IMS CHIPS Photo Mask Technology

Overview and Classification

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Introduction

IMS CHIPS was founded in 1983 as a non-profit organization by the Federal State Baden-Wuerttemberg. The concept behind is to provide infrastructure for the industry to develop electronic, micromechanical, and optical components, devices and systems. In addition to its 0.5 µm CMOS line, the 700m² class 10 clean room at IMS CHIPS also includes a mask front end line. As no inspection and no repair capabilities for mask substrates are available, IMS CHIPS does not see itself as another mask house but complementary to them. Besides providing several types of 6” test mask (substrate 6025), also 9” substrates (9035) can be processed. In addition, IMS CHIPS also provides and develops customer specific process solutions.
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1 Conventional Optical Mask
The simplest type of mask – a binary intensity mask (BIM) - consists of a structured opaque absorber (mainly chrome) on top of a transparent quartz plate. Exposing a wafer through the mask, the intensity profile is transferred into the photo resist. For a positive tone resist, bright features are later removed in the development process, leaving the unexposed areas as features on the wafer.
Main drawback of this type of mask is a low energy contrast for small features as shown in Fig. 1: While the phase still shows clearly “dark” and “bright”, the base level for intensity is increased due to the very close proximity of the neighbouring clear quartz areas. This “extra” energy reduces the contrast and therefore influences the quality of the resist profile. To overcome this limitation, phase shifting techniques have been developed to increase the energy contrast, allowing even smaller features to be printed. Further information can also be found here [0].

![Fig. 1: Principle of a Binary Mask (Courtesy ASML)](image)

2 Advanced Optical Masks
2.1 Alternating Phase-Shift Masks (AltPSM)
The base material for AltPSMs is the same than for BIMs, but beside simple “dark” (chrome) and “bright” (Quartz, 0° phase) there is a third condition of etched quartz (180° phase). Chrome lines on the reticle are bordered on both sides by quartz of different phases, 0° and 180°. As shown in Fig. 2, the phase value becomes zero at the crossover. As the intensity is proportional to the square of the phase, brightness also becomes zero at the corners, resulting in sharp printed resist lines.
AltPSM is a complex technique which requires a dual-exposure (AltPSM and “trim”) to remove residual phase-edge images. Further information can also be found here [0].
2.2 Attenuated Phase-Shift Mask (AttPSM)

Attenuated Phase Shift Masks (AttPSM) form their patterns through adjacent areas of quartz and a phase-shifting absorber material (e.g. MoSi, Ta/SiO₂). Unlike the “dark” absorber of a BIM, phase-shifting absorber material is not fully “dark” but allows a defined percentage of light to pass through. Due to the phase-shifting properties, the phase of this light is 180° out of phase with the light that passes through the quartz. Even the amount of light passing through the phase-shifter (6%) is not enough to expose the resist, the difference in phase helps to decrease the intensity in the dark areas to get a better contrast which enables smaller features to be printed on the wafer. Further information can also be found here [0].
2.3 Opaque MoSi On Glass (OMOG)
OMOG masks are pure binary masks which form their pattern through adjacent areas of quartz and opaque molybdenum silicide (MoSi). Unlike the phase shifting MoSi used for AttPSM, opaque MoSi does not allows the light to pass through. As OMOG blanks are equipped with a thin sacrificial chrome layer (hard mask), extremely thin resist films can be used for absorber patterning. Therefore the primary advantage over a standard BIM is an all-time increase in the resolution that can be achieved on the mask. This allows an optical proximity correction (OPC) e.g. by the use of sub resolution assist features (SRAFs) to overcome intensity smearing. Further information can also be found here [1].

3 NGL Masks
Beyond the optical lithography, there are several other approaches. Although some of them stay with the classical mask shape, a lot of new materials have been introduced. Membrane mask technology has left behind the basic mechanical properties of a continuous absorber layer. 13 nm Extreme-UV Lithography (EUVL) skips the concept of a transmission mask

3.1 Masks for EUVL
The basic setup of each EUVL mask is a substrate coated with a multi-layer stack and an absorber layer on top of it. By patterning the absorber, 13nm radiation will be reflected locally. There are several stack systems by different vendors available today. IMS CHIPS produced a first set of EUV mask in 2005 for the setup of the ASML alpha-tool. Further information can also be found here [2, 3].

Fig. 4: EUV Principle (Courtesy Carl Zeiss)
3.2 Templates for Nano Imprint Lithography
Masks ("Templates") for the SFIL Nano Imprint Lithography are fabricated similarly to AltPSM masks. The two major differences are the final size of the substrate (65mm x 65mm) and the need for an elevation of the patterned area ("Mesa"). Further information can also be found here [4,5,6].

![NIL Template](image)

**Fig. 5: NIL Template**

3.3 Membrane Masks
Charged beam techniques as ion- or electron projection requires thin masks with real openings for the beam to pass through. A sample of a 3um thin patterned membrane with a diameter of 126mm is shown in Fig. 6. Dependant on the application, diameter and thickness can vary in a wide range. Further information can also be found here [7, 8].

![Membrane mask](image)

**Fig. 6: Membrane mask**


4 Specifications

IMS CHIPS fabricates test masks and prototypes on 6” and 9” substrates (according to the 6025 and 9035 SEMI standards). This includes single and multiple level e-beam exposures, etching, registration and CD measurement. Due to the wide variety of techniques and applications, the specification highly depend on the type of mask and pattern and will be agreed in discussion with the customer in order to best fulfil their requirements.

5 Literature

[0] Handbook of Photomask Manufacturing Technology, Editor Syed Rizvi, CRC Press, Taylor & Francis, 2005