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Simple and Low-Cost Rapid Prototyping fabrication by Using a Photolithography

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Abstract

This work describes improvements to the original process, including reduced cost of fabrication. It has successfully overcome all of the major hurdles the semiconductor industry roadmap provides. To accomplish that, it has experienced significant modifications and has substantially broadened the frontiers of optical and electronics research and engineering. Photolithography is the essential stage in the semiconductor fabrication process that determines chip quality. Because the fabrication process is a batch process with varying chip quality, uniformity has always been a primary goal of the process. This case study focuses on improving the photolithography step in order to improve uniformity and critical dimension accomplishment, both of which are quality parameters for semiconductor devices. should be examined for improved optimization. This paper will discuss the most current improvements in the Photolithographic process, as well as the incorporation of a variety of resolution-enhancing approaches. A photoresist layer (Photosensitive Dry Film 1 meter for Circuit Photoresist Sheet 30 cm Width) is applied to the material to be patterned. The photoresist layer is exposed to ultraviolet (UV) radiation through the mask. This stage is completed in a mask aligner, which aligns the mask and wafer prior to the subsequent exposure stage. Depending on the mask aligner generation, the mask and substrate are brought into contact or close proximity (contact and proximity printing). Depending on whether positive or negative

photoresist was used, the exposed or unexposed photoresist components were removed during the resist development process. Mask design is created, it can produce various mask designs in micro level scale (um) as a DWG file by AutoCAD program. DWG file is converted to a PDF file with a PDF converter. The resulting PDF file mask design is printed as positive film. in this experiment, uniform layer glass is used as substrate, aluminum deposited with a length of 2.5 cm and width of 2.5 cm with thickness 0.2 cm.

Keywords: lithography, Microfabrication, photo Resist, UV lithography.

1. Introduction

Photolithography is a technique that uses light exposures to pattern a layer of photoresist, it was invented by Alphonse Louis Potvin in 1855 by incorporating light and lithography. In 1965, mass manufacturing processes in the semiconductor and optical industry [1]. It is a process that transfers shapes from a template onto a surface using light and is used in micromanufacturing applications. The use of low-cost electronics microfabrication tools has advantages such as flexibility, since its inception tens of years ago [2]. the microelectronics sector has grown dramatically [3]. Improvements in microfabrication processes have resulted in a constant increase in the complexity of microcircuits while lowering the cost to the customer [4]. This seeming contradiction stems from the quest toward miniaturization. The switching speed and power consumption of individual circuit elements are enhanced by lowering their size, and switching speeds have risen by 100 times [5]. the total area of the film being processed determines the overall cost of manufacture which is unaffected by the complexity of the circuits, increasing packing density, or the lower the manufacturing cost per circuit element, the more devices per unit area of silicon [6]. The half of the cost per bit of memory devices every two years is a good example of this impact. Miniaturization appears to be a trend that will continue until a significant technical barrier or fundamental physical limit is reached [7]. Lithography is the capacity to define detailed patterns on the surface of a glass wafer a critical step in the creation of microcircuits. To address the demand for smaller geometry devices, optical lithography techniques have continually grown and improved [8]. One key advantage of optical lithography is that it is essentially a parallel information transmission method, making it suitable for bulk copying of complicated designs. (As an illustration of the amount of information that must be sent, consider the layout of a complex circuit having devices with minimum dimensions of the order of 2 um spread over an area of

8 mm x 8 mm [9]. A design with 16 x l06 pixels might be created on wafers 150 mm in diameter, with each wafer comprising approximately 6 x l09 pixels. Using optical lithography, wafers can be created at a pace of about one per minute, resulting in an effective data transfer rate of l08 pixels per second (100 MHz) [9]. Other factors that have contributed to optical lithography's success include the availability of sufficient light sources, lenses, and photosensitive materials designed specifically for use in microfabrication [10]. It is a photosensitive polymer, which changes its solubility in a matching developer when exposed to light. A positive photoresist is one that gets more soluble upon exposure and dissolves the exposed portions [11]. Negative photoresist occurs when exposed parts of photoresist become less soluble and unexposed areas are eliminated during development. Photolithography [12]. Lithography is the printing method used in the semiconductor industry to mass-create chips like microprocessors and memory that are at the heart of electronic gadgets. Lithography costs 50% of the cost of creating a modern chip (integrated circuit) [13]. Historically, advancements in chip cost and performance (Moore's Law) have been constrained by lithography capability. Chip firms, governments, and universities continue to make significant investments in lithography [14]. To keep Moore's Law continuing, the researcher squeezes more transistors on a chip by making each transistor smaller; lithography advancements enable printing smaller features without materially raising the chip's cost [15].

