5^{th} Young Inventors Awards – Silver Award Winner

Mr Randall Law, who graduated with BEng(Elect) first-class honours in 2004, received the Silver Award in the Asia-Pacific Young Inventors Awards 2004 for the work done during his final-year undergraduate project in collaboration with A*STAR's Data Storage Institute (DSI). Under the supervision of **Asst Prof Hong Minghui** and DSI senior engineer **Ms Wang Weijie**, he helped to develop a cheap and versatile alternative technique that can create extremely small patterns in nanotechnology, a major driving force in today's scientific research.

Conventionally, the size of patterns drawn using laser light is limited to its wavelength (the diffraction limit), which is usually not small enough to be of use in nanotechnology unless advanced and costly techniques are used. By forcing a laser through a hole in an optical fiber smaller than the laser wavelength, some laser energy survives for a short distance beyond the aperture. By placing a recording material extremely close to the hole, patterns can be drawn that are many times smaller than the wavelength of the light used, hence overcoming one of the fundamental physical limitations of using light in nanotechnology.

Another interesting feature of the proposed technique is the use of a special ultra-fast laser that packs all its energy into pulses that are about 10,000 billion times shorter than 1 second. This produces novel effects in the recording material due to the speed of the laser pulse, thus drawing lines that are about 200 atoms wide, smaller than half the diameter the hole in the optical fiber.

Now in their fifth year (in association with Hewlett-Packard Co), the Asian Wall Street Journal's Young Inventors Awards aim to recognize and reward ingenious thinking, effort and experimentation that lead to the discovery and creation of new ideas. 87 entries were received in 2004 from universities and tertiary institutions in the region (such as Australia, India and Philippines).

The Silver Award Winner received a $5000 cheque (paid to NUS), HP computer equipment and an all-expenses trip to HP Labs in Palo Alto, California. Born in Singapore, he is currently pursuing his PhD under the A*STAR Graduate Scholarship, conducting his research in Information Storage Materials Laboratory (a new laboratory which was jointly developed by ECE Dept and Data Storage Institute).

Laser Nanopatterning in the Optical Near-field for High Density Data Storage

Randall Law

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Introduction

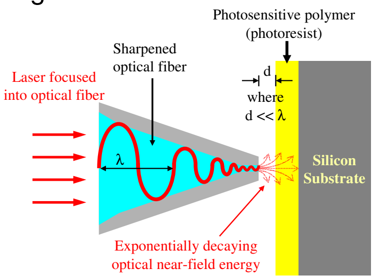
- Nanotechnology can potentially revolutionise many of today's industries.
- Nanofabrication is crucial for producing future high speed, low power and high storage density devices.
- In conventional lithography, the diffraction limit prevents the fabrication of features that are narrower than half the laser wavelength (λ/2) used.

Near-field Optical Lithography

- ***Imagine*** a light source that is much smaller than the wavelength (λ) of the laser light used:

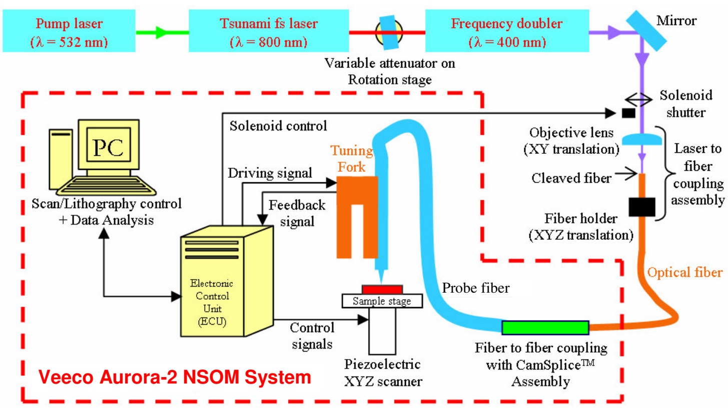
Breaking the Diffraction Limit

Exponentially decaying optical near-field energy (evanescent waves) exist at a very short distance from the nanoscale aperture in the optical fiber.



- Evanescent waves can expose the photoresist before they spread or dissipate if d << λ.
- A femtosecond (fs) pulsed laser (λ: 400 nm) was used with a near-field scanning optical microscope (NSOM) to achieve near-field scanning optical lithography (NSOL).

Lithography Equipment Setup



Ultra-fast Laser Nanofabrication *Integration of the Aurora-2 NSOM and femtosecond laser systems for ultra-fast nanofabrication in the optical near-field.*

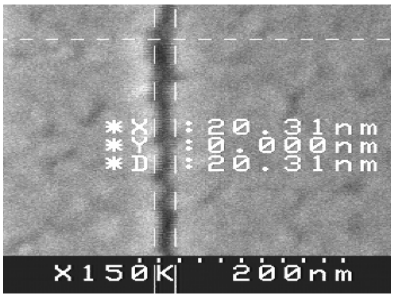
- Femtosecond laser provides extremely high peak power for ultra-fast processing.
- Unlike a costly electron beam lithography system which requires a ultra-high vacuum, this system operates in air or chemical environments, making it extremely versatile.

Advantages and Unique Features

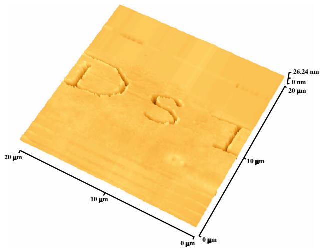
- A minimum line width of 20 nm (~100 silicon atoms), less than half the 50 nm diameter of the optical fiber aperture used, was achieved with low average laser powers and little optimisation of photoresist used.

Minimum Line Width

20 nm (λ/20) nanoscale line fabricated with a low average laser power of 0.01 mW, significantly narrower than the expected resolution from the 50 nm (λ/8) diameter NSOM aperture.



- Relatively low cost, simplicity and flexibility of system makes it suitable for research, mask production and low volume specialist products.



Flexible Patterning

Complex structures can be fabricated with NSOL for research and mask fabrication in the semiconductor industry.

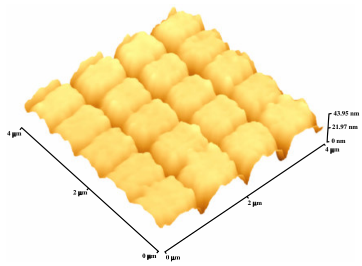
- Larger patterns are easily fabricated by increasing laser power, reducing writing time dramatically.

Future Research and Potential

- A large array of fibers can be used with a single laser source to provide high speed parallel writing.
- Exploit multi-photon effects and material optimisation to improve resolution several-fold in the next few years.

Patterned Magnetic Media

Regular arrays of isolated elements can be used for high density data storage devices of the future, allowing us to create hard disks that are more than 10 times their present capacity.



Conclusions

- NSOL with femtosecond lasers is a possible contender to other nanofabrication techniques for fast and cheap prototyping in the near future.
- There is still enormous potential for the system performance to be improved, as well as a vast range of possible applications in nanotechnology.