MASK AND RETICLE FABRICATION USING ELECTRON-BEAM LITHOGRAPHY IN A RESEARCH AND DEVELOPMENT LABORATORY

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ABSTRACT

We report in this paper the main steps in the production of masks, reticle and master plates by using electron-beam lithographic system, ZBA-21 (JENOPTIK). We here report a routine to be followed by researchers when specifying masks or reticles to be made by e-beam lithography. The correct layout definition and subsequent conversion to e-beam system are determined by several factors, among them: electron-resist type, pre and post processing bakes, development parameters. We adopted the AZPF514FL as the principal resist for our processing line. This choice is based on the property of that formulation which is know as chemically amplified, CAR, with a great advantage over other resists in the sensitivity parameter.
We present the main experimental procedures in the laboratory to obtain the chrome reticles and masks plate for electronic devices and IC manufacture.

INTRODUCTION

The process for mask making was preliminary based upon the suppliers information and data sheets. After that we define or trim the parameters to our environment conditions.

The AZPF514FL is a chemically amplified resist (CAR), with advantages over the diazoquinone based ones, mainly the sensitivity to e-beam exposure.The positive tone resist AZPF514FL contains three components: a novolak resin with a acetal inhibitor type and a radiation sensitive component which generates a strong acid upon radiation. In the CAR resists the induced event by primary radiation do not contribute "per se" to the change of resist solubility but, only to generate a catalyst, a Brönsted strong acid not stoichiometrically consumed in the "dark" resist reaction. On this step the acetal inhibitor is cleaved by hydrolysis reaction catalized by the acid. The acetal products act as dissolution promotors. The hydrolysis reaction is time consuming [1].

This reaction has a low activation energy, occurs in room temperature and is completed in thirty minutes (at a reasonable exposure dose), however this reaction speed is increased by performing a post-exposure bake (PEB) at moderates temperatures [2].

The hydrolysis require an external water source, so, the reaction is incomplete while the resist is in the e-beam vacuum chamber.

The operation conditions must be rigorously controlled, i.e., the elapsed time between steps, the temperature and fundamentally the balance base-acid, avoiding the contact between the plate and air contaminants that could interfere with the catalyst.

There is a trade off between the developer concentration [3], exposure dose and resist contrast. The compromise of these variables are discussed in this paper, taking in account the experimental conditions in the lab (CCS-Unicamp).

We emphasize the similarities and differences of our results with that reported elsewhere and those suggested by the suppliers in the data sheets.

EXPERIMENTAL

1. Data Processing

From the files, created in CIF or GDS-II, and generated by design softwares a layout inspection must be done at each level. After that operation each level (mask level) is submitted to a format conversion to the

specific format of the ZBA-21 system. At this step it is possible to introduce proximity effect correction factors.

2. Exposure

The ZBA-21 system is an equipment intended to produce mask (on glass plates) and direct write on wafers. The performed beam has a variable rectangular shape and has an energy of 20keV with variable intensity from 0.4 up to 4A/cm^2. It has a beam position control by double channel and use vector-scan/step-and-repeat principle.

During the exposure process, with the layout data completed, the repetition scheme and dose are defined. After the final adjustments of the electrooptical column the exposure is made in an automatic mode.

3. Plate Processing

The masks were made using glass and quartz plates with the following characteristics:

Resist Type	AZPF514FL
Resist Thickness	400nm
Plate Dimensions	4 and 5 inches
Plate Thickness	60 to 90 mils
Material	Low thermal expansion. Borosilicate and Synthetic Quartz
Metallic Film	Chromium - low reflectivity
Film Thickness	85nm

The data sheets from the suppliers refer to the developer, the appropriate conditions for stock and the life time of those plates after production [4]

The material is very susceptible to the transport conditions and care must be taken to prevent damage during this step.

Immediately after exposition, the plates were removed from the vacuum chamber and transported, inside a desiccator, to the bake oven. The post bake exposure (PEB) was determined based on general conditions reported in the literature. Alternative bakes of 30 minutes at 21°C and 3 minutes at 60°C were used. The PEB temperature is fundamental. Below 60°C, longer periods are needed to complete the reactions and at higher temperatures the engraved structures became distorted [5].

This distortion is attributed to the diffusion of by-product acid in the unexposed resist. To overcome this difficulty the PEB was made at 60°C and not in room temperature, minimizing the chance of contamination with ambient air [6].

