Near field scanning ellipsometry - polarization resolved NSOM

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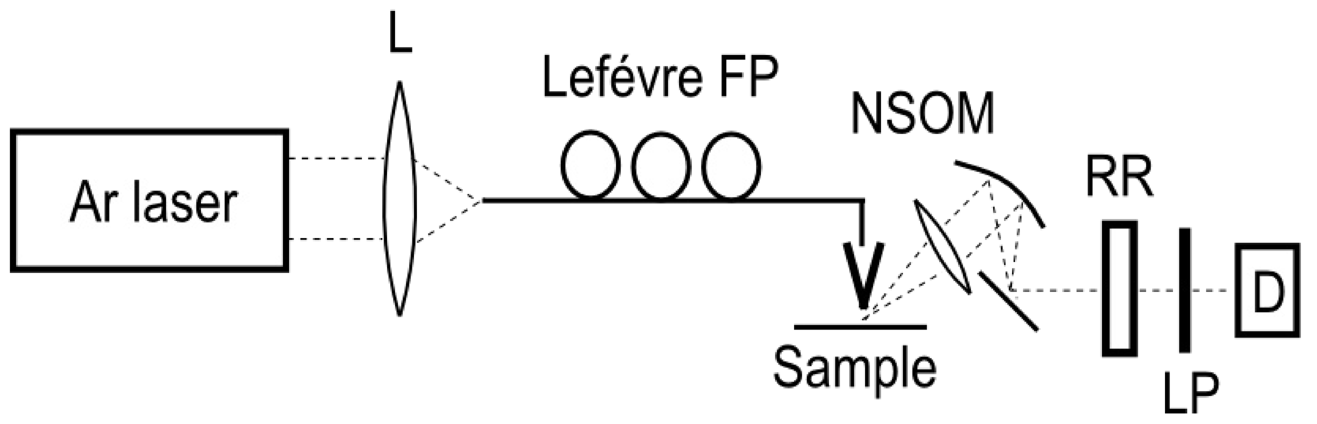
Motivation

