SELECTIVE ETCHING OF LPCVD Si_3N_4 OVER SiO_2 USING SF_6

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ABSTRACT

A Si_3N_4 etch process using a Plasmatherm 2406 etcher and SF_6 was determined. RS1/Discover was used to design an experiment which varied SF_6 flow rate, power, and pressure. A maximum nitride etch rate of 1300 A/min. was obtained with a corresponding nitride to oxide selectivity of 2:1. Selectivities as high as 6:1 were obtained but with nitride etch rates of less than 100 A/min. An acceptable baseline process, having a nitride to oxide selectivity of 3.24:1 with a nitride etch rate of greater than 850 A/min was established.

INTRODUCTION

Low Pressure Chemical Vapor Deposition (LPCVD) of silicon nitride, performed at 700 to 800 degrees celcius results in a stoichiometric compound of Si_3N_4 typically used for an isolation material in the Local Oxidation of Silicon (LOCOS) process [1]. In this process a 'pad' oxide of less than 500 angstroms is grown and then a nitride layer is deposited. This nitride layer is patterned and used to define the active areas for future device fabrication. For best results, the pad oxide is made as thin as possible to minimize the bird's beak effect. Therefore, it is important that the nitride etch possess the highest possible selectivity to the underlying oxide layer. If the oxide is completely removed and the bare silicon is exposed to the etch, subsequent oxides may contain surface defects and be of poor quality.

There are essentially two distinct etching mechanisms at work in any plasma etching process; chemical and physical. In a plasma, radicals are created which are highly reactive. These radicals migrate to the surface of the wafer where a chemical reaction occurs forming volatile products. Energetic ions are also present in the plasma. By applying a potential across the plasma, these ions can be accelerated towards the wafer surface where they physically bombard the surface enhancing the chemical reaction of the radicals and preventing polymer formation [1]. As ion bombardment increases, the etch becomes anisotropic in nature and selectivity decreases.

Work is currently underway in RIT's microelectronic facility on CMOS and NMOS processes which employ a LOCOS process. Preliminary work has indicated an insufficient etch uniformity over the wafers using a Tegal 700, which was not acceptable for successful LOCOS processing [2,3]. It is therefore imperative that a uniform nitride etch process be developed which has sufficient selectivity over oxide.

This project investigated using a Plasmatherm 2406 Reactive Ion Etcher (RIE) to obtain a satisfactory nitride etch process. This tool is capable of precise control of pressure,power, and gas flow and can be operated in either manual or automatic mode. The Plasmatherm is constructed as a parallel plate single wafer reactor.

SF6 was decided upon as the etching gas due to it's safety factor (nontoxic and noncorrosive), it's availability, and its performance [2,3,4,5,6]. Selectivities as high as 15:1 have been obtained using only SF6 [6], with a selectivity of 6:1 being obtained here at RIT [2].

EXPERIMENT

Twenty-five n-type <100> wafers were prepared by first growing an oxide layer of approximately 2000 angstroms at 1050 degrees for 30 minutes. Approximately 1800 angstroms of nitride was deposited onto the oxide layer using an LPCVD reaction of SiH2Cl2 and NH3 for 30 minutes. The wafers were then patterned using KTI820 to form several millimeter sized line/space pairs. The nitride layer was then selectively etched using a Tegal 700 plasma etcher. A resist layer was patterned with the same mask oriented perpendicular to the previous nitride/oxide pattern. Figure 1 shows the resulting wafer after patterning.

Each of the experimental runs consisted of three initial thickness measurements of each layer (Si3N4, oxide, and resist), a 1 minute etch in the Plasmatherm, and three final measurements of each layer. The thickness measurements were performed on the Nanospec film thickness measurement tool (program 6 for Si3N4, program 1 for oxide, and program 11 for resist). Film thickness differences were determined for each layer and etch rates were calculated as being equal to the change in film thickness divided by the change in time.

