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Process Development for Fabrication of Photomasks using LASER Pattern Generator

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Abstract

This paper describes the development of photomaskfabrication process for a wide range of structures written on Chrome blanks using 413 nm wavelength LASER pattern generator. For development of requisite processes, test structures ranging from 0.4 µm to 500 µ min size were designed and fabricated. Apart from the writing process, all other unit processes used for the fabrication of structures were chemical processes which were individually optimized to develop an integrated fabrication process. The process was validated by writing SAW resonator structures comprising of IDT's and reflectors as per the specified tolerances.

Keywords: *Chrome Blanks; Critical dimension (CD); LASER pattern generator; Mask fabrication; Mask Process; Resonator; Wet etching.*

1. INTRODUCTION

Photomasks are precision glass plates having microscopic images of electronic circuits used as basic input for fabricating any device/chip. The most important aspect of photomask fabrication is fabrication of a perfect critical dimension which not only determines the quality of the photomask but also its suitability for fabrication of the requisite device. To achieve an optimum yield (Eynon, 2005), photomask also needs to be defect free as any defect irrespective of its size or shape gets replicated in the device structure during photolithography, rendering the devices unusable.

First Photomask fabrication process called Rubylith developed in 1960's, was completely a manual process. However, once the fully automated writing tools became available, Rubylith no longer remained useful because of its various limitations and the shrinking size of the devices which could not be achieved with Rubylith. In the present times one of the most commonly used tool for photomask writing is the LASER pattern generator, primarily because of being a fully automated process tool providing a versatile writing process control. Smallest dimension that a Laser pattern generator can write mainly depends upon the wavelength of the LASER used (Babin, 2005; Bohan *et al.* 2002).

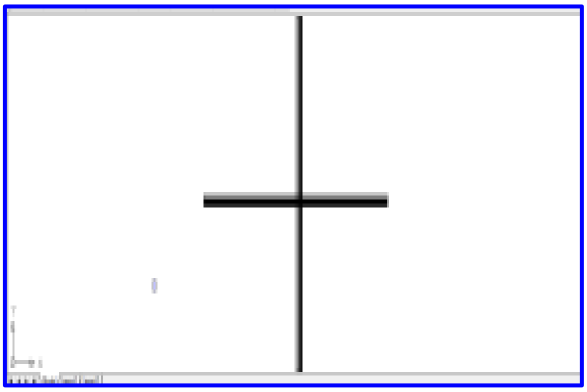

Fig. 1: Test structures-Assorted size Long lines Inset: Expanded view of the line set

2. EXPERIMENTAL DETAILS

For the present study reported in this paper, Heidelberg DWL 200 LASER Pattern Generator

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having a Krypton ion LASER of 413 nm wavelength, capable of writing device structures up to 0.6 μm was used. All the test and device structureswere written on Nanofilm make master grade Chrome blanks, each being a multi-layered structure comprising of Sodalime substrate with subsequent layers of Chromium, Chromium oxide and AZ1518 Photoresist. Post writing unit processes viz., development of features, etching of Chromium oxide/chromium and Photoresiststripping were successfully developed and implemented for completion of the photomask fabrication process. The developed photomask fabrication process was validated by fabricating user devices as per user specified design tolerances, using the fabricated photomask.

