Local Photomask Fabrication Capability to Support Hard-Disk Drive Manufacturing in Thailand

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Nithi Atthi[1]

Abstract

This paper reports the status of mask making tools and processes at Thai microelectronics Center (TMEC) in Thailand. In addition, the applications employing those masks fabricated which are used in Thai academic and Thai industries especially the Hard-Disk Drive (HDD) industry which contributes substantial amount to Thailand Gross Domestic Productivity (GDP). In this respect, local mask making capability could increase the local content and lead to the development of prospective upstream high technology such as semiconductor fabrication in Thailand.

Keywords: Photomask, Photolithography, TMEC

Introduction

At present, the semiconductor industry in Thailand orders 100% of photomask from overseas. Those masks are normally for patterning on Print Circuit Board (PCB), Sensor devices, Micro-Electro Mechanical System, (MEMs), Micro-Aerodynamic structure, or even Integrated Circuits (ICs). At TMEC, The photomask making tools are locate in class 100 cleanroom which is sufficiently clean and sufficient for making a photomask for 0.5 micron pattern linewidth to support the fabrication of prototype of electronic devices at the research and industry levels. This make TMEC can reduce the import of photomasks and shipment time, in the mean time increase the design iteration and flexibility. This allows fast turn around time for design and could lead to new innovative devices.

Background

The photomask is a master pattern for semiconductor device fabrication. The photomask made from Soda lime has High Thermal Expansion, (LTE) which is suitable for pattern linewidth higher than 5 microns. Later the material has changed to Quartz glass which has a Low Thermal Expansion, (LTE). This HTE property of the quartz glass make it suitable for making pattern linewidth smaller than 1 micron. On the top surface, photomask is coated with Chromium and Chromium oxide film (Chromium on Glass, COG) . The purpose of the chromium film is to block Ultraviolet (UV) light and the chromium oxide film make the photomask are very durable and used as anti-reflective coating (Atthi et al.,2007). Generally, the chromium and chromium oxide film thickness is 74 nm and 26

[1]Thai Microelectronics Center (TMEC), National Electronics and Computer Technology Center (NECTEC), 51/4 Moo 1, Wang Takien District, Amphur Muang, Chacheongsao, 24000. THAILAND
*corresponding author; e-mail: nithi.atthi@nectec.or.th.

nm, respectively. The schematic cross-section of the photomask is illustrated in Figure 1. There are 2 common types of photomasks according to light transparency; (1) Binary Intensity Mask (BIM) and (2) Grayscale Lithography Mask (GSL-mask).

BIM allows homogeneous light intensity and energy across its transparency area. BIM is also widely used in the semiconductor industries. In contrast, GSL-mask allows different light intensity and energy depending on the patterns on the areas which the light passes through. Normally, Gray Scale mask is mainly use in MEMS because MEMS structure require 3-D patterning which vary the photoresist film thickness. To form these 3-D structure with BIM, it's require many lithography process steps while using GSL-mask require only single-shot exposure to make entire patterns. The photomask making process of GSL-mask is done in the same way as BIM, however the main difference is the patterns on photomask. Regardless of the mask types, in general all photomasks ae designed through Compuer Aid Design (CAD) program. The design from CAD is then converted and then used as an input file in a photomask making tool which expose lasers onto a photoresist coated photomask according to the patterns in the design file (Atthi et al.,2007).

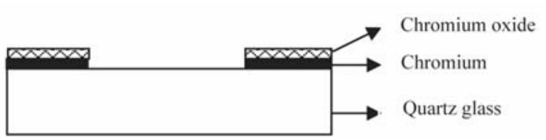

Figure 1. A cross section of a photolithography mask (Nithi et al.,2007).

Photomask Process and Facilities at TMEC

Photomask making process covers from the layout design stage. In this paper, the layout design is done through L-edit or Autocad as shown in Figure 2. When the the design stage is done, the process of making patterns on photomask starts similar to the photolithography process on wafer except that the light source is now a laser. Photomask blanks are ordered and purchased from overseas. The photomask blanks size must be compatible with the pattern generator (PG) at TMEC. Normally, PG at TMEC can support photomask dimensions from 1 to 6 inch and there is no limit on the shape of the mask substrate, i.e. square, rectangular or circular shape.

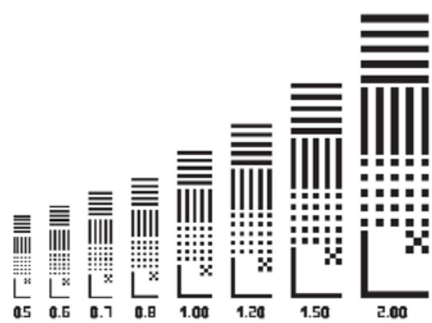

Figure 2. Mask layout from L-edit.

