A Quantitative 193 nm DUV Microscope

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Abstract

A new deep UV transmission microscope for traceable micro- and nanometrology is currently being set up at the Physikalisch-Technische Bundesanstalt (PTB), the National Metrology Institute of Germany. This DUV microscope employs a 193 nm excimer laser as the light source, adopts a high NA dry objective (NA = 0.9), and therefore features not only extremely high performance (high optical resolution, magnification, etc.), but also easy operation (no special requirements for sample preparation). Due to its sophisticated illumination concepts and strategy, the 193 nm transmission microscope is especially suitable for quantitative and traceable determination of the linewidth of micro- and nanostructures with the measurement uncertainty of down to 10 nm. It would be consequently one of the competent optical metrology tools for lithography industry.

1 Introduction

In the metrological field of quantitative characterization of micro- and nano-structures, optical microscopy always plays an extremely important role. In the mean time, rapid advances, for instance in lithography, nanotechnology and modern biology, put unceasing demands for further improvement of the lateral resolution of currently available optical microscopes. Recently a significant progress in optical microscopy has been realised by means of employing the deep UV radiation with a wavelength of 193 nm, enabling not only a significant resolution enhancement, but also, especially for the current 193 nm lithography, "at-wavelength" characterization of photomasks.

2 Principle

A DUV transmission microscope is under development at PTB, whose fundamental optical system is detailed in figure 1. The DUV laser light is delivered to the microscope body by means of a multi-mode optical fiber, reducing potential negative influence of laser acoustical noise and vibrations. By carefully choosing the fiber coupling method and the multi-mode fiber length, highly incoherent laser light could be obtained directly after the fiber. The illumination and imaging system of the 193 nm DUV microscope will provide various imaging modalities ranging from ordinary bright-field (*Option 1* in Fig. 1) to special structured illumination schemes [*Option 3* and *4* in Fig. 1], which help to further enhance the flexibility and performance of the microscope. The transmission microscope would possess the analysis capability of polarization microscopy if pairs of polarisers (*Option* 2) are employed in the illumination and imaging paths.

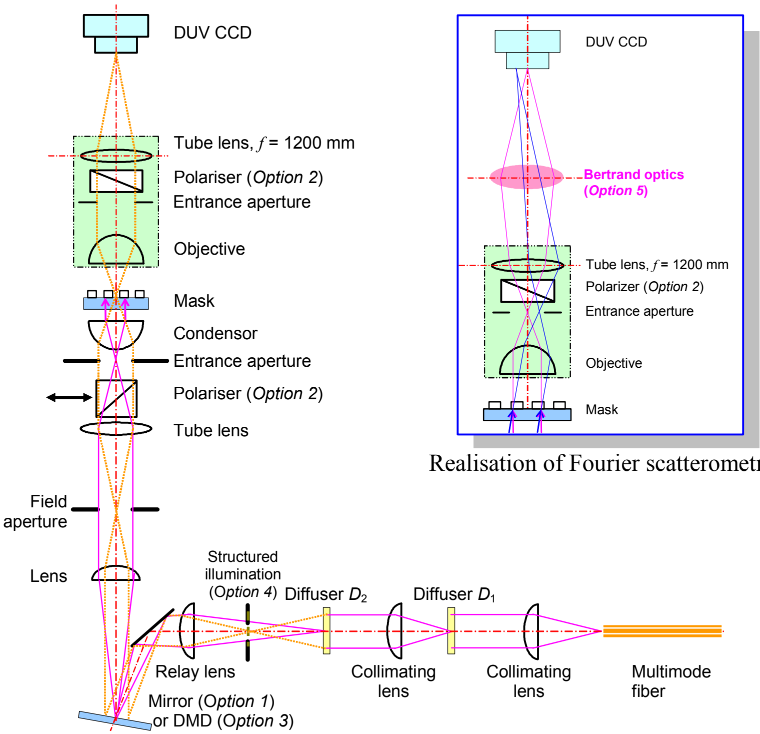


Figure 1. Optical configuration of the CD-measurement-oriented DUV transmission microscope developed at PTB, Germany

The functionality of Fourier scatterometry can be introduced to the DUV transmission microscope by inserting a Bertrand optics (*Option 5* in Fig. 1), with which the optical Fourier transform of the micro-/nanostructure under test could be directly imaged.