The developer AZ518MIF used, was suggested by the plate supplier. This is a solution of tetramethylammonium hydroxides (TMAH) a solution free of metallic ions at 0.18N concentration. With this developer solution, working under controlled temperature (21°C) the resist dose was maintained at 4.5μC.cm^{-2}.

However the dark erosion velocity was unacceptably high. Excessive rugosity was observed and the image contrast was deteriorated. The possible defects like the voids are amplified.

To decrease the dissolution rate of the unexposed resist we use a lower concentration of developer solution, 0.14N, and a much lower dark film loss was observed, although this procedure had a sensitivity penalty to the resist.

The development was always made by horizontal immersion with soft agitation. The agitation (shaking) is fundamental to make sure that it is a homogeneous process. But this agitation decreases the developer life time. The air containing carbon dioxide (CO_2) neutralizes the base by this reaction: $2OH^- + CO_2 \rightarrow CO_3^{--} + H_2O$ and the titer developer changes gradually. In diluted basic solutions, this mechanism is of crucial importance to be time reproducible in resist development process. With fresh solution the development time was stabilized to be 3.0 minutes. When this time increases to about 20% the developer must be changed to a fresh one.

Using diluted developer we observe a better image contrast, meanwhile the used dose to sensibilize the resist was increased from 7μC.cm^{-2} up to 9μC.cm^{-2} in the earlier experiences.

Next, one post-baking of 5 minutes at 60°C before chromium etch was made. This corrosion, made by immersion, uses a cerium nitrate ammonium solution with the following formulation [7]:

- 25ml of glacial acetic acid (H_3CCOOH)
- 50g of Ce $(NH_4)_2$ $(NO_3)_8$
- D.I. water to complete a 500ml solution

With this solution at 21°C, the etch time is 50 seconds.

The last step consists of resist removal by immersion in a solution of H_2SO_4 : H_2O_2 : : 4:1 at 70°C [8]

All the steps were done in clean room facilities, (100) class.

RESULTS AND DISCUSSION

A set of circuits and device masks were made using these step sequences shown here. Structures with dimensions from 1μm and length up to 30,000μm were engraved over chromium over glass and quartz plates. Below we show photographs of masks after etch of chromium.

Our results dictated the possibility of using this positive tone resist to obtain images of tested dimensions, even with exceded resist life time. The resist senility has, as a consequence the loss of one of the most important characteristic i.e., the sensibility. This limitation mentioned above does not imply that the plates can not be used, but this imposes limitation on process throughput, which is not the case for a research and development laboratory. At this point, the operator and technical staff became fundamental to adequate the changes in operational conditions.

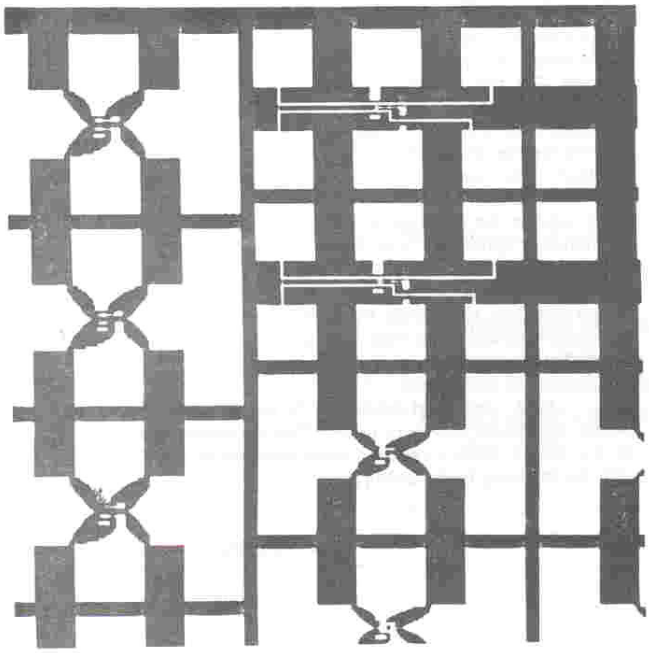

Fig 1 - Integrated circuit mask, GaAs HBT devices (Jenatech microscope, 100X, transmited light, minimum linewidth is 1μm).

