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The Possibilities of Silicon as Flexible Printed Circuit Board (Biochips): An interface between electronics and non-electronic world[1]

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Abstract:

The ubiquitous microprocessor has dramatically increased the world's data processing capacity. The limiting factor in expanding computer analysis and control for clinical and biotechnological applications is the interface between electronics and the non-electronic world.

Emerging applications in a number of areas are expanding the need for chemical sensing. For example, there is a trend in clinical testing away from use of centralized laboratory facilities and toward testing which can be done quickly in a physician's office. The monitoring of biological fluids for illicit drugs or for hazardous chemicals, particularly when there is workplace exposure, is increasingly important. Monitoring of toxic substances in industrial effluents in the environment is becoming a priority. While analytical instruments and laboratory procedures are available for collecting the required data, these approaches are often unacceptably expensive or slow. Availability of low-cost, portable, direct-reading instruments could have an impact on data collection comparable to the effect that microprocessors have had on data processing. Due to its dependence on instrumentation, analytical chemistry has long benefited from advances in electronics. For example, ion selective electrodes (ISEs) became practical early in the 20th century when vacuum tubes provided high input-impedance instrumentation, and the solid-state operational amplifier now pervades chemical instrumentation.

Sensors and actuators bridge this boundary, transducing physical and chemical conditions to electronic signals, or using electronic signals to bring about a physical or chemical change. In this paper, the focus is on fabrication techniques for flexible silicon cables, which can be used in biotechnology as bio sensors (thin membrane), complete PCB (Printed circuit board) for interfacing components on a biochip, and in hearing aid equipment. The experiment carried out in clean rooms of class 100, as part of research in (nano tools) at Microelectronic Center, Technical University of Denmark.

Introduction:

In this project we interconnected substrates with flexible regions which are made in silicon with micro systems technology. we followed the complete process sequence for fabrication of Siflexbor2. In micro fabrication, we took into account the various steps, beginning from the wafer selection to deposition by diffusion process, LPCVD, photolithography, e-beam evaporation, reactive ion etching, wet etching, electroplating in IPP and then final structures. Siflex prints have a considerable advantage over usual flexible prints. Siflex print uses silicon as a substrate and has the advantage to be thermally and mechanically compatible to integrated circuits, biotechnology, and micro systems based on silicon. The applications of Si-Flexprint are within the medical electronics as hearing aids, biochips, and delicate sensors. People can also use the chips to test their genes and see what diseases they could be susceptible to, pharmaceutical companies can use them to test billions of new drugs compounds and tailor medicines to individual needs, scientists can use the chips to keep track of diseases

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which mutate too rapidly for the drugs to catch up with them (i.e. HIV). Biochips helped to dramatically accelerate the identification of the estimated 80,000 genes in human DNA, an ongoing world-wide research collaboration known as the Human Genome Project. The microchip is described as a sort of word search function that can quickly sequence DNA. Biochips may also be useful in hospitals for detecting specific causes of local infection and in agriculture for testing for pesticides in the soil.

Description:

In order to use the Silicon wafers as substrate, we processed with four basic operations of semiconductor devices

1. Layering
2. Patterning
3. Doping
4. Heat treatment

Here we would like to describe briefly about various processes and equipments, which we used in our process sequence from very beginning to the end of process.

RCA Cleaning:

Contaminants present on the surface of silicon wafers at the start of processing, or accumulated during processing, have to be removed at specific processing steps in order to obtain high performance and high reliability semiconductor devices, and to prevent contamination of process equipment, especially the high temperature oxidation, diffusion, and deposition tubes. In 1970, the RCA Laboratories developed a cleaning procedure for silicon semiconductor device fabrication technology, which has become the industry standard; it uses several reagents containing hydrogen peroxide.

The RCA cleaning procedure has two major steps, used sequentially:

i) Removal of insoluble organic contaminants with a 5:1:1 H2O: H2O2: NH4OH solution (RCA -1).
ii) Removal of ionic and heavy metal atomic contaminants using solution of 6:1:1 H2O: H2O2: HCL (RCA-2).