The experimental design was developed using RS1/Discover and consisted of varying three factors of power, pressure,and SF6 flow. Power was varied from 50 to 200 watts, pressure was varied from 20 to 200 mtorr, and SF6 flow was varied from 10 to 50 sccm. The monitored responses were nitride etch rate, oxide etch rate, and nitride to oxide selectivity. The design model was specified to be a quadratic interaction model. The design type was specified as a CCI (central composite inscribed) design with multiple centerpoints. The experimental RSM design resulted in a response surface curves describing a desired response with

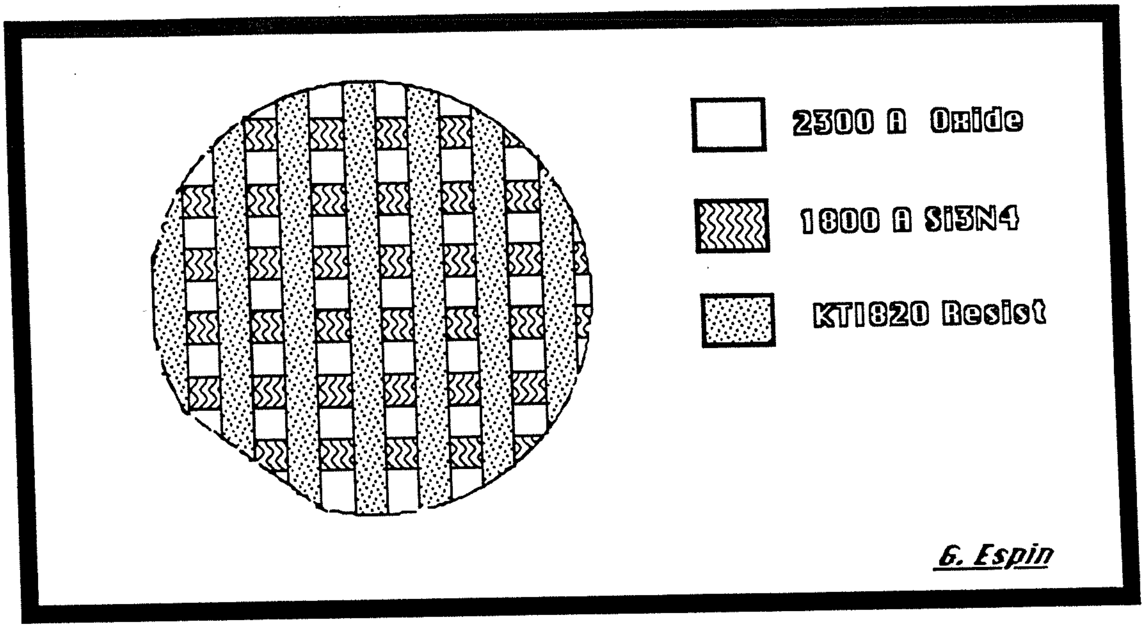

Figure 1: Final patterned experimental wafer

respect to two factors (one being held constant). From such a curve an optimum operating point was determined and evaluated for validity.

Once the design was completed, independent runs were performed to obtain an operating condition possessing both a satisfactory nitride etch rate and selectivity to oxide. At this point, the wafers were examined for etch uniformity over the wafer and nitride etch rate with respect to resist.

RESULTS/DISCUSSION

The results of the RSM design were inconclusive. Etch rates which were satisfactory (greater than 800 A/min) possessed corresponding selectivities of less than 2:1. Selectivities as high as 6.6:1 were obtained, but in these cases nitride etch rates were less than 200 A/min. A typical response surface curve obtained is given in Figure 2. Curves such as Figure 2 indicated that selectivity increased as pressure increased and nitride etch rate increased as power was increased. In order to increase both selectivity and nitride etch rate simultaniously, additional runs needed to be performed off the upper-right portion of the design. It was hypothesized that this area, which was not covered by the initial design, would yeild acceptable etch condition.

Further runs were performed at experimentally sound points off the design. These additional runs are indicated in Figure 2. From these runs, a satisfactory operating condition [6] was obtained from the additional runs which resulted in a nitride etch rate greater than 850 A/min with a corresponding selectivity of 3.24:1. Uniformity of the etch was within +/- 100 A with the etch proceeded in from the wafer's edge. This indicted a