2. Experiment

Photolithography begins with a substrate. The substrate is used as the foundation of the “film” on which a pattern will be created. Substrate choice depends on the ultimate operational goal of a given device. Glass can be used because transparency is desired. However, different substrates can require special attention, so processing must be optimized individually for each material. This part includes a detailed description of the photolithography including the following process, cutting into the required size, careful cleaning, robotic wafer handling apparatus, improving adhesion of photoresist coating, adhesion promotor, photoresist material coating, in this experiment, uniform layer glass is used as a substrate, aluminum deposited with a length of 2.5 cm and width of 2.5 cm with thickness 0.2 cm.

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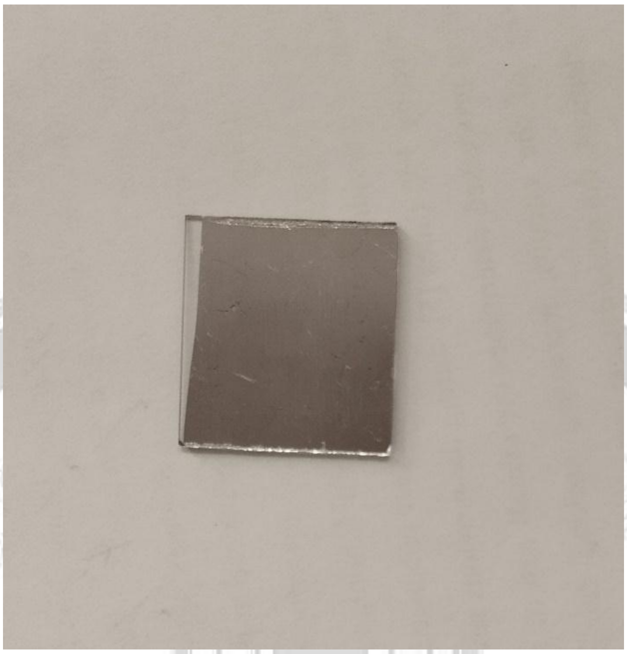

Fig (1) Aluminum deposited on a glass substrate

The next step is the mask, also known as a reticle, which contains what you wish to print on the wafer opaque patterns on a transparent substrate, making the photomask use its own lithography process usually by using beams of electrons to expose a resist, pattern on the mask defined by the chip design data. mask is head copy of pattern and is essential parts of microfabrication process. It is very important to miniaturize the submicron scale and be cost-effective in the making process. For exposure, chrome masks with glass plates are commonly utilized. Vacuum keeps these on the aligner, and a wafer may be securely pressed onto the masks. During exposure, good contact with a small gap. between the mask and the wafer is crucial to ensure that the exposed features match the features on the mask and are not impacted by light diffraction exposure, they are expensive and cost hundreds of dollars per mask, and the procedure is time-consuming. Instead, masks on film, sheets were utilised during the fabrication techniques' development. The benefits of this mask are its low cost (less than $1.5 per mask) and quick turnaround time. Because these masks are flexible, a unique method of maintaining them is required in order to minimize the gap between the masks and the wafer. Mask design is created, so various mask designs can be produced in micro level scale (um) as a DWG file by AutoCAD program. DWG file is converted to a PDF file with a PDF converter. The resulting PDF file mask design is printed as positive film as shown in Fig (2).

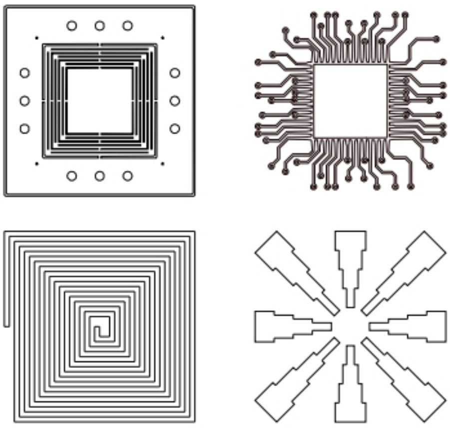

Fig (2) Four pattern masks designed by AutoCAD

dry photosensitive film 1-meter circuit photoresist sheet with 30cm width as shown in Fig (3) and cut to size with features include universal use in the creation of PCB boards, attachment to the glass surface to make it photosensitive, hole filling, and etching are all options. Excellent hole-covering abilities, excellent resolution, and material flexibility durable under pH 8.0, 8.5 circumstances, 1.5 mils dry film fully covers a 0.25inch height hole, suitable for standard plating bath, no wrinkle or colour error, and specifications of width 30 cm, length 100 cm, and trimming to the required size. The steps for using photosensitive dry film are as follows: Take off the cover, clear the area, then attach the film carefully, be sure to make it flat and leave no air, and iron the film slightly to fix it. To expose place the printed design on the photosensitive board. The dry film will darken from pale blue to deep blue. another film must be removed and immersed it in developer water. When developing, clean the board. (1 developer water for every 100 of water).