The RCA cleaning technique does not attack silicon, and only a very thin layer of silicon dioxide is removed in the process. The procedure was also designed to prevent replicating of metal contaminants from solution back to the wafer's surface.

Low Pressure Chemical Vapor Deposition (LPCVD):

Low Pressure Chemical Vapor Deposition system designed to deposit some of the layers which function as di-electric, conductors or semiconductors. Operating at low pressure the mean free path of the reactant gases increases, assuring a high uniformity of the deposited film thickness, but the deposition rate decreases. The process runs in the "Reaction Rate Limited Regime", i.e. the transport rate of the reactant gases to the wafer surface is higher than the reaction rate.

Photolithography- HMDS (Hexamethyldisilizane):

Hexamethyldisilizane (HMDS) is widely used in the semiconductor industry to improve photo resist adhesion to oxides. The HMDS reacts with the oxide surface in a process known as silylation, forming a strong bond to the surface. The methyls, meanwhile, will bond with the photo resist, enhancing the photo resist adhesion. It should be noted that HMDS is a suspected carcinogen, so it should be handled with care.

SSI 150 dual track spinner with thick (10μm) photo resists facility:

The SSI 150 dual track spinner automatically coats four inch wafers with photo-resist and applies both a de-hydration bake and a soft bake (post-coat bake) in a cassette-to-cassette operation. It is important to use caution around the moving transfer plates and the moving spin module.

BHF (Buffered Hydro Fluoric Acid):

Hydro Fluoric acid, an acid used to etch silicon di-oxide, often diluted or buffered when it is used. A mix of hydrogen fluoride and ammonium fluoride (NH4F) used to allow oxide etching at slow controlled rates. HF acid is very dangerous; HF burns are particularly hazardous. An insidious aspect of HF burns is that there may not be any discomfort until long after exposure. These burns are extremely serious and may result in tissue damage.

Plasma Asher:

The Plasma Asher system is used for ashing of photo resist. In plasma ashing, a radio frequency (RF) electric field breaks down the non-reactive gaseous O2 molecules into plasma of reactive mono-atomic oxygen radicals. The highly reactive radicals react with the organic polymers in the photo resist to form gaseous products (CO, CO2, gaseous H2O, etc.) that are pumped away.

KOH Hood:

Potassium hydroxide (KOH) etches SI in the (100) direction much more rapidly than other planes. With a 54.7deg angle to the (100) etch, a 100u wide circular surface feature would etch rapidly to a depth of 70.6u, in an inverted pyramid shape, then slow when only the (111) etch is left. Normal etch rates are 80u/hr in (100) and less than 10u/hr in (111), when mixed 25wt% in DI, at 80C. Masks are usually nitride. Although there is a moderately slow oxide etch rate.

Chemicals used in the KOH hood are corrosive and toxic, and care must be taken in handling them. Besides the vinyl gloves, which must be worn at all times in process one should also wear the face shield. Know the location of the eyewash and safety shower as well.

Four Point Probe:

The four-point probe is used to measure sheet resistivity of a diffused layer in a silicon substrate, or a deposited conducting film .The system includes a probe head with four probes in line, separated by distance of 40 mils, a current source, and a digital voltmeter.

The current source passes a current, I, through the outer two probes of the probe head, and the voltage drop, V, across the inner two probes is then measured by the DVM .The sheet resistivity is proportional to the ratio V/I. There is a correction factor, which depends on the geometry of the probes and the wafer.

Ellipsometer:

The Ellipsometer name is derived from the elliptical polarization of the light used to measure the thickness and index of refraction of transparent films. The system detects the change in the polarization state of the light, which occurs when the light is reflected from the surface of the sample, and then calculates the thickness and index of the film based on this change. The components on the polarizer arm produce the elliptically polarized light. The polarizer arm orients the incident light beam at an angle of 70 degrees with respect to the normal of the sample wafer that has been placed upon the wafer stage.