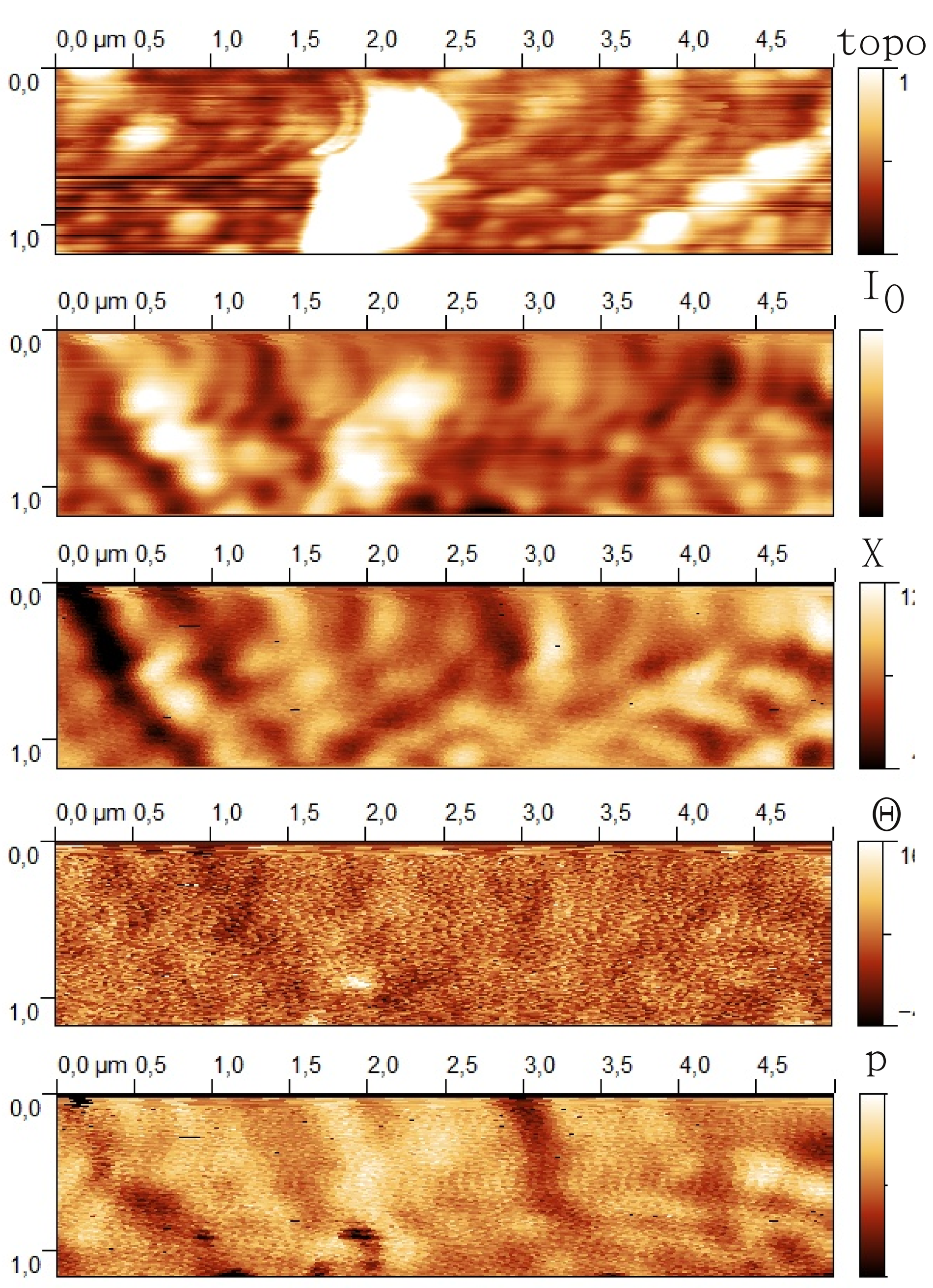
Ellipsometry is a firmly established extremely sensitive measurement technique. With the advent of near-field scanning optical microsopy, probing of polarization properties of samples with resolution beyond the diffration limit is of great interest. While polarization resolved NSOM isn't a novel technique, almost all approaches used so far rely on probing the light with rotating polarization filters. Drawback of such technique is that one cannot retrieve all four components of Stokes vector, describing the polarization of light. We present here an alternative method based on rotating compensator followed by fixed linear polarizer able to probe all ellipsometric parameters including i.e. the degree of polarization.

