SiO_2

Thickness measurement of SiO_2 layer on Si-wafer.

Introduction

Silicon is the basic material for the production of integrated circuits in the semi-conductor industry. During the production Si-wafers are doped and coated by functional layers, whose thickness and dispersion functions are measured by Ellipsometry. A silicon chip with SiO_2-layer is one of the most frequently measured type of sample in Ellipsometry.

Sample

Si-wafer (substrate) with SiO_2-layer with variable thickness (30-100 nm).

Instrumentation

Spectroscopic Imaging Ellipsometer EP³-SE, automatic sample handling stage, 10x Objective

Task

Local measurement of layer thickness and recording of a thickness map a

Steps of evaluation

- Optimize the ellipsometric image contrast with the angles of analyzer and polarizer (fig.1)
- Search for points of interest in the ellipsometric contrast image in real time
- Set Regions of Interest (ROIs, boxes in fig.1) where to measure
- Execute a script which measures spectra of Delta/Psi in all ROIs simultaneously
- Fit a spectrum (fig.2) in order to obtain the mean layer thickness in the ROI. Optionally the dispersion of the refractive index is obtained.
- Record a well focussed contrast image (fig.3) Let the EP^3 record a set of contrast images from which it calculates maps of Delta and thickness map of the layer (fig.4).

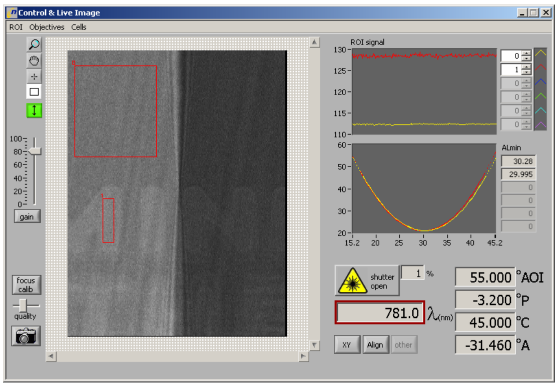

Fig. 1: “Control & Live Image” with Regions Of Interest (boxes no. 0 and 1 in the ellipsometric contrast live image on the left)

Measurements

The live-contrast-image (fig.1) is a micrograph of the sample where layer thickness is correlated with the greyscale. The sample is seen in real time when positioned by the XYZ-sample-stage. In a suitable position Regions Of Interest (ROIs) are set in the image. The measurement is done for all ROIs simultaneously. To this end the layer thickness variation in the field of view should be less than approximately 100 nm otherwise one is limited to one ROI at a time. Classic spectroscopic ellipsometers have at best about 40 µm lateral resolution with the microspot-option. By contrast the EP^3 has 2 µm lateral resolution(= smallest size of ROI with 10x objective) without any microspot option. Measurements with the EP³ are executed from scripts. There are scripts for variable angle of incidence spectra and for wavelength spectra. Fixed angle and fixed wavelength measurement of Delta/Psi is the fastest option, since it takes 6 seconds. The latter measurements gave the thickness results 43.0 nm (ROI 0) and 34.9 nm (ROI 1) at 55° angle of incidence and 781 nm wavelength.

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The thickness is the fit parameter, which is varied by a numerical algorithm to minimize the mean square error between measured and simulated Delta/Psi. Si and SiO_2 have the advantage that their refractive indices are found as tables in the literature with 10^{-4} accuracy. Therefore, there is no need to measure the refractive index in this case.

In case of mixed or doped semiconductor materials it is often necessary to measure the dispersion parameters of the refractive index, e.g. Cauchy-parameters, as fit parameters besides the thickness. To this end a wavelength spectrum (fig.2) was measured. The fit of the measured spectrum is already good using the refractive index from literature.

A delta map is obtained in the EP^3-View software from recording a series of images with variable contrast, i.e. variable polarizer angle. Each of these images (fig.3) is well focussed due to Nanofilm's unique objective scanner. The polarizer angles of signal minimum are interpolated for each pixel of the field of view. The map of minimum angles is converted into a delta map by a formula of nulling ellipsometry. The conversion of the delta map into the thickness map (fig.4, 5) uses the same fitting algorithm as explained above. Since the layer thickness is said to vary from 30 to 90 nm. A short wavelength e.g. 532 nm would cause an ambiguity in the relation of the observable Delta and the layer thickness. A unique relation is necessary for the calculation of the thickness map from the Delta map. Therefore a long wavelength, i.e. 781 nm, is selected for the recording of the delta map and the fit range for the thickness

Results

Measurements of a SiO_2-layer with variable thickness covering a Si-wafer have been done with multiples ROIs and single wavelength ellipsometry and with spectroscopic ellipsometry. Alternatively to multiple ROIs the Imaging Ellipsometer EP³ offers the mapping of the layer-thickness. A thickness profile is obtained from the

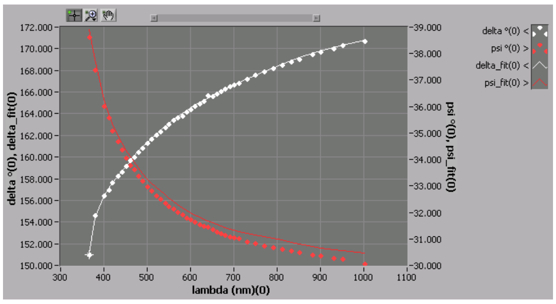

Fig. 2: Spectrum of Delta/Psi, fit with thickness d = 26.21 ± 0.15 nm of SiO_2-layer on Si-wafer

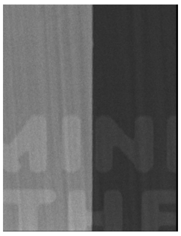

Fig.3: Ellipsometric contrast image focussed by objective scan, 55° angle of incidence, 781 nm wavelength, 350 µm x 450 µm field of view, 2 µm lateral resoluti-on

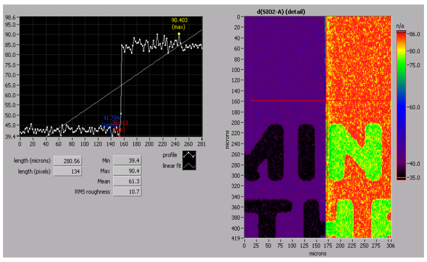

Fig.4: Thickness profile (in nm, left) along red line in the thickness map right, recorded within 1 minute, 4 µm lateral resolution) according to the sample area shown in fig.1 and 3.

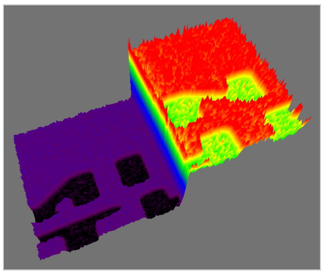

Fig.5: 3D-thickness profile according to fig.4

Conclusion

The imaging ellipsometer EP³ offers automatic recording of layer-thickness of SiO_2 similar as other ellipsometers. But only the EP³ measures Delta/Psi/thickness in multiple Regions Of Interest simultaneously. The mapping of Delta/thickness is the second unique feature.

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