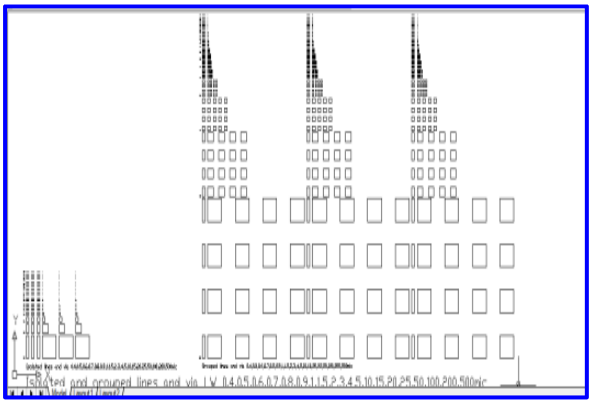

Fig. 2: Test structures-Isolated lines, Grouped Lines &via

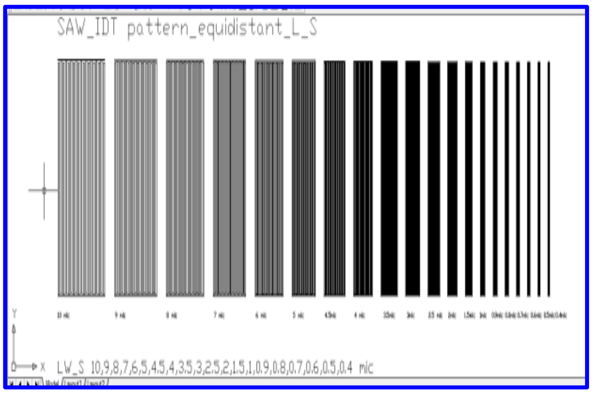

Fig. 3: Test structures-SAW IDT structures

The LASER writing process was developed using variety of test structures designed for various unit processes including, writing process, developing and etching processes fig. (1-3). The photomask data for both Bright Field (BF) and Dark Field (DF) photomasks, was prepared in drawing exchange format (dxf) using AutoCAD and in gdsii format using K-Layout softwares.

For studying the effect of process variabilityon the dimensions of the fabricated line structures, a test structure shown in fig.1 above, comprising of assorted lines having widthranging from 1.0 µm to 500 µm and lengths upto 52 mm was designed. For studying variation in critical dimension (CD) due to development/etching time and pattern density test patterns having CD from (i) 0.4 µm to 5 µm and (ii) 0.4 µm to 500 µm on a single photomask were also designed (fig. 2). The test structures fabricated in this photomask include isolated lines, grouped lines and via. To develop an optimized photomask fabrication process a test pattern (Fig: 3) of Surface Acoustic Wave (SAW), Inter Digital Transducer (IDT) having feature sizes ranging from 0.4 µm to 10 µm was designed and used. Based on the measurement data obtained from evaluation of fabricated test structures, the optimized process was validated by fabricating actual SAW resonator mask.

Complete photomask writing was carried out using 2 mm write head of LASER Pattern Generator. The pre coated pre baked chrome blanks used for writing photomasks were of 3” X 3” size, having 5800Aº thick Photoresist.

3. RESULTS & DISCUSSION

Photomask writing processes for both BF and DF masks weredeveloped by optimizingwriting process variables; exposure energy, defocus values and spot size correction (SSC) of the LASER beam. Feature development, etching of the written features and stripping of the residual photoresist, which are post writing unit processes (Rizvi, 2005), were subsequently developed using the wet chemical approach. The requisite development and etch times were respectively, determined by measuring the remaining photoresist/Chrome oxide-Chrome thickness for individual development/etch time period (fig. 4 & 5). The stripping time was determined for complete dissolution of the residual photoresist from the etched photomask (fig. 6).

For development of the requisite process, test structures shown in (fig. 1 & 2) were written on the chrome blanks and then chemically processed to obtain the intended structures as per the design. Dimensions of the etched structures were subsequently measured to evaluate the developed process.

The measured variation in line width of fabricated line structures (1.0 µm to 500 µm) is shown in fig. 7.

