# Comparison of dark field microscopy with alternating grazing incidence illumination and bright field microscopy

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A newly developed prototype which is based on alternating gracing incidence illumination at a wavelength of 374 nm is presented and compared with a standard optical bright field microscopy at a wavelength of 365 nm. Both method are applied to measurements at a Si line of a linewidth of approx. 130 nm. Pro and cons of both systems will be discussed.

## 1 Introduction

The quantitative and traceable measurement of linewidths e. g. on masks, wafers or silicon structures down to 100 nm and below is a large challenge for metrology. The next generation of masks, the 65 nm technology node in 2007 according to the international technology roadmap for semiconductors requires measurement tools with resolution down to 130 nm. An important criterion for the choice of the measuring method of linewidths on masks or wafers is the CD linearity. "CD" stands for "critical dimension" and is used as a synonym for linewidth.

At the PTB, there was developed a new dark field microscopy method with alternating grazing incidence illumination (AGID) in the last years [1]. This procedure enables measurements of linewidth with a better CD-linearity (CD: “critical dimension”) as bright field microscopy [2]. The new Leica water immersion objective at 248 nm could extend the CD linearity for an optical bright field microscopy down to 220 nm [3]. The AGID procedure should be able to reach at least a two times better CD linearity [1].

A new prototype which is based on the AGID procedure and realised at the PTB within a research project is presented. The results of the linewidth measurement using this special dark field microscopy method are compared with the measurements, which were accomplished using a conventional bright field linewidth measuring system.

## 2 Measurement task

For the determination of the linewidth there can be used different tools, like optical, electron or scanning probe microscopy. Each of them has there own advantages and disadvantages. The optical tools have the advantage, that they cause lowest modifications of the measuring object.

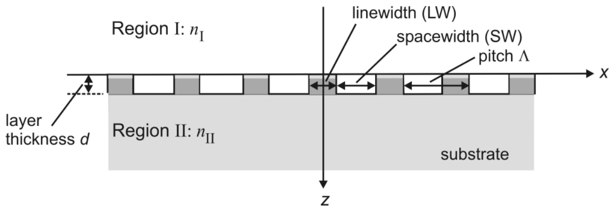



***Fig. 1*** *Measuring object, definition of the measurands*

## 3 Experimental Setup

Our new AGID prototype uses as light sources two diode lasers with 374 nm. Shifting the sample towards the optical axis, a focus series with a UV camera is taken and by means of focus criteria the focal image is determined. This focal image is compared with different adapted rigorous simulation models (Rigorous Coupled Wave Analysis (RCWA) respectively Finite Elements (FEM)).

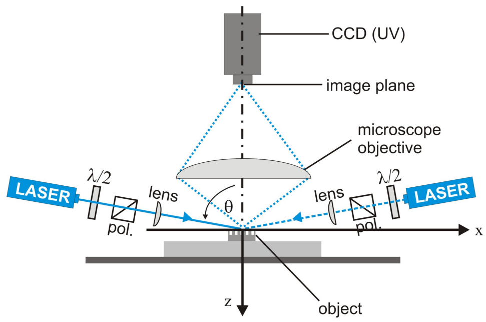



***Fig. 2*** *Experimental set-up of AGID*

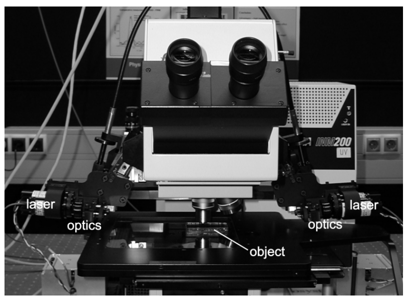
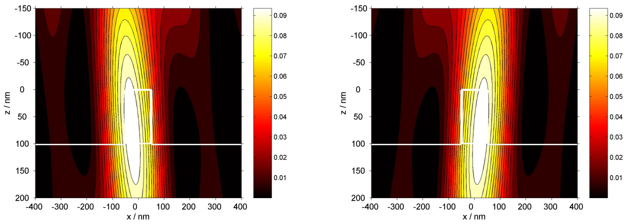