The production tools include;

(1) Photoresist coater "Polos model MCD-200" capable of coating film as thick as 5000±56 angstroms (Ratiporn et al., 2007).

(2) Hotplate "EMS model 1000" used to prebakes the photoresist film that is coated on the photomask substrate. The purpose of this process step is to evaporate the photoresist solvent left on the photomask substrate. The hotplate can heat up to 200±1°C and can support substrate up to 6 inch.

(3) Pattern generator "Heidelberg Instrument model Direct Write Laser-233 (DWL-233)" then projects laser on the photoresist film that is coated on the photoresist film. This is to create set of patterns on to the photoresist film which coated on photomask according to a design file (Atthi et al.,2006). Formats of the files can be CIF, GDSII, and DXF, for instances. The smallest pattern linewidth (Critical Dimension, CD) is 2 microns with less than 5% error from the designed patterns as depicted in Figure 3. The alignment error is within ±0.5 microns of the reference position.

(4) The exposed photoresist is then developed in a developer.

(5) After develop, the photomask uncovered by the photoresist is etched away in a Chromium etchant. The remaining photoresist is stripped off.

(6) The photomask is then cleaned after photo resist stripping. TMEC has developed a tool for developing photoresist, etching, stripping photoresist and clean the wafer after photoresist stripping. The tool is named DESC-1 which stands for Develop-Etch-Strip-Clean 1.

The dimensions and positions of the pattern generated on photomask is then inspected in the DWL-233. As far as defects are concerned, the defect inspections are done by visual inspection by using an optical microscope (OM) and compare with the input CAD file (Die-To-Data) covering 100% of the photomask areas. TMEC uses the same standard as that used by KLA-TENCOR to identify defect types. TMEC can control the process such that there is no killer defects on photomask and other types of hard defects which the size larger than 1 micron are less than 10 defects per sq.inch (Atthi et al.,2006).

Besides for very high accuracy measurements, the pattern linewidth is done in Field-Emission Scanning Electron Microscope (FE-SEM). Once the mask fabrication is done, the photomask is stored in and anti-Eletrostatic discharge (ESD) material case to protect the photomask from contamination.

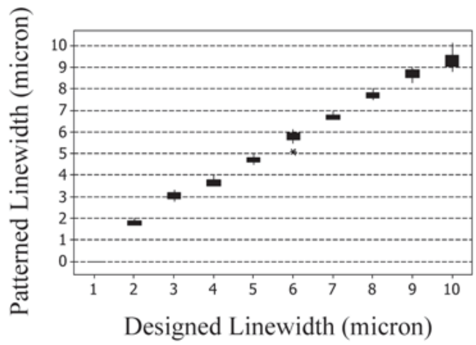

Figure 3. Relation between Paterned linewidth and Designed linewidth (Atthi et al.,2005).

As far as data preparation is concerned, the time required for data conversion of CAD file into DWL format depends on the complexity of the design and its size. The processing of the photomask depends on the same factors. The average time required to fabricate a 3x3 sq.inch is 3 hours per photomask. This dimension is the most popular among academic institution. 4x4 sq.inch photomasks is popular in PCB and assembly industry while 3x5 sq.inch photomasks are used in the HDD industry to form ABS on read/write heads and 6x6 sq.inch photomasks are very common in Integrated Circuit wafer fabrication. The average time for fabricate 4x4 sq.inch, 3x5 sq.inch, and 6x6 sq.inch photomasks are 3 and a half hours, 4 and 6 hours per photomask, respectively as depicted in Table 1.

Table 1. Mask making process time.

Process step	Process time
Full plate photomask writing	
< 3 sq.inch	20 min.
3x3 sq.inch	30-40 min.
4x4 sq.inch	60-80 min.
3x5 sq.inch	90 min.
5x5 sq.inch	120-150 min.
6x6 sq.inch	180 min.
Inspection after develop	60-90 min.
Inspection after etch	60-90 min.
Photoresist stripping and Cleaning (Lot)	30 min.
Final inspection by using OM	30 min.

Nowadays, TMEC can provide a 12 hours photomask making service per day, therefore the maximum throughput for a certain size of mask <3x3 sq.inch, 3x3 sq.inch, 4x4 sq.inch, 3x5 sq.inch, 5x5 sq.inch, and 6x6 sq.inch are 88, 88, 88, 66, 44 and 44 photomasks per month, respectively.