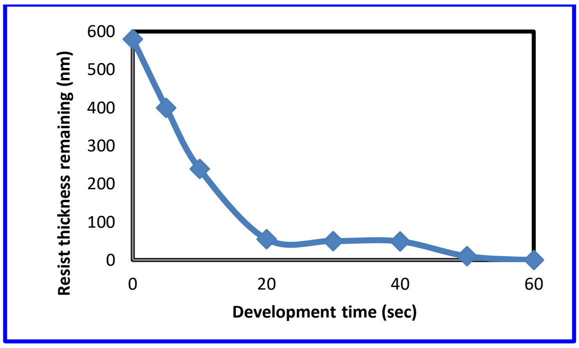

Fig. 4: Determination of Development time

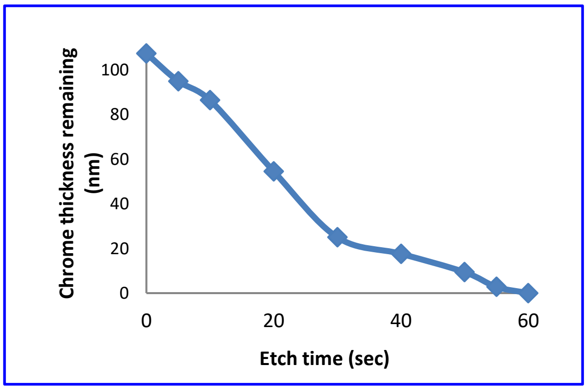

Fig. 5: Determination of Etch time

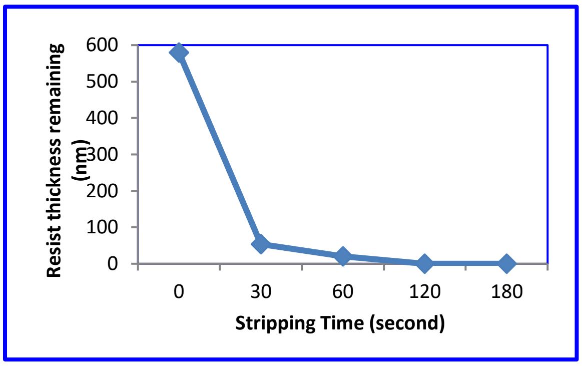

Fig. 6: Determination of Stripping time

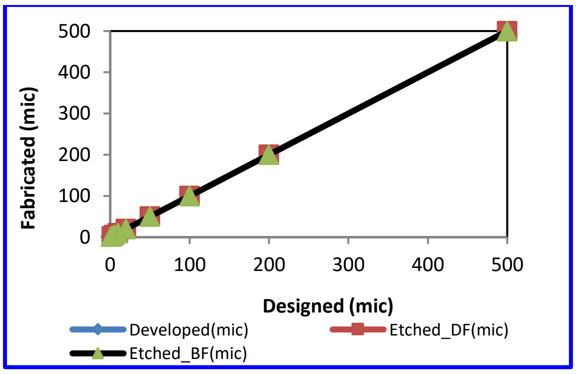

Fig. 7: Masking linearity (Line width-LW)

As can be seen from this fig. 7, line width variation is from 0.1 µm to 0.3 µm for 1.0 µm to 500 µm which is similar to that observed in isolated, grouped lines and via (fig. 8 -11) for both BF and DF photomasks.

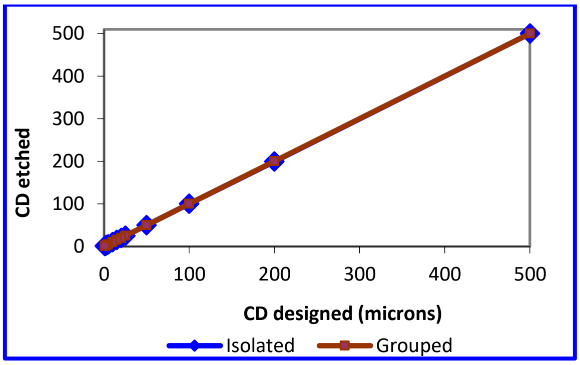

Fig. 8: Masking linearity-isolated and grouped lines - Dark field (DF)

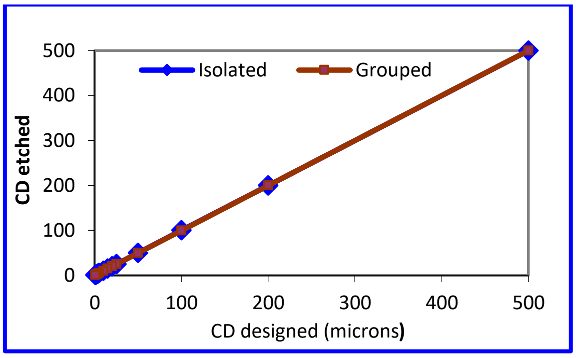

Fig. 9: Masking linearity-isolated and grouped lines - Bright field (BF)

