Preparation of DNA bases with laser light at 157 nm

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Abstract

By applying laser ablation at 157 nm ultra-thin films of the DNA bases Adenine, Guanine Cytosine, were prepared by etching of initial crystal samples to few nanometres size thickness on Si substrates. This was possible because only photochemical dissociation is taking place on DNA bases following illumination with laser light at 157 nm and localized damage. For a laser fluence of 0.5 mJ/cm^2 per laser pulse, 0.25 nm of film thickness was removed on the average making possible precise sub-nanometer control of film thickness.
High resolution AFM images reveal similar morphology between exposed to light and non exposed areas suggesting limited chemical change on the surface of the remaining substrate. The cytosine crystals were damaged with the appearance of surface cracks penetrating the crystal volume when the laser fluence exceeded the average value of 2 mJ/cm^2. This was due to photochemical damage due to the change of the thermo dynamical equilibrium of the crystal.

Experimental

❖ Thin films of DNA bases were grown from solutions on silicon wafers.

❖ The crystals of DNA bases was improved by growing them in a vibration/sound-free chamber under temperature stabilized conditions over a long period of time (3 days or longer).

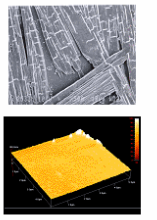
❖ The crystals were grown at different shapes and forms, which depend on the experimental conditions.

❖ The crystal samples were etched with laser radiation at 157 nm at a given laser fluence.

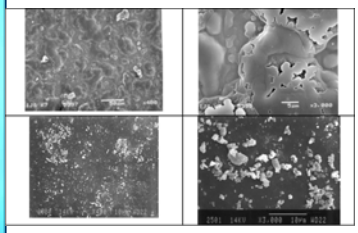
❖ The exposed surface was investigated by SEM and AFM.

Results

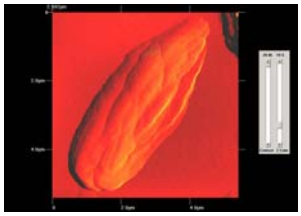
Prior to irradiation



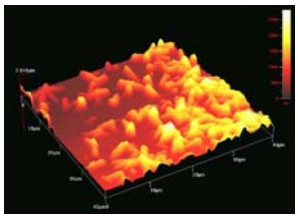
AFM and SEM surface morphology images of cytosine crystals grown from solutions on Si wafers. Crystals were grown at in a variety of shapes depending on the experimental conditions.



SEM images of guanine crystals grown from solutions on Si wafers. Crystals were grown at different shapes depending on the experimental conditions.



AFM image of adenine crystal. Long adenine crystals are formed from agglomerations of such crystals.



AFM mage of adenine crystals grown from solutions on Si wafers. The thickness of the crystals is varied 2 μm for 40 μm long crystals.

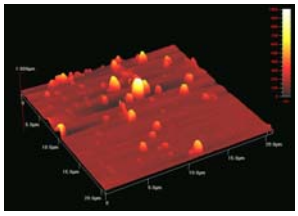
After irradiation

➢The energy of one photon at 157 nm is compensated to break one chemical bond of the organic parent molecule.

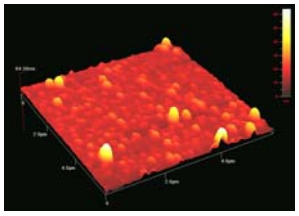
➢The photo-fragments were ejected away from the irradiated surface with supersonic speed.

➢High resolution AFM images of exposed and non-exposed areas reveal limited chemical changes for the illuminated part of the surface for most of the cases of cytosine and guanine samples.

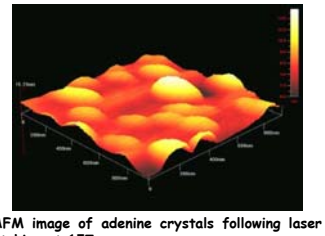
➢ In the case of adenine, the crystals were grown forming rather a non-uniform agglomeration of small size crystal. The surface roughness was reduced following laser illumination at 157 nm.



AFM image of adenine crystals following laser etching at 157 nm. The surface roughness was reduced to 30nm following laser illumination at 157 nm with 4000 pulses with the laser fluence of 0. 5 mJ/cm^2 per pulse.

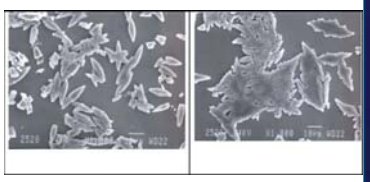


AFM image of adenine crystals following laser etching at 157 nm. The surface roughness was reduced to 1μm following laser illumination at 157 nm with 2000 pulses with the laser fluence of 0.05 mJ/cm^2 per pulse. The etching rate of the crystal was 0.5 nm for a laser fluence of 1mJ/cm^2.

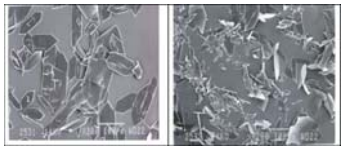


AFM image of adenine crystals following laser etching at 157 nm.

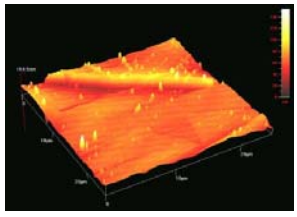
The surface roughness was reduced to 5nm following laser illumination at 157 nm with laser fluence of 1 mJ/cm^2 per pulse.



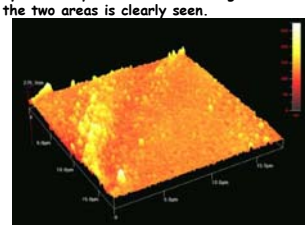
SEM images of non-radiated (left) and radiated (right) adenine crystals. Crystal homogenization is evident for the radiated crystals.



SEM images of non-radiated (left) and radiated (right) cytosine crystals. When the laser fluence exceeds the threshold value of 2 mJ/cm^2 ,the crystal collapses due to induced stress from the laser pulse which destroys the thermo dynamical equilibrium of the crystal.



AFM image of non-irradiated and radiated cytosine crystals where the edge between the two areas is clearly seen.



AFM image of non-irradiated and radiated guanine crystals where the edge (boundary) between the two areas is clearly seen.

Conclusions

➢Preparation of thin films of DNA bases of adenine, guanine and cytosine with atomic resolution thickness control and surface roughness was done by etching of initial thick samples with laser light at 157 nm.

➢The films were prepared with an average etching rate of 0.5 nm for a laser fluence of 1 mJ/cm^2.

➢Etched films indicate improve surface roughness in comparison to initial films prepared from solutions on Si substrates.

➢ The method overcomes the difficulty of film preparation for spectroscopic investigation of the DNA bases over a wide spectral range.

EMRS SPRING MEETING
STRASBOURG May 31 - June 3, 2005