3 Realisation

In this DUV transmission microscope a pulsed 193 nm ArF excimer laser (Coherent OPTexPro-T) is used as the light source. As one of the key components of the microscope, the objective features high numerical aperture and large magnification (M = 400), in the meantime, has quite short working distance (~200 µm) and limited object field (± 10 µm), imposing essential challenges to the mechanical construction of the microscope body.

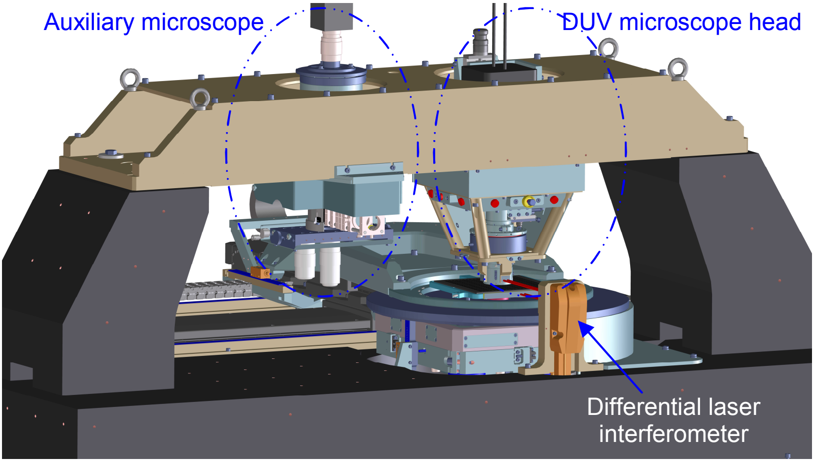


Figure 2. Mechanical construction of the DUV microscope

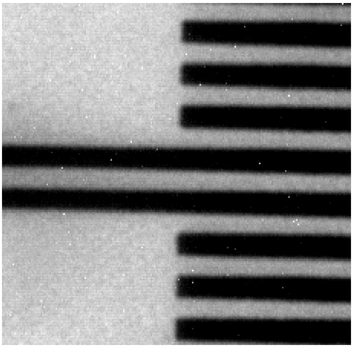
An auxiliary visible reflection microscope has been finally introduced, as shown in Fig. 2, with which fine structures within the region of interest (ROI) can be located and pre-determined. A 2D translation stage with the positioning accuracy of ~1 µm is utilized to seamlessly translate the object under test from the auxiliary microscope to the DUV microscope.

The mechanical set-up is characterized by an ultra-stable bridge construction on a granite base, and is designed with the help of finite element analysis (FEA) to realize a positioning stability in the nanometer range. Due to its higher resolution and lower uncertainty, this DUV microscope is even applicable and suitable for the current 32 nm node lithography technology.

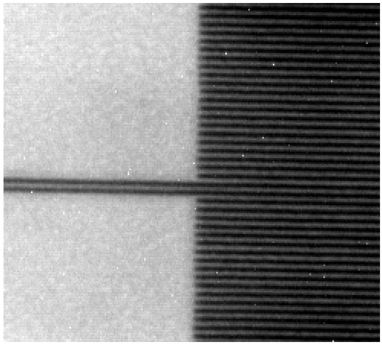
Traceability of the measurement results to the SI unit 'meter' will be accomplished by means of laser interferometry. A differential laser interferometer with sub-nanometer resolution is employed to in-situ and real-timely measure the relative displacement of the structures under test within the object plane of the microscope.

4 Preliminary results and outlook

To testify the potential capability of the microscope objective for 193 nm wavelength, a simple experimental setup has been established. As can be seen from Fig. 3, without any special efforts a single-line structure with the linewidth of 100 nm can be resolved by the microscope objective.



Half pitch = 500 nm



Half pitch = 100 nm

Figure 3. Image of a linewidth standard [3] with HP = 100 nm obtained by a simple test setup to demonstrate the potential resolving power of the DUV microscope objective.

This 193 nm DUV microscope shall be ready in the year 2010, and is planned to offer calibration service in the near future. With home-developed image analysis and interpretation algorithm, it could determine the CD values of micro-/nanostructures with an uncertainty of about 10 nm.

References:

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