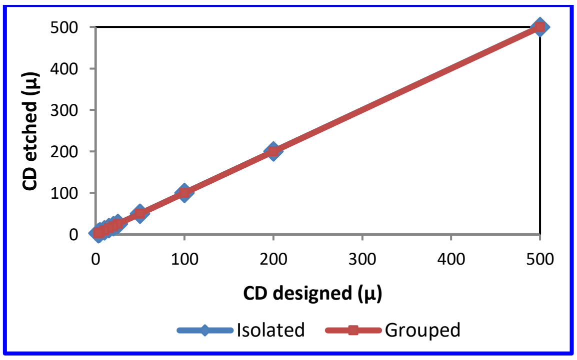

Fig. 10: Masking linearity-isolated and grouped via Dark field (DF)

The mask linearity observed in BF and DFSAW IDT test structures (fig. 3) fabricated using the same process also shows line widths and line spacing's (fig. 12 & 13) as per the design. Proximity effect usually being predominant in such structures is found negligible. For the purpose of process validation, a SAW resonator BF mask with IDT's and reflector was designed and then written using the developed process.

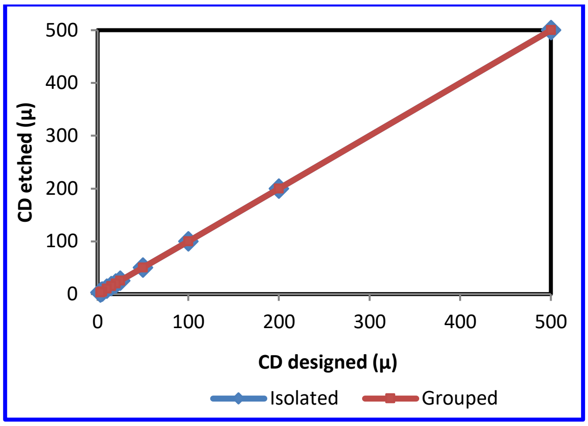

Fig. 11: Masking linearity-isolated and grouped via Bright field (BF)

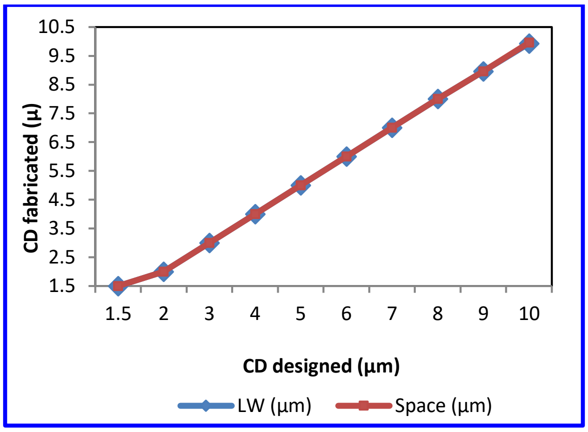

Fig. 12: Masking linearity-SAW IDT-Bright field (BF)

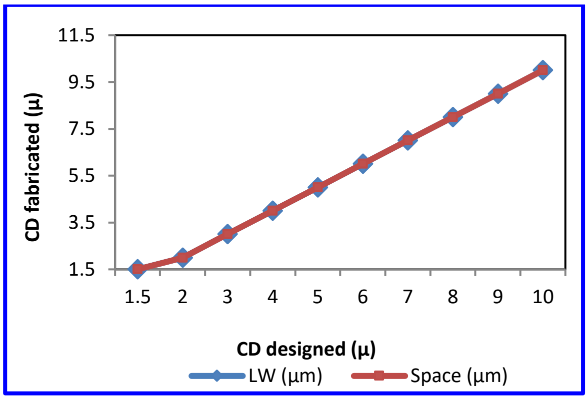

Fig. 13: Masking linearity-SAW IDT-Bright field (DF)

The optimized process parameters for both BF and DF photomasks are shown in Table 1.