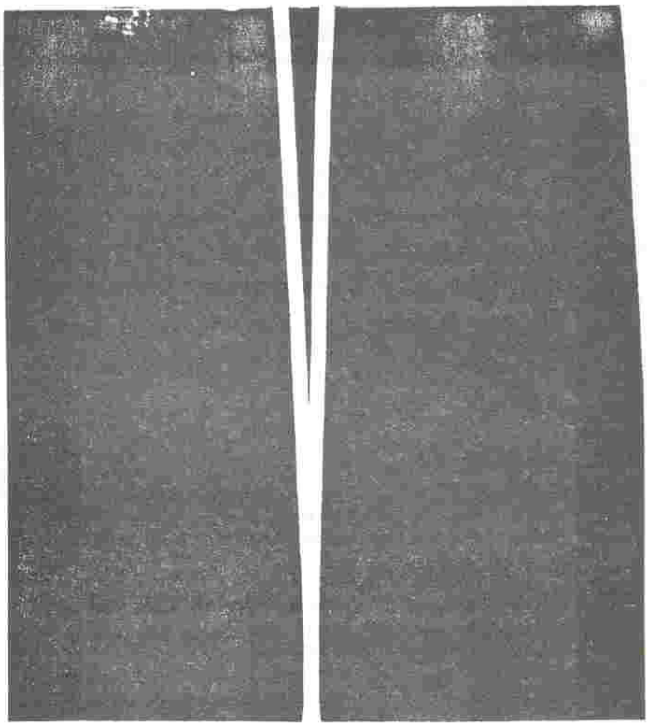

Fig. 3 - Electrooptical device mask - light power divider (Jenatech, 875X, transmited light, minimum linewidth of 4μm and angle less than 1 degree between branches).

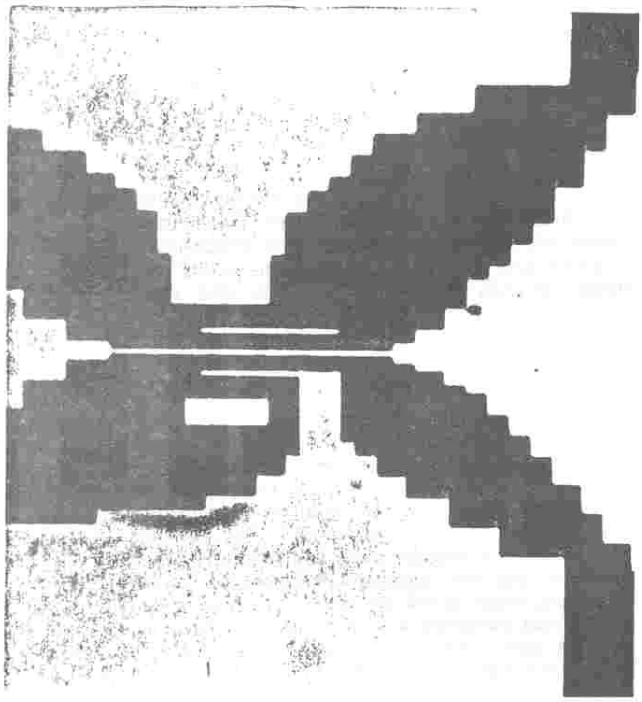

Fig 2 - Detail of HBT IC mask (Jenatech microscope, 100X, transmited light, minimum linewidth shown in this photo is 1μm).

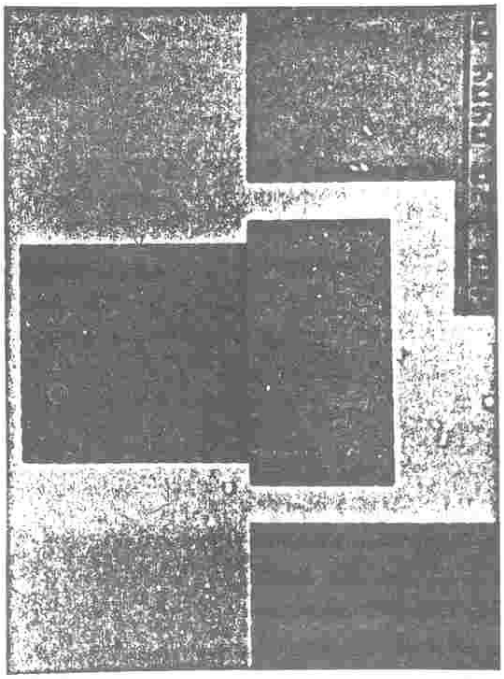

Fig. 4 - Laser pad mask (JEOL SEM, bottom dark trace is 100μm).

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