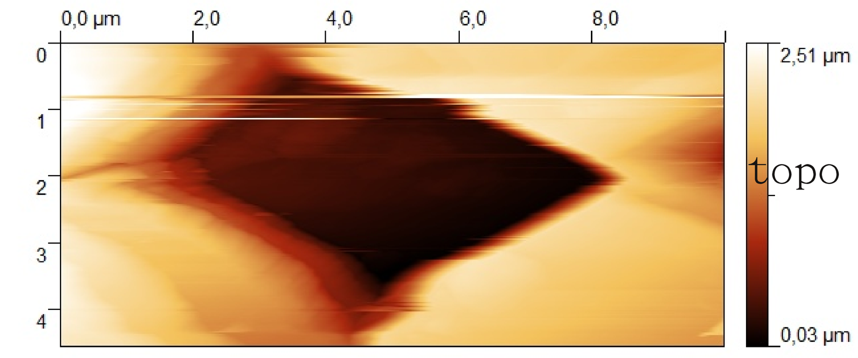
First experimental setup



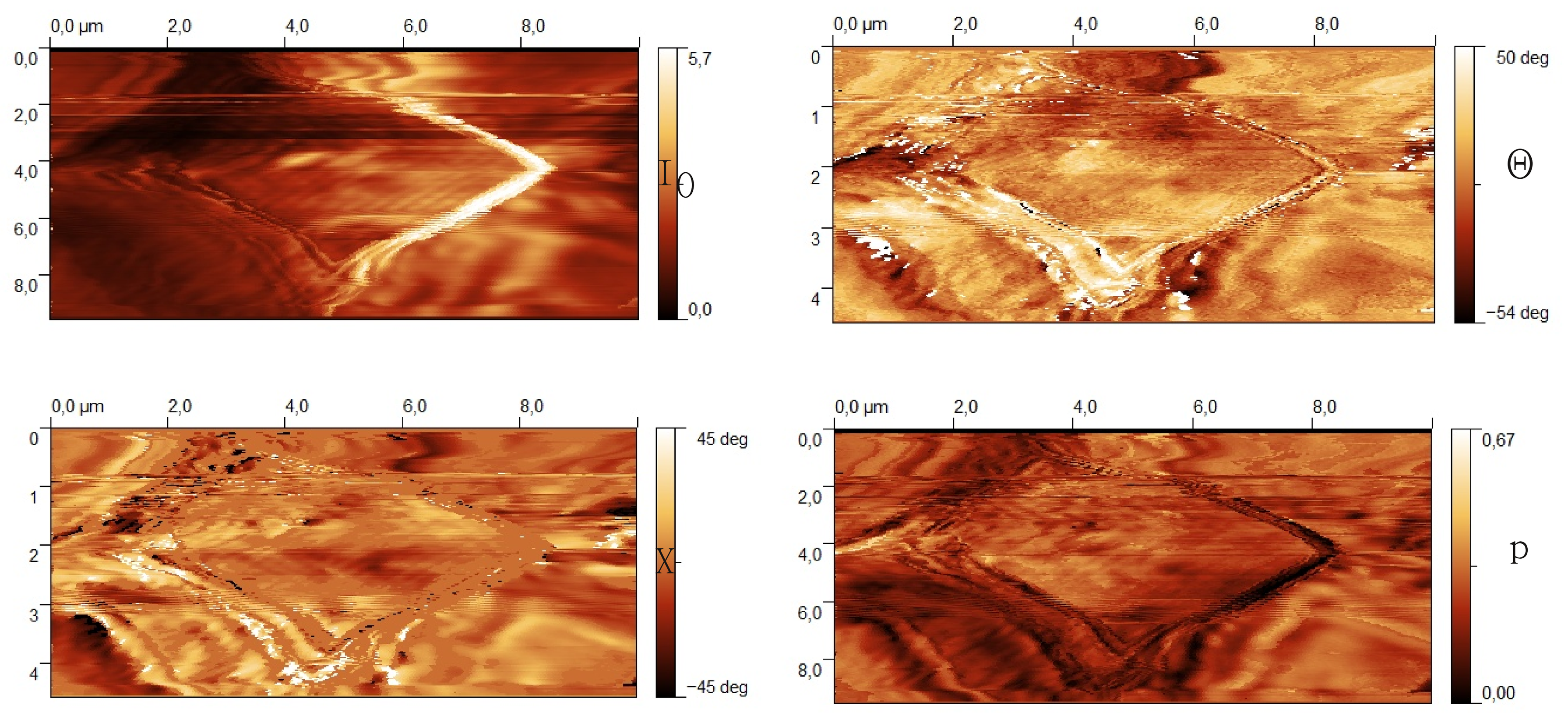
Experimental setup was as follows: lineary polarized light (633 nm) from argone laser was focused by lens (L) into the optical fibre leading the light into the standard aluminium coated NSOM fibre probe. Lefévre paddle fibre polarizer (FP) was mounted on the fibre to alter the incident polarization (or compensed fibre induced birefrigence). Light collected from the sample passed through a rotating retarder (RR) followed by fixed linear polarizer (LP) before reaching photomultiplier tube, used as a detector.
Dependence of intensity on angular position of fast axis of the retarder was recorded for every scan point. Intensity (I0), ellipticity (X), tilt (Θ) and degree of polarization (p) were evaluated for every scan point from the obtained fourier dependence.