The design of the SAW resonator and the fabricated mask having CD of 1.69 μm are shown in fig. 14(a) & 14(b) and 15(a) &15(b). Evaluation of the fabricated mask features was done using SEM (fig. 16(a) & 16(b)).

Table 1: Optimized Process

Parameter	BF	DF
Energy (mW)	80	85
Defocus	-90	-90
Filter	10%+30%	10%+30%
SSC (x, y)	300, 500	300, 500
Dev time (s)	60	60
Etch time (s)	60	60
Strip time (s)	180	180

Dimensions of fabricated structures obtained from the SEM measurements were found between and 1.682 μm & 1.720 μm, a deviation of 8 nm to 30 nm across the structure, which is within tolerance limit of 5% or 0.1 μm, validating the process.

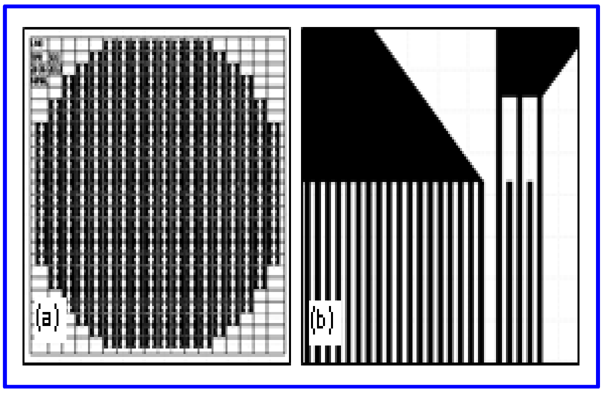

Fig.14: (a) Mask design (b) IDT & Reflector structures

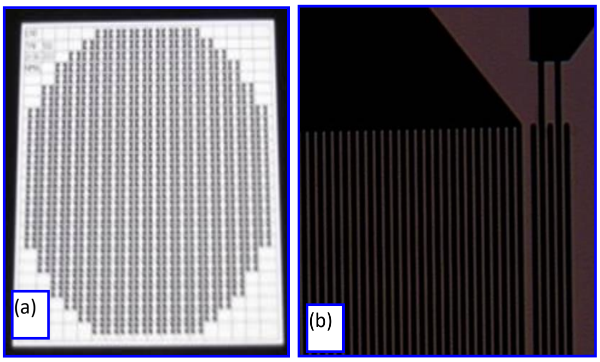

Fig. 15: (a) Fabricated Mask (b) Etched IDT &Reflector structures

The observed variation in the CD of the fabricated structures is primarily due to the wet chemical processes used being isotropic as also reported by Buck & Grenon (1993), Park & Lee (1998) and Taravadeetal (2002).

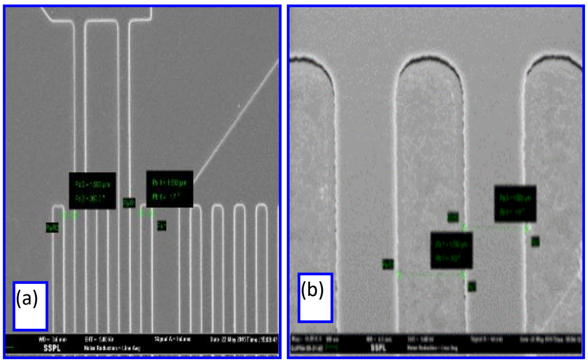

Fig. 16: SEM of (a) developed (b) etched IDT fingers

4. CONCLUSION

The optimized mask fabrication process developed using the designed test structures described above is suitable for fabrication of photomasks with feature sizes ranging from 1.5 µm to 500 µm. The wet processes developed have however, limitation in terms of their capability to etch features smaller than 1.5 µm, due to the being isotropic in nature.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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