The reflected beam is examined by the analyzer arm components, which are also oriented at the same fixed angle with respect to the wafer. By rotating the polarizer to a critical angle, and thus preparing a unique polarization state of the incident light, the reflected beam will be linearly polarized. If the analyzer is now rotated at 90 degrees to this line of polarization, the intensity of the light passing through the analyzer and striking the photo multiplier tube will be a minimum, ideally zero.

The instrument is "tuned" to this null (automatically), and the values of the polarizing filter angle and the analyzing filter angle are used by the system to calculate the thickness (t) and index of refraction (n) of the film. Since several values of thickness will produce the same analyzer and polarize settings for the null. A unique thickness is not determined. You must have a rough estimate of the thickness, and then select that value of thickness calculated by the system, which most closely matches your estimate. The Ellipsometer will then provide a very accurate measurement of the film's thickness.

Profilometer:

The profilometer can measure small vertical features ranging in height from 100 A to 650,000 A. The height position of the diamond stylus generates an analogue signal, which is converted into a digital signal stored, analyzed and displayed. The radius of diamond stylus is 12.5 microns, and the horizontal resolution is controlled by the scan speed and scans length. There is a horizontal brooding factor, which is a function of stylus radius and of step height. This brooding factor is added to the horizontal dimensions of the steps. The stylus tracking force is set to 50 milligrams. The scanning head contains a viewing camera, a motor driven stylus and analogue electronics to detect and amplify the transducer signal.

Scribing:

Lines used to separate die on a wafer, the wafer will be sawed along the scribe lines or just to scribe the wafer no. for process sequence.

D-I Water:

Purity of this water is measured by its resistivity with the standard being 80 M ohms.

Masking Oxide:

To deposit oxides on the silicon wafer by means of oxidation (Wet or dry)

Photo Resists:

This is a light sensitive layer which is deposited onto the wafer and exposed using high intensity light through a mask. The exposed photo resist is dissolved with developers (depending on the polarity), leaving a pattern of photo resist, which allows etching to take place in same areas while preventing it in others. For Integrated circuits after baking the typical thickness ranges from 0.5 to 2.0 micrometer. For micro fabricated structures thickness of 1cm and above.

Negative Photo Resist (Image reversal):

Photo resist that removes the area that were not protected from exposure by the opaque regions of mask (specifically chrome is used (800Å thick), which reflects the uv light) while being removed by the developer in regions that were protected .A dark or light field mask is often used with negative PR.

Flood Exposure:

Flood exposure is used to expose the whole wafer with same intensity of UV light to make it more soluble in developer (specifically the areas which have been exposed during mask alignment).

Strip Resist:
Strip resist is a removal process of PR, by means of plasma Asher. Usually we go through the rough and fine strip by dipping the wafers into acetone and then into ultrasonic cleaner before going to the plasma Asher.

Reactive Ion Etching:
An etching process that combines plasma and ion beam for removal of the surface layer. The etchant gas enters the reaction chamber and is ionised. The individual molecules accelerate to the wafer surface .At the surface the top layer removal is achieved by the physical and chemical removal of the material.

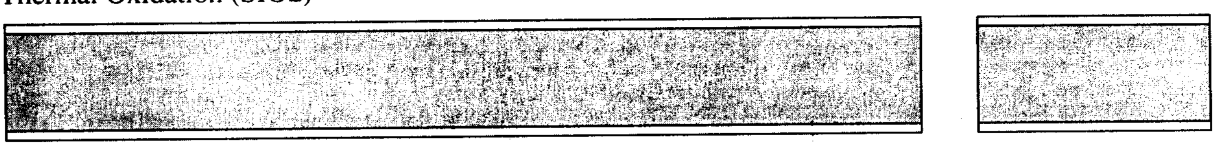
Sputtering:
A method of depositing a thin film of material on wafer surface, A target of the deposited material is bombarded with radio frequency excited ions, which knocks atoms from the target. The dislodged target material deposits on the wafer surface. (In our process we used cr and au for sputtering).