Fig (3) Photosensitive Dry Film 1 meter.

UV Lamp 220V Sterilizer 8W T5 Tube can be used as shown in Fig (4), with **specifications, wavelength:** 253.7 nm, germicidal UV light Tube, T5 (G5) **Lamp type,** round tube **glass bulb type**, with **disinfection area of** 8W 12m² and **tube length equal** 31 cm.

Fig (4) UV Light Tube

In this work, it is needed to form a positive film mask for microfabrication patterns because UV exposure decomposes a development inhibitor, and developer solution dissolves negative photoresist in the exposed areas. As a stencil, a flat plate of glass is coated with a thin film of opaque material. Figure (5) shows negative and positive photoresists.

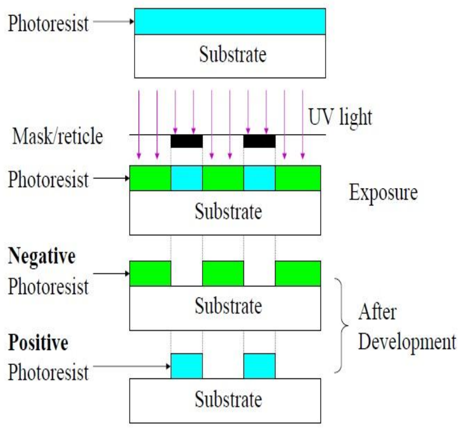

Fig (5) Negative and Positive Photoresists [9].

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The photoresist-coated substrate is put onto the wafer sample holder single-side mask aligner. Then patterned mask is put on the substrate. Then it is aligned to contact with the substrate and mask. After aligning the substrate and mask, it was exposed to UV for 3 minutes (exposure power approximately 8 mWcm2) carried out in a single-side mask aligner. In the alignment process, it is needed to align the mark on a mask and the mark on the wafer. In microfabrication, the most common method of exposing features on a photoresist layer is with an ultraviolet (UV) aligner. The UV aligner requires a mask that comes into contact with the wafer and has UV light-blocking or transmitting properties. To ensure that features are precisely transmitted to a photoresist layer, the UV aligner exposes a collimated UV light. The UV aligner's power output changes with usage. The wafer is baked again to ensure structure changes (20 – 30 minutes at 120 – 180 degrees), mild alkaline solution dissolves the region of the photoresist, Photoresist coat elsewhere remains firm. The most commonly used photoresists are aqueous-based developers. After the exposure process was finished.

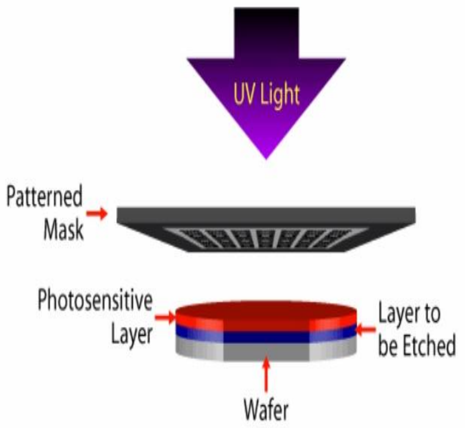

Fig (6) UV light shed on the wafer [4].

First, Place the substrate in the developer (Universal PCB developer, caustic soda free, mild alkaline solution that shown in Fig (7)) for 2 minutes. second, mix the can contained in 200 ml tap water in a suitable container. stir well with a plastic or glass rod until all the powder has dissolved. warm water can be used (approximately 50 C) to dissolve the powder faster, allow the solution to cool down and use between 20-25 C, depending on the strength of the solution and temperature, developing time should range between 15-30 seconds, gloves should be worn

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when working, supplied container should be used to measure the water required, the prepared solution should be used within 4 weeks.

Fig (7) Universal PCB developer (sodium hydroxide, NaOH).

