed by this setup,

printing several cell types and biomaterials simultaneously. However, this setup is not suitable for fragile cell type such as hepatocytes. Further, the inventor has found that the biomaterial used to print the mixture obstructs cell-cell interaction required to maintain function and differentiation. A matrix to compare the different type of scaffold technologies is shown in Table below.

		Invention	Nanoimprint	RP Technologies	Conventional
1	Max. Resolution	~ 100nm	<100nm	>1000nm	<100nm
2	Material Range	Large	Large	Limited	Large
3	Custom shape	Yes	Limited	Yes	No
4	Complex organs	Yes	No	No	No
5	3D	Yes	Yes	Yes	No
6	Cost	Low	Low	High	Low
7	Scalability	Yes	Yes	No	Yes

Table showing Head-to-Head comparison of various scaffold fabrication technologies

Application of inventive process for Organ/Tissue Engineering

Tissue engineering is an essential technology in the emerging regenerative medicine industry. It can be defined as the engineering of functional tissues and organs for the repair of diseased body parts. Autologous tissue engineered devices are formed by combining patient-derived cells with a degradable material and implanting the combination in the body. The material is termed a scaffold or matrix. It is porous or gelatinous in nature, ensuring the incorporation of cells within the substrate and not solely on the surface. The goal of tissue engineering is to circumvent the limitations of conventional clinical treatments for damaged tissue or organs based on the use of organ transplants or biomaterial implants. The most essential limitations of these treatments involve shortage of donor organs, chronic rejection and cell morbidity.

The dominant method of tissue engineering involves growing the relevant cells in vitro into a scaffold that attempts to mimic the function of extracellular matrix. Without any three dimensional supporting structures the cell will form a random two-dimensional mainly monolayer of cells. Thus the primary function of a scaffold serves as an adhesion substrate for the cell. In addition the scaffold provides temporary mechanical support and guidance to the growing tissue.

In recent years various researchers have relied on decellularized organs, heart and thorax, from cadavers to provide architecture, geometry and cellular constituents to build bioartificial organs. These scaffolds are reseeded with cells and cultured in a perfused bioreactor for weeks and the resultant construct could perform some or most functions of an organ. In other simple organs such as the cornea, bladder, skin and bone the organ scaffold matrix was replaced with a totally synthetic scaffold.

The clinical success in the reports from the previous paragraph suggests that the approach of providing 3D scaffold support is the best approach to regenerative medicine. However, to harvest scaffolds from cadavers is a serial process and have many issues associated with this technique, such as transmission of diseases, number of cadavers available, skilled surgeons to extract the parts, ethical and quality control issues. With the inventive technology, a physiologically similar environment, with the correct chemical signals, totally synthetic organ/tissue scaffold could be recreated for regenerative medicine.

There is a clear need for the development of tissue engineered organs. However, the main problems for the engineering of more complex tissues are angiogenesis, growing blood vessels to supply the new tissue with blood, and developing 3D matrices on which to grow new tissue.

The use of cheap, high throughput, high resolution and 3D manufacturing technology of the invention offers a solution to the problems faced by researchers in developing a vascularized, 3D matrix. This would further the cause of tissue engineering research and improve healthcare in general.

Other biomedical applications for these scaffolds, when used in cell culture, could be used to develop better drug models for pharmaceutical companies to perform drug testing, lower the cost of clinical trials, and drug development.

The inventive process has wide ranging applications, and some of the applications are listed in the Table below.

	Application/Industry	3D technology critical to industry?	Will 3D technology improve technology?	Invention's Technology value add to industry?	Industry size
1	Organ/Tissue Engineering Scaffold	Yes	Yes	Yes	Potentially Large, Emerging
2	Hybrid Plastic/ Organic Electronics	No	Yes	Yes	Large Emerging
3	Silicon/Gallium Arsenic Devices	No	No	No	Large, Mature
4	Organic Lasers	No	Yes	Yes	Potentially Large, Evolving
5	Photonics	Yes	Yes	Yes	Large, Evolving
6	LCD	No	Yes	Yes	Large, Evolving
7	Micro-fluidics	No	Yes	Yes	Potentially Large, Evolving
8	Biotech	Yes	Yes	Yes	Potentially Large, Evolving
9	Hard Drive	No	Yes	No	Large, Mature

5 Table showing possible applications from technology developed under this invention.

Other applications

- 10 Simple single layer process have many applications such as fabricating non-symmetric micro grating for LCD applications, miniaturization of optical components for communications, and micro lens to focus light onto photovoltaic device for efficient collection of light in green energy applications.

15 ADVANTAGEOUS EFFECTS OF THE INVENTION

By combining 2D lithography and nanoimprint technology, high resolution sub micron 3D structures can be fabricated, at low cost. Besides the applications discussed herein like organ/tissue engineering, many new applications of nanoimprint such as LCD monitor industry, contact lens industry, surface texturing of plastic products, semi conductor industry and hard drive industry and even counterfeiting technology can use the invention.