Measurements on aluminum islands and silicon grating

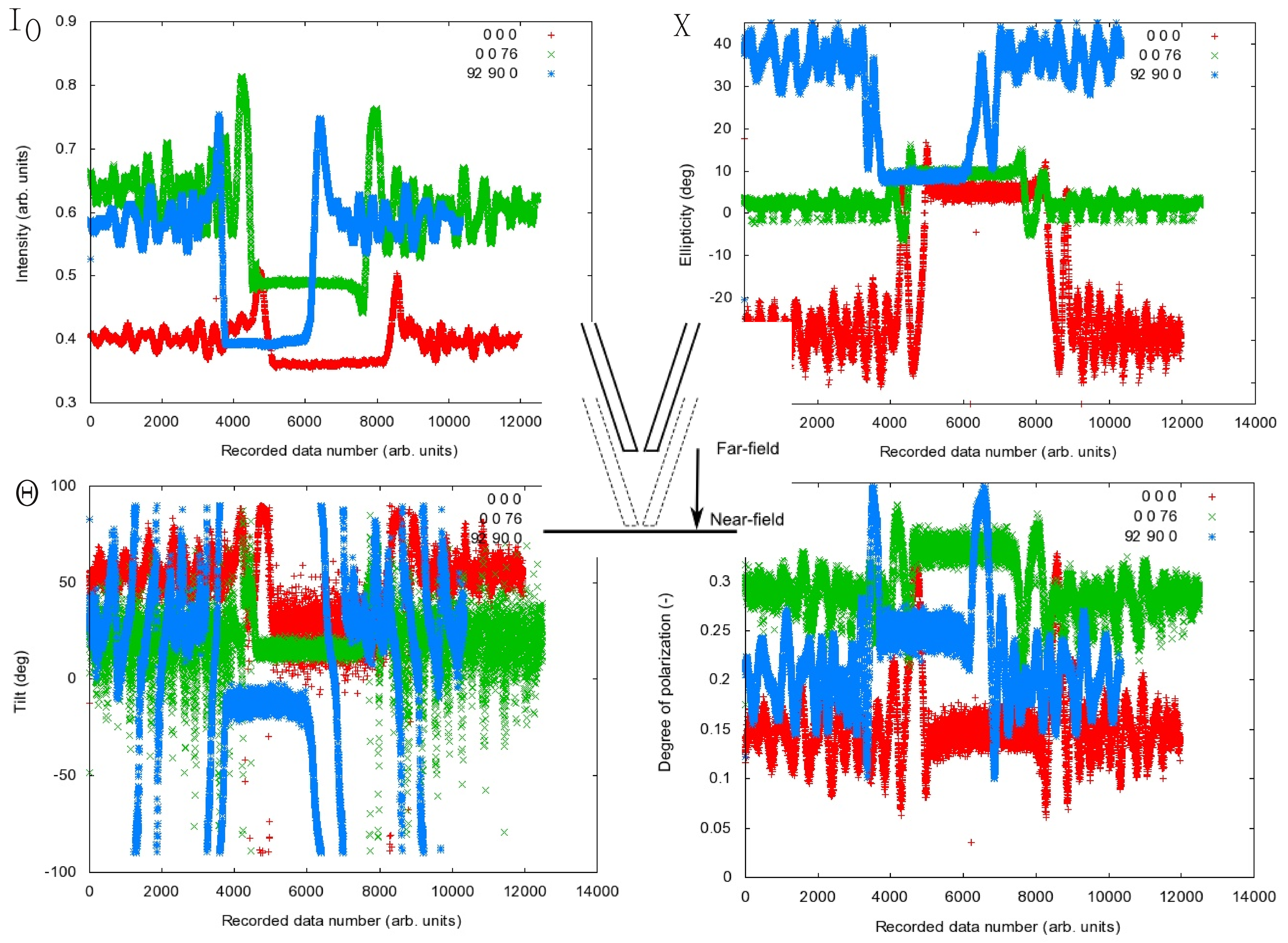




Possible values of X are in the range of -45 to 45 degrees, for Θ the possible range is -90 to 90 degrees and values of p may vary from 0 (completely depolarized light) to 1 (completely polarized light).
Although many of the features seen in the images may be artefacts (topographically induced or originating in the evaluation process), some interesting features may be pointed out:
1. Rather big object (probably dust) in the topographical image which can be seen in the fitted intensity is absent in the remaining three images and it seems that some information about the underlying surface has been retrieved.
2. Other objects seen on the images seem not to represent some artefact orginating in the evaluation method but rather containing different information about the sample surface.