Photomask applications

Regarding the previous sections, TMEC can produce various patterns on a photoresist film; Figure 4a 2-D pattern of newly-born child, Figure 4b salutation letters to Her majesty Queen Sirikit for her 72[th] birthday, Figure 4c 3-D Air Bearing Surface of a read/write head for HDD industry on Chrome-photomask, Figure 4d contact hole arrays for ICs, Figure 4e small gears in MEMS, Figure 4f Optical Proximity Correction pattern in ICs, Figure 4g Microlens in optic devices and Figure 4h Eye piece lens scale in an optical microscope.

The production of the photomask at TMEC increases continuously every year as shown in Figure 5. This is still far less than the capability of the photomask making facility. Therefore, it is believed that the capability of TMEC photomask facility can support the photomask demand in Thailand. This also reflects on the reduction of photomasks ordered from vendors and this saved TMEC budget to 2 million Baht in fiscal year 2007.

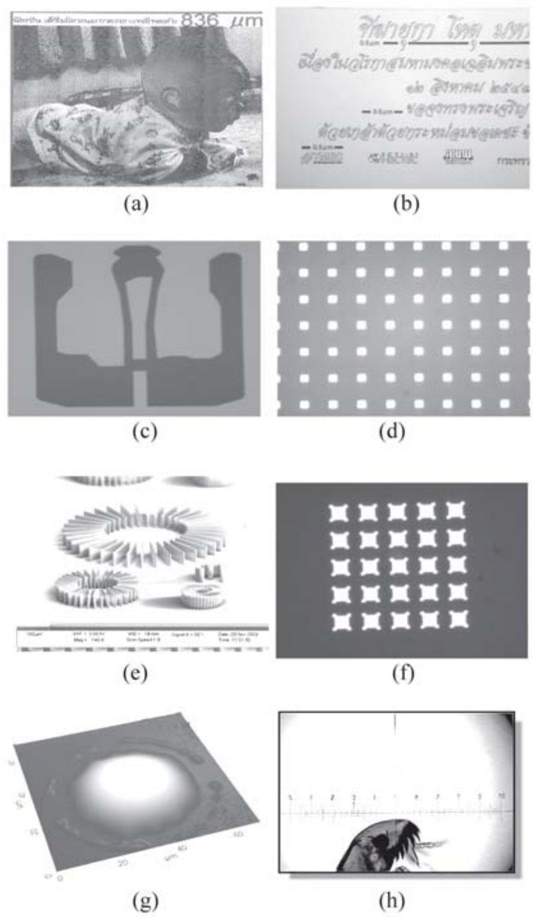

Figure 4. Applications of photomasks (a) 2D newborn baby on photoresist, (b) Salutation letter to her majesty Queen Sirikit, (c) Air bearing surface of a read/write head, (d) contact holes in ICs, (e) Gears in MEMS, (f) Optical Proximity Correction pattern in ICs, (g) Microlens and (h) Eye-piece lens in an optical microscope.

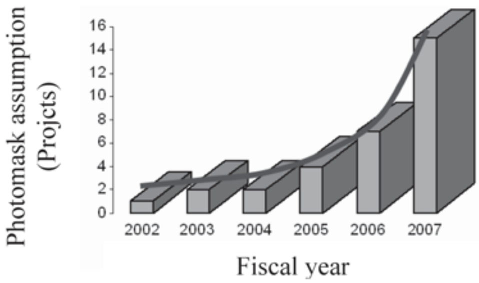

Figure 5. TMEC photomask consumption during 2002-2007.

Customer Service Limitation

The service is mainly limited to the material of the photomask substrate and the facilities at TMEC. The summary is listed in Table 2.

Table 2 TMEC photomask making process customer service limitation.

Substrate type:	Quartz, Soda lime, Glass, Wafer
Substrate shape:	Square, Round, Rectangular
Substrate size:	1 to 6 inches
Data type:	CIF, GDSII, DXF
Minimum CD:	2 micron
CD tolerance:	< 5% from design
Position error:	< 0.5 micron from origin point
Defect size:	< 1 micron
Defect density:	< 10 pieces per sq.inch.
Defect tolerance:	Zero killer defect

Conclusions

The photomask fabrication facility at TMEC has comparable quality compared to that imported from abroad. It is capable of support the demand from public and private sectors in Thailand. Due to lower cost of photomask making, which produced at TMEC could reduce the total cost and reduce the photomask lead time.

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