Deglazing:
Deglazing is a process in which we put the wafers into BHF for removal of oxides.

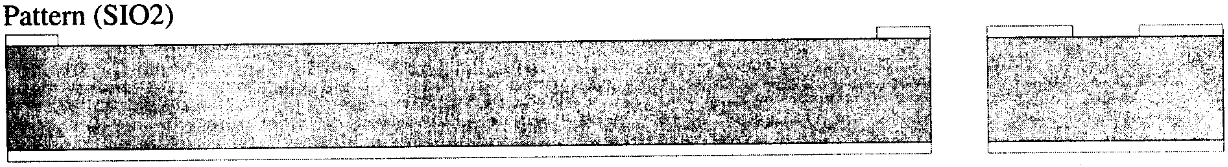
Reversal Bake:
A process in which wafers are kept for heating in order to prevent unexposed areas (in case of Negative PR) from flood exposure.

Complete Process Steps:

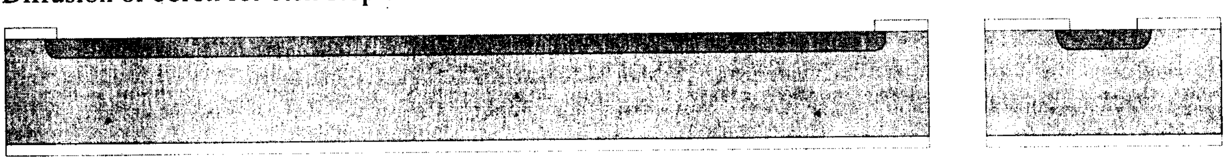
Thermal Oxidation (SIO2)



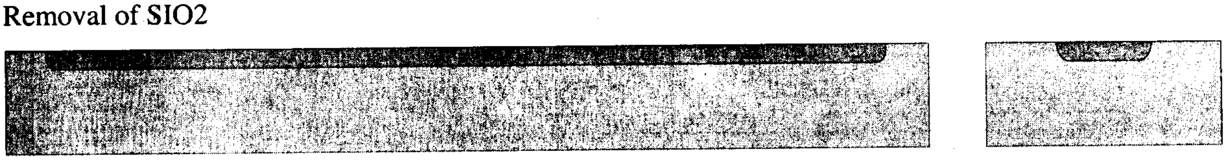
Pattern (SIO2)



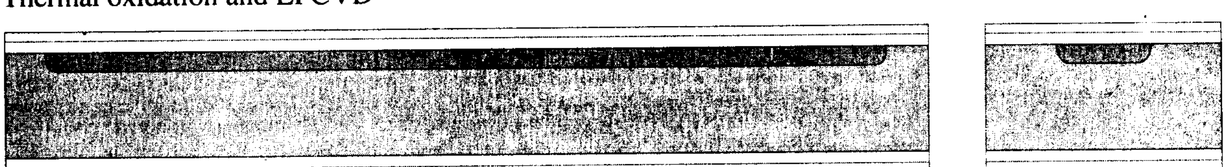
Diffusion of boron for etch stop definition



