Dots brighten up dyes

Appl. Phys. Lett. **92,** 63309 (2008)

A three-dimensional bit-by-bit optical memory system in polymers doped with quantum dots and azo-dyes has been demonstrated by researchers in Australia. The team, from Swinburne University of Technology (Hawthorn, Australia) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Molecular and Health Technologies (Clayton South, Australia), have shown that two-photon absorption can be used to excite resonance energy transfer from luminescent CdS quantum dots to azo-dye molecules. The resultant isomerization of the azo-dye molecules leads to a pronounced refractive-index change, which can be used to represent data bits. This two-photon-excited energy transfer process in the quantum-dot and azo-dye polymer not only enables high efficient multilayer information recording in the volume of thick samples, but also offers a refractive-index window for readout. The method avoids destructive readout, which is a common problem for fluorescence readout schemes. To prove the concept, the researchers successfully demonstrated the efficient recording of three letters on different layers in a thick polymer sample.

Nanodots enable terabit capacity

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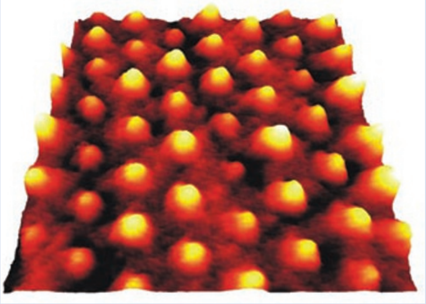
Researchers in Germany have developed a method of making regular patterns of fluorescent molecular nanodots. Stephan Rath and his colleagues from the University of Stuttgart used de-wetting techniques combined with topographically structured substrates as templates to create regular and closely packed patterns of dots. The researchers expect that when used for data-storage purposes such fluorescent nanodots and near-field optics can overcome issues such as optical diffraction and crosstalk, which limit data densities in conventional optical memories, for example, in DVD or Blu-ray.

The nanodots are made up of organic photochromes, which are optically bistable and can switch between two isomeric forms. Fluorescence is emitted in only one of the isomeric forms, providing a scheme for binary on–off detection.

Rath and his co-workers have shown that the dots can be individually addressed in the optical near field. With dot sizes of 50 nm in a hexagonal closely packed dot pattern, they achieved storage densities of about 75 Gbit inch^{-2} and are of the opinion that storage densities of up to 1.2 Tbit inch^{-2} are possible.



To make the nanodots, the researchers deposited thin organic films in ultrahigh vacuum conditions on helium-cooled substrates. Controlled annealing to room temperature transforms the films into homogeneous distributions of isolated dots. This process is based on de-wetting, which is common for quite different materials (liquids, polymers and metal melts), but has been applied to molecular thin films for the first time.

To achieve regular and closely packed patterns of dots, topographically structured substrates were used as templates. This enabled the researchers to control the size, density and arrangement of the nanodots on areas a square millimetre in size.

Phase-change insight

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The phase-change process that is key to many optical data-storage applications is now better understood thanks to researchers at the University of Cambridge, UK. The researchers have described for the first time how the entire write/erase cycle for the $Ge_2Sb_2Te_5$ composition can be reproduced using simulations of molecular dynamics. Such Ge–Sb–Te materials are used in optical DVDs and non-volatile electronic memories (phase-change random-access memories). In both, data is stored by means of fast, reversible phase changes between crystalline and amorphous states. Despite much experimental and theoretical effort to understand the phase-change mechanism, the detailed changes involved at the atomic level are still unknown. The researchers found that very high densities of connected square rings, characteristic of the metastable rock-salt structure, form during melt cooling and are also quenched into the amorphous phase. However, their presence strongly encourages homogeneous crystal nucleation. As this simulation procedure is general, the microscopic insight provided into crystal nucleation should open up new ways to develop superior phase-change-memory materials, for example, with faster nucleation, and different compositions and doping levels.

Third-harmonic answer

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A team of researchers in France claims that third-harmonic generation could be an ideal mechanism for three-dimensional optical data storage. The group says that its technique is very fast and can enable storage capacities of several terabits per cubic centimetre.

Conventional techniques for reading information stored in three dimensions suffer from one main drawback: the achievable reading depth is limited by the propagation of light within the storage media. Nonlinear interaction techniques, such as two-photon absorption fluorescence, have been proposed to overcome this problem, but photobleaching can degrade the durability of the data medium.

The technique developed by Lionel Canioni and his colleagues from the University of Bordeaux is based on a change in the third-order susceptibility of zinc phosphate glass doped with silver.

"The elementary data-bit is a small voxel exhibiting the same linear optical property [refractive index] as the surrounding medium, but a different nonlinear optical property [third-order susceptibility]," says Canioni. "The propagation of the light is not affected. In our case, the last data layers can be read as easily as the first one in the data medium."

Intense laser irradiation creates silver clusters close to the focal volume with a size comparable to that of molecules. These photo-induced clusters resonate with the read beam, giving rise to third-harmonic light.

"We have used the same set-up, with a different laser pulse energy, to write and read a three-dimensional bit pattern in our glass," says Canioni. "Since we deal with a very fast nonlinear process, the bit is read almost instantaneously. Using our experimental conditions [bit spacing: 3 μm; layer spacing: 10 μm], 1 Gbit cm^{-3} could be stored inside the glass. Better performance can be achieved with a high-numerical-aperture objective even if the objective working distance limits the number of layers."

Canioni also feels that, with the advances in femtosecond lasers, this third-harmonic data storage could become industrially viable, as only low optical powers are required.