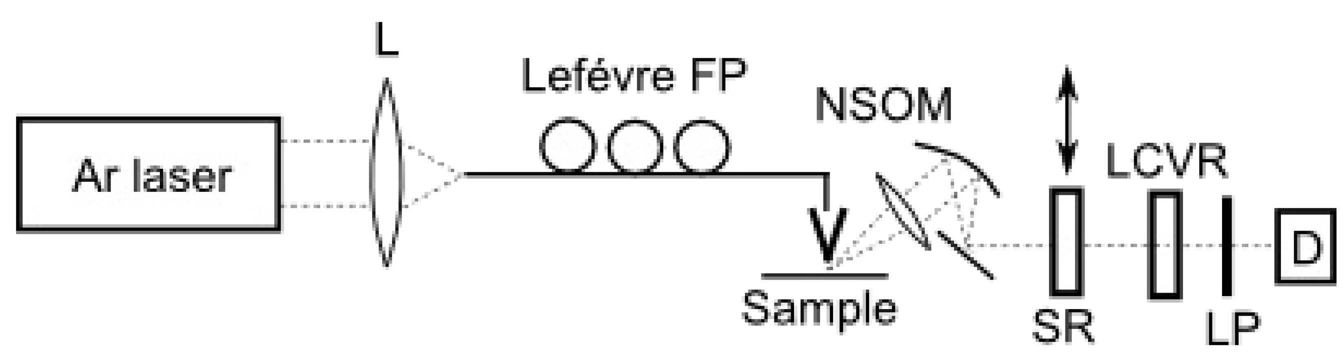


Approach of NSOM probe from far-field to near-field of the sample



Intensity and polarization status of light recorded during aprroach of moderately damaged (larger aperture) NSOM probe towards the near-field of Si sample surface and subsequently during the probe retraction from the surface (setup of the device was the same as in the previous). The scale in the horizontal axis is not linear as the rate of the approach was changing and in the near-field of the sample the probe was kept in static position. The period in the near-field can be clearly identified (e.g. in the plot of I_0) as a stable plateau. Oscillations during the approach of the probe towards (and retrieval from) the sample surface are a result of interference. Three plots on each graph represent three settings of the Lefévre LP (the polarization status may be deduced from the far-field). It can be clearly seen that the polarization state chages dramatically upon impact of the probe on the surface (i.e. in X). Similar behaviour has been also found for other probes and probably being effect of the probe geometry.

Second experimental setup



The presented method suffer from several drawbacks reducing its precision and thus increasing error in obtaining polarization parameters. The most important among these is the mechanical rotation of the compensator. This causes slightly different angular velocity at different angles and more importantly very long measurement time (it took up to 3hours to obtain the presented scans) affecting i.e. the thermal stability during the scan (causin i.e. the drift that can be seen in the figures to the left). This drift also complicates any numerical analysis that we need to perform for quantitative measurements.

New measurement setup has been proposed. It introduces liquid crystal variable retarder (LCVR) instead of the mechanically rotating one. Due to its nature it is impossible to obtain all ellipsometric parameters at once. However this is possible by performing another measurement of the same area by placing a static retarder (SR) before the LCVR. The main disadvantage of the LCVR is an exponential dependence of retardance produced by LCVR on applied voltage. This needs a calibration of LCVR prior to every measurement (due to significant temperature dependence of LCVR).

Conclusion

We have developed a measurement setup for polarization resolved NSOM measurements capable of identifying all four ellipsometric parameters. Results obtained on standard NSOM and AFM calibration samples are interesting and warrant futher investigation.

From both the approach curves and 2D measurements it is seen that there is enough information in the polarisation resolved NSOM data for local optical analysis of the sample.

The main task for further investigations is to speedup the measurement (thermal drift) with novel setup and compare experimental results with numerical analysis. Only after numerical analysis we can state that the method is capable to produce quantitative results, as the number of