It is found that developing time depends on the exposure time and the strength of the developer. The interactions between the resist and the developer affect the geometry of the photoresist profile and, more importantly, the linewidth control. The application technique for developers to photoresist is crucial for maintaining development uniformity and process latitude. Then the substrates should be cleaned, and the final resist image such that it can tolerate severe implantation or etching environments. the substrate was etched, and the etchants ($Fe2Cl3$) that have instructions, pour the solution into a plastic container or a dedicated etching tank, best results come out when the solution temperature is 45 C, maximum etching temperature should not exceed 55 C, depending on the strength of the solution and temperature, etching time should varies, always wear the safety gloves. Place the substrate in etchants for 30 minutes. A wafer is treated with etchant which only dissolves the exposed wafer surface, the control parameter is equal to the reaction time. The photoresist layer is removed by immersing into the photoresist remover (Acetone) for 20 min with ultrasonic agitation. Wash the substrate with isopropanol alcohol, then it is dried in an oven for 15 min at 100°C to be hardened. The exposed or unexposed photoresist parts are removed during the resist development process, depending on whether positive or negative photoresist was utilized.

3. Results And Discussion

The optimization of photolithography with the limited equipment that was available in this laboratory resulted in the ability to create microscale devices on-site, which was not possible before this research was conducted. This can affect the capabilities of diverse research groups, as a wide variety of patterns and devices can now be designed and fabricated using similar methods and equipment. The resulting microfabrication patterns are given in Fig (8), the photo of microfabrication is illustrated. It is found that some patterns are clear and some are not because of defects in mask patterns and decomposing during processing. There are found that some contamination in the images given in Fig (8) of the microfabrication pattern. It may be possible the contamination of the mask and residues of the photoresist and the laboratory is not dusting proof. Moreover, the goals of photoresist photo-sensitive coating are correct thickness good uniformity, and consistent lithographic response. Lithography limits are related to the wavelength of the radiation that exposes the photoresist. The minimum feature size (line width or line spacing) that can be established is given by Eq (1)

$$F = 0.5 * \lambda / NA \qquad \text{Eq (1)}$$

The Numerical Aperture, NA, is equal to n sin where n is the material's refractive index between the mask and the wafer. (Usually air, so $n = 1$) and theta is the Hal angle of the '2 most divergent rays' that can pass through the lens. This must be less than 90 degrees, so NA is less than one.

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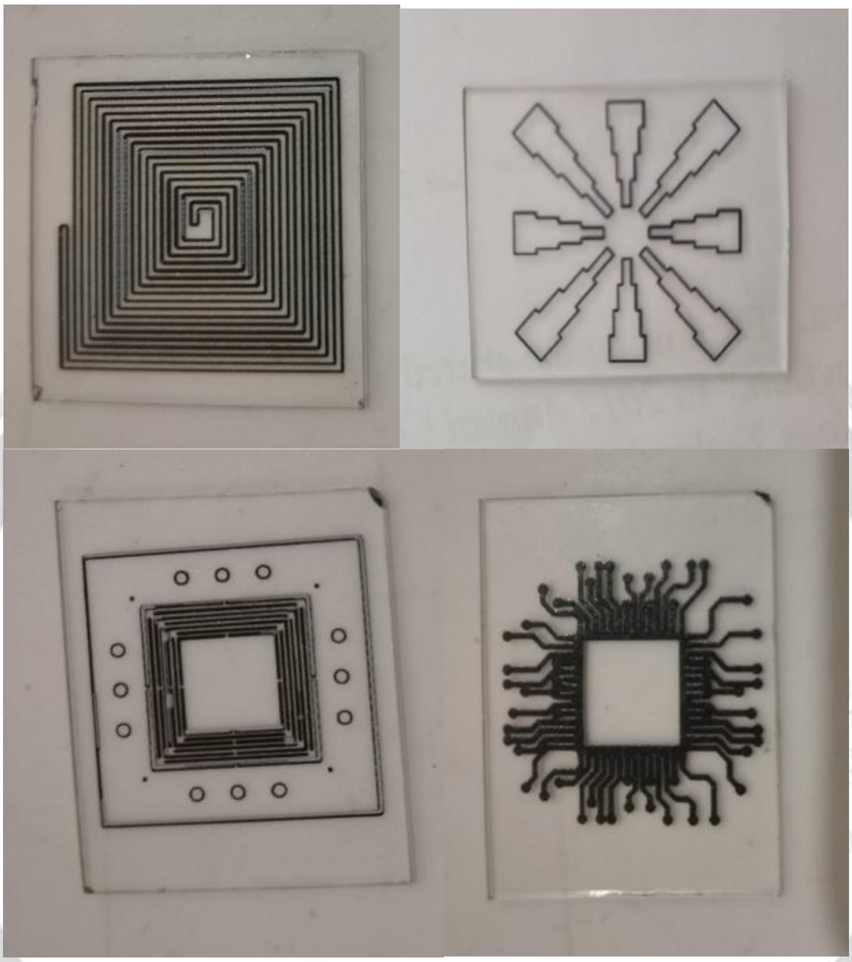

Fig (8) Resulting microfabrication patterns.