***Fig. 3*** *Photo of AGID prototype*

In Fig. 4 an AGID simulation for a 100 nm chrome line is shown and it can be seen, that by using this alternating darkfield illumination the proximity effect of neighbouring edges can be suppressed efficiently. As the main signal isn't located directly at the edge position of the line, a model based evaluation of the linewidth is necessary. For rigorous modelling we use two different approaches RCWA and FEM. For the RCWA simulations we use the software packages "MicroSim" which was developed at the Institute of Technial Optics in Stuttgart, Germany and for the FEM simulation we use the software packages "DIPOG" from the Weierstrass institute (WIAS), Berlin, Germany.



left sided illumination　　right sided illumination

***Fig. 4*** *RCWA simulation of AGID for a Cr line with LW = 100 nm at 375 nm*

### 4 Measurement example

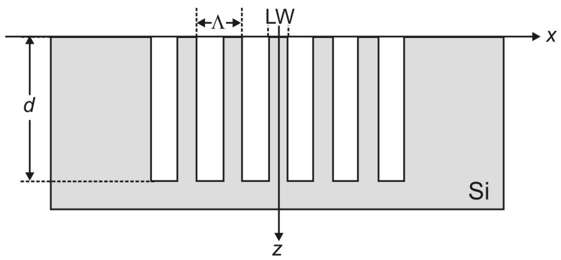



***Fig. 5*** *Si structure with 6 etched spaces*

As a measurement example we used an etched Si-structure with geometrical condition as shown in fig. 5. The target of the measurement is the determination of the linewidth of the middle bar with approx. LW = 130 nm. The period is $\Lambda$ = 1363 nm and the layer thickness is $d$ = 670 nm. The appropriate bright field microscopy image is represented in fig. 6 and the appropriate dark field images for left and right sided illumination is represented in fig. 7.

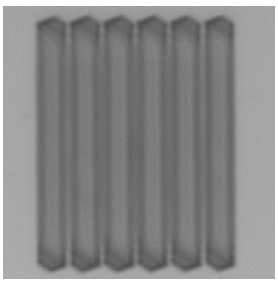
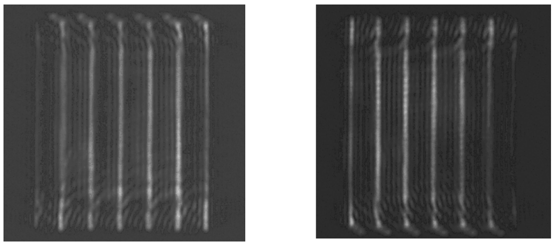


***Fig. 6*** *Image of bright field microscopy at 365 nm*



(a)　　(b)

***Fig. 7*** *AGID images: (a) illumination left sided, (b) illumination right sided*

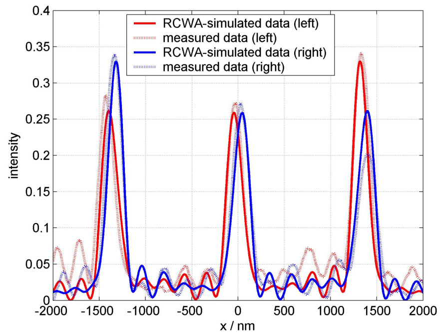



***Fig. 8*** *Model based evaluation of the bar in the middle of the structure results in a linewidth of 130 nm*

### 5 Discussion and outlook

As one can see in fig. 6 it's quite difficult to resolve clearly this small structure of 130 nm using bright field microscopy at 375 nm. The AGID prototype can separate the left and the right side signal of the middle bar and results in a linewidth of approx. 130 nm (see fig. 8). As AGID suppresses efficiently the proximity effect and leads to a better CD linearity, it is a meaningful addition to existing optical linewidth measurement tools. Further measurements will be done regarding to CD linearity and repeatability.

### References

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