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Short Note

LIMIT OF LITHOGRAPHY: ANGSTRÖM-LITHOGRAPHY

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Much of the tremendous progress in integrated circuits and technology and performance over the past 30 years has been fueled by the progress of lithography. The ability to print increasingly smaller features has enabled higher speed transistors, higher packing densities and lower power dissipation in CMOS circuits.

In the last decade excimer lasers have been introduced as light sources. KrF excimer lasers produce light in the deep ultraviolet (UV) at a wavelength of 248 nm. This source is used currently to produce the most advanced circuits with minimum design rules of 250 nm. Actually, the 248 nm deep UV is used to print the transistor gate features as small as 160 nm with Resolution Enhancement Technology (RET) which allows in some cases, printing of features somewhat below the conventional diffraction limit.

RET allow sub-diffraction printing by controlling the phase as well as amplitude of the light at the image plane in the printing system through the use of phase shifting masks. An other method uses pre-distorted amplitude patterns at the image plane to compensate for some diffraction effects (optical proximity effect correction (OPC)). Further, control of the distribution and angle of light (off-axis illumination, OAI) at the illumination aperture can accentuate higher diffraction orders leading to improved performance.

There are four leading candidates for next generation lithography technology: X-ray proximity, ultraviolet lithography, ion projection lithography and SCALPEL projection electron beam lithography.

A new lithography process was used in order to reach the limit of ~ 1 nm resolution. Using the porous alumina templates, Qin et al. [1] deposited electrochemically a nano-wire comprising alternately, segments of Au then short segments of Ag or Ni (with length tailored by the deposition charge). The template is then dissolved, and an aqueous suspension of nano-wires cast onto a slide. The silicon dots act as a gutter-shaped support. Ni segments are then etched using nitric acid, leaving gaps. Au-Ag nano-wires are coated with Au/Ti bi-layer, and Ag etched away with a solution of CH_3OH, NH_4OH and H_2O_2. The latest work has achieved 1 nm gaps [2].

Of high importance is the photo-resist used in lithography. The chalcogenide photo-resist (as e.g. glassy As_2S_3) is largely investigated and used. The photo-structural changes are induced at a larger scale and depend on the width of the used light beam. If the beam is correctly tuned, then, at its center of maximum intensity, a special phenomenon could be exploited: the formation of thin strips of chiral atomic configurations in the chalcogenide glass. The chiral configurations create anisotropy in the crystal and determine a very finely defined resistance to etching (positive photo-resist).

Recently, we approached the problem of the anisotropy in amorphous chalcogenides, with special emphasis on As_2S_3 glass, induced by light. We have demonstrated that the photon beam induces a chiral atomic configuration along the light propagation direction. The chiral chains into the non-crystalline network of e.g. As_2S_3 when nano-wires are considered, have been modeled in [3] (Fig. 1).

The chiral line can be tuned with high resolution. One chiral row of atoms comprises long chiral configurations of diameter extending down to minimum 2÷3 Å. The inscription resolution of the chiral lines into As_2S_3 glass depends on the laser beam concentration, but it is activated with more probability in the centre of the beam. Thus, a better resolution could be achieved at the angström-scale.

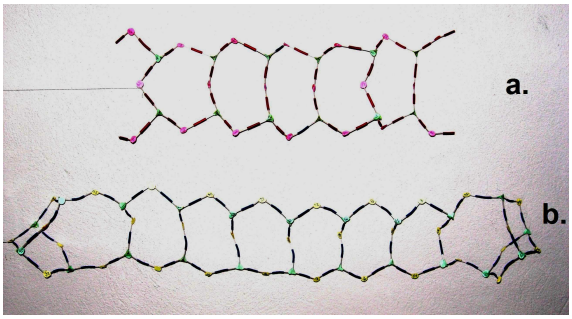

Fig. 1 Typical chiral, photoinduced configuration (a) and a non-chiral configuration (b) in As_2S_3 model.

References

[1] Qin et al., Science **309**, 113 (2005).
[2] Materials Today, September 2005, p. 10.
[3] M. Popescu, F. Sava, A. Lőrinczi, J. Non-Crystalline Solids, 2005, under print.