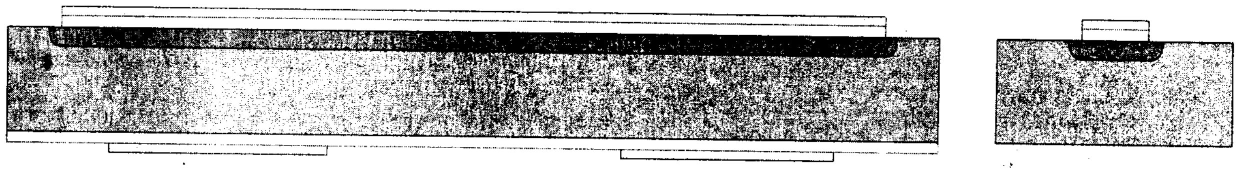
Removal of SIO2



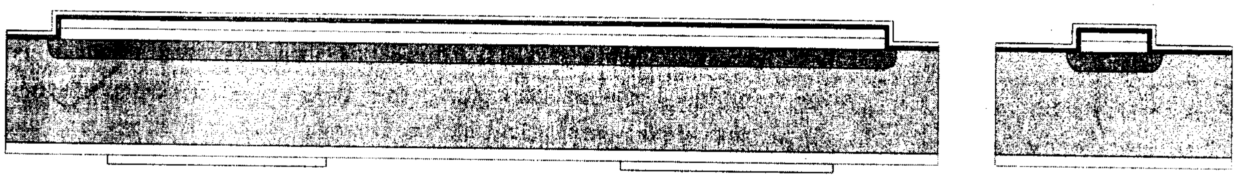
Thermal oxidation and LPCVD



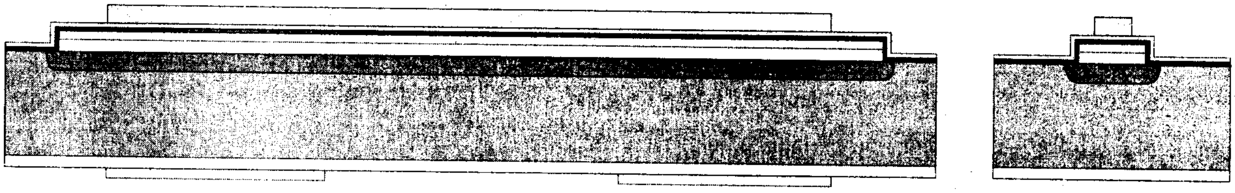
Pattern SIO2 and SI3N4



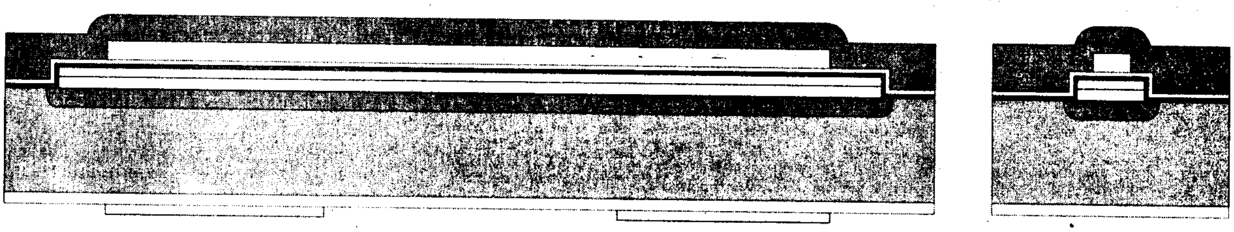
Evaporate Plating base



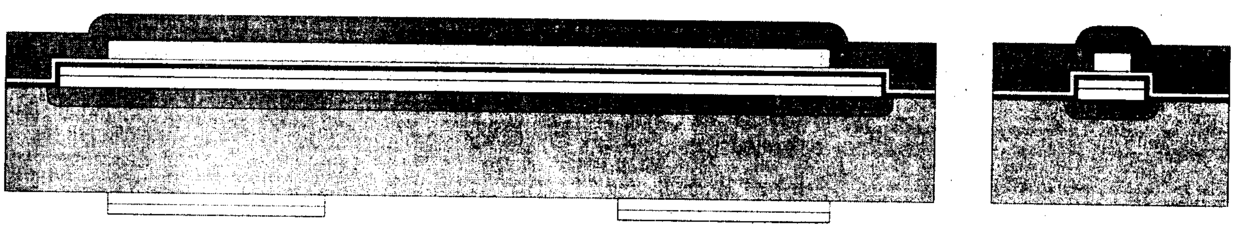
Electroplate Au in photo resist mould



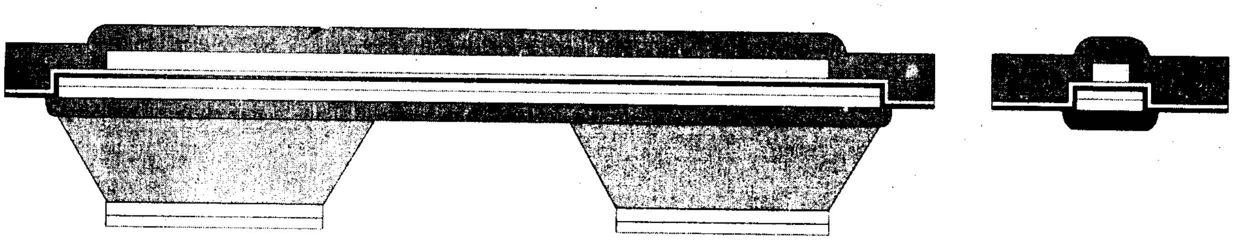
Electroplate Protective Ni layer



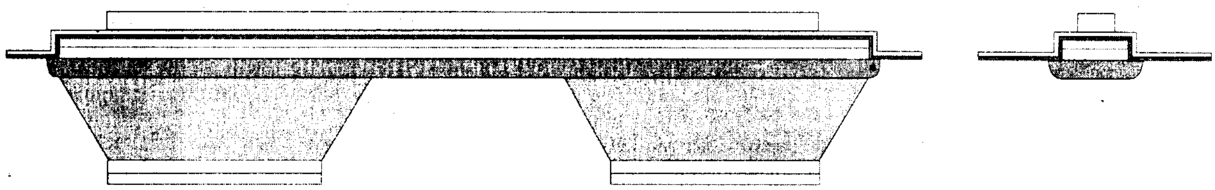
Open SIO2 on backside



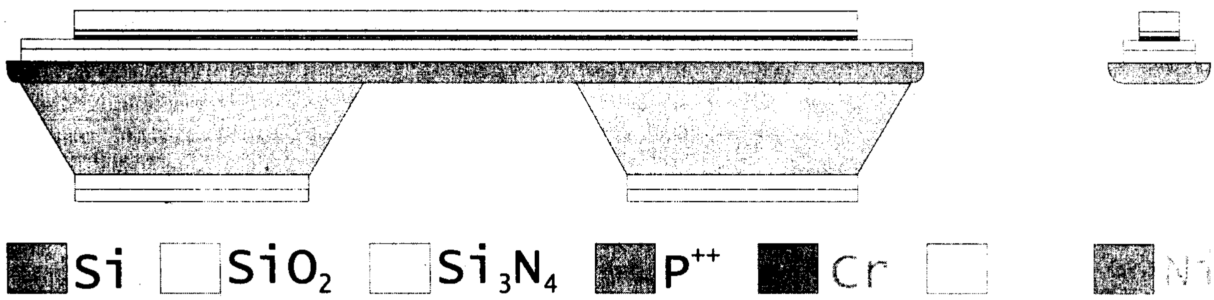
Anisotropic etching of Si in KOH



Selective etch of Ni



Etch of plating base



Conclusions and Discussion:

In this detailed experiment, we concluded that dimensions can be shaped for further flexibility. Moreover, with the development of implantable monitoring devices, we can develop the personal or remote sensing. The application area for these flexible prints can be catheters, implantable systems, aero planes, and satellites. Biochips can also be used for weight control. The chip delivers high-frequency electric pulses to the stomach to stimulate the feeling of 'fullness' and thus curb the need to eat. Future applications include inject able neuro-muscular simulators for the paralyzed. These simulators could be managed by wireless communication control systems sewn on the paralyzed person's sleeve. Also in the pipeline are curved silicon-based arrays of photo sensors that can be fitted on the back of a damaged eye's retina for improved vision.

The main focus of this experiment was to develop a fabrication technique that could be helpful for the application area within area of chip fabrication and bioinformatics. This work can further be extended to make a complete biochip for clinical use.

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