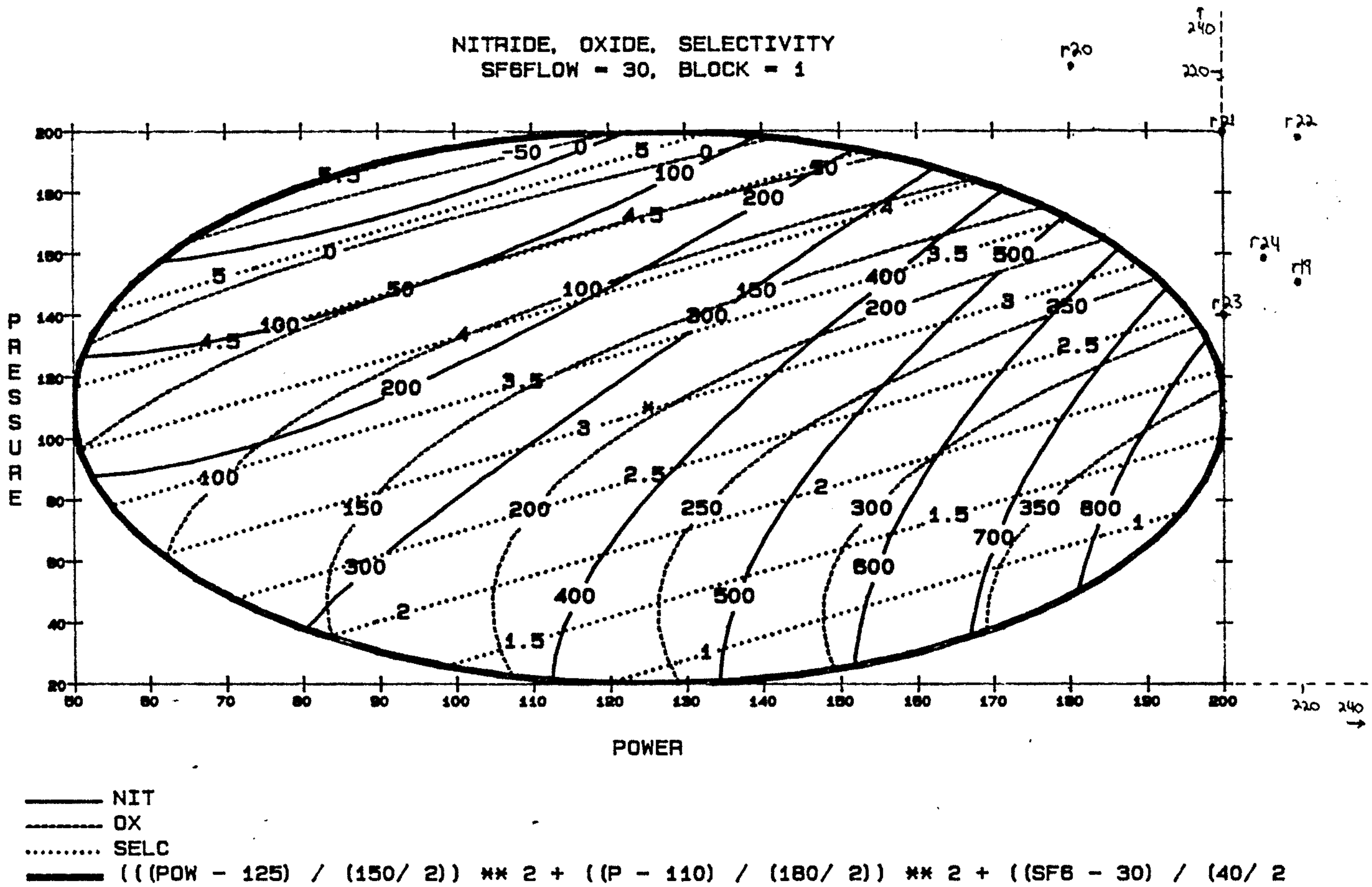

Figure 2: Response Curve for SF6 flow equal to 30 sccm

depletion of the reacting species near the center of the wafer. It is believed this will not occur in LOCOS processing because far less nitride surface will be etched (the checkerboard pattern of Figure 1 was used for this experiment). Also, resist etching was minimal with an etch rate less than 200 A/min on all runs.

CONCLUSIONS

An initial design did not produce an acceptable operating point. It did indicate that increasing both pressure and power should produce increases in selectivity and nitride etch rate. Additional wafers were used to obtain an acceptable operating point with a selectivity of 3.24:1 and a nitride etch rate of greater than 850 A/min. Etch uniformity was within +/- 100 A. Depletion effects were noted but it is thought that they will not pose a problem in LOCOS procesing. Resist etching was acceptable with etch rates not exceeding 200 A/min.

Further work would be helpful in examining the effects of temperature variation and in optimizing the process.

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