Comparison of cost of microfabrication

The cost comparison of standard microfabrication and our low-cost microfabrication method. It estimates the cost for a one-time microfabrication process. It is found that our low-cost microfabrication method is very low in mask-making processes. Our low-cost microfabrication method is cheaper than standard microfabrication about $500 for one time of microfabrication. And it is also found that microfabrication patterns have been successfully fabricated.

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Conclusions

Based on the results of the foregoing experiment, it can be concluded that various elements, such as process latitude, pinholes, particle and contaminant levels, step coverage thermal flow, resolution, adhesion, expose rate, sensitivity, and exposure source, have an effect on photoresist performance. The smaller the substrate area, the lower the resolution and the more difficult it is to distinguish the content of the pattern. Negative photoresist is cheaper with poor resolution while positive photoresist is expensive with better resolution. Temperature can influence photoresist viscosity and spin coating thickness.

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تصنيع نماذج أولية بسيطة ومنخفضة التكلفة باستخدام الطباعة الحجرية الضوئية

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الخلاصة

يصف هذا العمل التحسينات التي أدخلت على العملية الأصلية، بما في ذلك انخفاض تكلفة التصنيع. لقد نجحت في التغلب على جميع العقبات الرئيسية التي توفرها خارطة طريق صناعة أشباه الموصلات. ولتحقيق ذلك، فقد شهدت تعديلات كبيرة ووسعت بشكل كبير حدود البحوث والهندسة البصرية والإلكترونية. تعد الطباعة الحجرية الضوئية هي المرحلة الأساسية في عملية تصنيع أشباه الموصلات التي تحدد جودة الرقاقة. نظرًا لأن عملية التصنيع عبارة عن عملية دفعية ذات جودة شرائح متفاوتة، فقد كان التوحيد دائمًا هو الهدف الأساسي للعملية. تركز دراسة الحالة هذه على تحسين خطوة الطباعة الحجرية الضوئية من أجل تحسين التوحيد وإنجاز الأبعاد الحرجة، وكلاهما معلمات جودة لأجهزة أشباه الموصلات. ينبغي فحصها لتحسين التحسين. ستناقش هذه الورقة أحدث التحسينات في عملية الطباعة الحجرية الضوئية، بالإضافة إلى دمج

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مجموعة متنوعة من أساليب تحسين الدقة. يتم تطبيق طبقة مقاومة للضوء (فيلم جاف حساس للضوء ١ متر للصفائح المقاومة للضوء بعرض ٣٠ سم) على المادة المراد نقشها. تتعرض الطبقة المقاومة للضوء للأشعة فوق البنفسجية من خلال القناع. تكتمل هذه المرحلة باستخدام مصفف القناع، الذي يقوم بمحاذاة القناع والرقاقة قبل مرحلة التعرض اللاحقة. اعتمادًا على جيل مصففات القناع، يتم ملامسة القناع والركيزة أو قربهما (طباعة التلامس والقرب). اعتمادًا على ما إذا كان تم استخدام مقاوم الضوء الإيجابي أو السلبي، تمت إزالة مكونات مقاوم الضوء المكشوفة أو غير المكشوفة أثناء عملية تطوير المقاومة. يتم إنشاء تصميم القناع، ويمكنه إنتاج تصميمات قناع مختلفة بمقياس المستوى الصغير (um) كملف DWGبواسطة برنامج AutoCAD. يتم تحويل ملف DWG إلى ملف PDF باستخدام محول PDF. تتم طباعة تصميم قناع ملف PDF الناتج كفيلم إيجابي. في هذه التجربة تم استخدام طبقة موحدة من الزجاج كركيزة، وتم ترسيب الألمنيوم بطول ٢.٥ سم وعرض ٢.٥ سم وسمك ٠.٢ سم.

الكلمات الدالة: الطباعة الصورية، الصناعة الدقيقة، المقاوم الضوئي، الطباعة الصورية بالاشعة فوق البنفسجية.