CLAIMS

1. A system to manufacture high-throughput and low cost sub-micron 3D structure products, the said system integrating 2-photon lithography and nanoimprinting.
2. A process to manufacture high-throughput and low cost sub-micron 3D structure products, the said process integrating 2-photon lithography and nanoimprinting.
3. A mold making process for manufacture high-throughput and low cost sub-micron 3D structure products using a system integrating 2-photon lithography and nanoimprinting wherein the 2-photon lithography using proprietary software can fabricate 3D molds of any shape and molds of different shapes can be combined to form complex molds.
4. A system to manufacture high-throughput and low cost sub-micron 3D structure products as claimed in Claim 2, using 3D write technology to pattern a template for the 3D mold.
5. A process to manufacture high-throughput and low cost sub-micron 3D structure products as claimed in Claim 2, using 3D write technology to pattern a template for the 3D mold.
6. A system integrating 2-photon lithography and nanoimprinting to manufacture high-throughput and low cost sub-micron 3D structure products, wherein nanoimprinting is by Thermal NIL thermal or UV NIL or Roll-to-Roll nanoimprinting.
7. A process integrating 2-photon lithography and nanoimprinting to manufacture high-throughput and low cost sub-micron 3D structure products, wherein nanoimprinting is by Thermal NIL thermal or UV NIL.
8. A process to manufacture high-throughput and low cost sub-micron 3D structure products using the system of Claim 1, comprising the following steps:-
 - designing the 3D structures;
 - fabricating 3D mold template using 2-photon lithography;

transferring the features of the 3D structure onto the mold;

using the mold in nanoimprinting process such as Thermal NIL or UV NIL or
5 Roll-to-roll NIL;

to manufacture sub-micron 3D structures.

9. A process of Claim 2 for fabricating 3D mold templates for nanoimprint, using 2-
10 photon lithography wherein the initial template is 3D in shape (hemispherical or
other shape with curved side walls) compared to typical grayscale structures, which
has vertical or sloping side walls.

10. A process of Claim 2 for fabricating 3D mold templates for nanoimprint
15 wherein the process follows the NIL process flow, and includes:-

improved designs in mold manufacturing with library of shapes to establish
design rules for mass manufacturing of 3D devices, making molds with
these 3D templates;

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use of the stamp on NIL thermal, UV, stamping and roll-to-roll technology.

11. A method for fabrication of organ/tissue scaffolds using 2-photon lithography
and nanoimprint to create images of 3D structures of whole organ scaffolds of
25 complex organs such as kidney or liver, including the following:-

a. organ/tissue scaffolds fabricated by slicing a 3D CAD design of the
scaffold into multiple layers, each layer being individually fabricated
using nanoimprint to overlay and bond all layers to form the final
30 scaffolds, creating such scaffolds which are anatomically similar
to those created in vivo physical environment;

b. tissue engineering scaffolds;

c. fabrication of medical implantable devices.

35 12. A method for fabrication of simple 3D structures such as sinusoidal structures
and hemispheres in a single pass, using 2-photon lithography and a single

stamping nanoimprinting process for use in the manufacture of photonics, LCD industry, holographic tags, micro lens for focusing, bandages.

13. A method for fabricating of simple 3D structures wherein the material used in the NIL process could be either synthetic or biological material.

14. A process to manufacture scaffolds for tissue engineering using a system integrating 2-photon lithography and nanoimprinting as claimed in Claim 1, comprising the following steps:-

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- a. creating a 3D template using 2-photon lithography;
- b. transferring the image onto a mold by electroforming or any type of forming techniques, such as e-beam lithography or optical lithograph, depending on the type of molds (flexible, hard, size, surface properties, and resolution)

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- needed for the processing;
- c. designing the structures with a computer aided design program (CAD);
- d. using proprietary software with the 3D CAD drawing as input to automatically sliced the said structures into multiple layers;

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- e. eliminating layers with repeated patterns;
- f. fabricating templates for mold making;
- g. fabricating a master mold for each layer to produce a hard/flexible mold for a stamping/roll-to-roll nanoimprint tool;
- h. sandwiching each layer produced onto each other to form a complete organ scaffold with physical dimensions close to an actual natural scaffold.

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15. A process to manufacture medical devices such as bridges for nerves and bones requiring physical cues to guide growth of nerves and bones, using a system integrating 2-photon lithography and nanoimprinting as claimed in Claim 1, comprising the following steps:-

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- a. creating a 3D template using 2-photon lithography;
- b. transferring the image onto a mold by electroforming or any type of forming techniques, such as e-beam lithography or optical lithograph depending on the type of molds (flexible, hard, size, surface properties, and resolution) needed

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