SPIN ON GLASS ETCH PROCESSING FOR THE RIT NMOS PROCESS

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ABSTRACT

ACCUGLASS 104 was characterized for four micron via etching. The quality of the Spin On Glass (SOG) layer was improved by increasing the cure temperature to 600 degrees c for one hour. A buffered hydrofloric acid diluted 100:1 produced an etch rate of 2700 Angstroms per minute. A plasma etching process was design with a gas mixture of CHF3/CF4/O2 in a ratio of 10:3:1.5 wit a Tegal 700 plasma etcher. The SOG etch rate of this mixture was 600 Angstroms per minute. The selectivity of this plasma for SOG to poly silicon was 12:1. The wet process produced better image profiles for thick glass layers, while the plasma process etch rate is better suited for thin layers.

INTRODUCTION

Device designs requiring multilevel metal layer also mandate an interlevel dielectric layer. The requirements of this glass layer are that it must be conformal and that processing temperatures must be kept low. Spin on Glass layers can fulfill these requirements while staying within these constraints.

A requirement of an interlevel dielectric is the ability of this layer to be etched for metal vias. Standard NMOS processes, RIT's inclusive, require that these vias be four microns square.

Applied Technologies ACCUGLASS 104 is a siloxane, $Si(OCH3)4$, in solution with an alcohol solvent system. Application and prebake of this solution produces a sol-gel which can further be cured to drive out the organics. The cure step is a process which attempts to produce a pure silicon dioxide ($SiO2$) layer from the organic compound. Organic layers can be etched in oxygen plasmas, this is the same plasma used to strip photoresist. Therefore, an uncured SOG layer would be removed with the resist in a plasma ash. Additionally, the density of the SOG layer, and therefore it's etch rate, is directly related to the cure temperature. These two parameters require the optimization of the cure so as to achieve a viable interlevel dielectric using SOG.

carbon to flourine is a complex process when using different gases. One cannot just use the element ratio, atomic size and effective temperatures must also be considered. THis is beyond the scope of this presentation.

Use of CHF3 as a hydrogen source was the only alternative. However, this gas results in the hydrogen concentration being too high and shifting curve of figure 1 into the polymerization realm. Therefore, a mixture of CHF3 as a hydrogen source, CF4 as a flourine abundant source, and O2 to help remove reduce the hydrogen concentration.

The process for coating the SOG was as follows:

An optimum spin speed was found by doing a spin speed versus thickness for 2000 to 5000 RPM's. The results were plotted. A SOG spin application flow was then designed to give appropriate glass thicknesses. A multiple application scheme was designed n which the applications were seperated by a ten minute "mini" cure at the appropriate cure temperature. A typical SOG application process is listed below;

Spin Speed : 2000 RPM
Spin Time : 20 sec
Prebake Temp: 150'C
Prebake Time: 60 sec
Mini Cure : 10 mins in appropriate cure temp. betwee

n

applications
Two more applications using the above parameters
Cure Temp : 400'c or 600'c
Cure Time : 60 mins

Cured wafers were then subjected to various etch conditions to establish etch rates and selectivities. To find selectivities, poly wafers and wafers coated with just KTI 820 resist were also subjected to the etch conditions. THe etch rates were calculated to be the thickness lose divided by the time of the etch.

The etchants used and their flow rates were;

ratio in sccms	Etchant
	BHF
	10:1 BHF
	100:1 BHF
4:1	CHF3:O2
5:1.5:1	CHF3:CF4:O2
10:3:2	CHF3:CF4:O2
10:3:1.5	CHF3:CF4:O2

From the data collected by etching with these gases, and measurements made using either the Nanospec or Alphastep, the

Selectivity of silicon dioxide to silicon is an important parameter when etching interlevel dielectrics. Normally metal one is a polysilicon deposition. Therefore, to assure that the poly integrity will be maintained throughout the SOG etch, a high selective etch needs to be developed. Silicon and silicon dioxide etching selectivities can be controlled using flourine gases with oxygen and hydrogen. Reduction of carbon/flourine gases by the addition of hydrogen effectively reduces the etch rate of silicon while leaving the etch rate of the SiO2 unchanged. Oxidation of a carbon/flourine plasma by the addition of O2 increase the etch rate of silicon while again leaving the etch rate of SiO2 unchanged. Therefore to produce a highly selective etch of SiO2 to silicon, one would reduce a carbon/flourine plasma with Hydrogen (see figure 1 below). However, hydrogen handling is dangerous and expensive. This puts a limiting constraint on the etch processes of facilities unable to handle hydrogen (RIT).

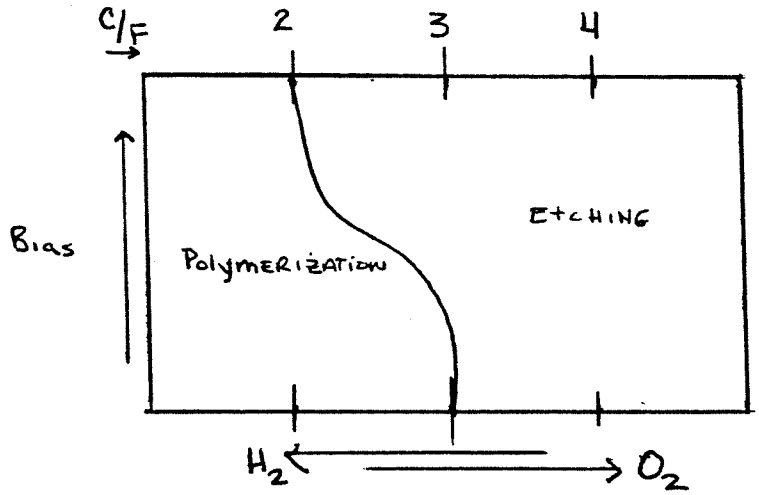


FIGURE 1

Without the use of pure hydrogen, a complex gas mixture could be formalized which effectively produce the same results. To be effective this process would have to be well controlled and monitored. For too much hydrogen would cause the curve of figure 1 to be shifted too far to the left, resulting in polymerization of the poly. Care must be taken so as to not let this happen, for future metal deposition would then be isolated from contact to the poly.

EXPERIMENT

Initially the focus of this investigation was centered on finding a suitable plasma etching gas mixture using RIT's Tegal 700 plasma etcher that would have the effect of adding pure hydrogen to a flourine plasma. Later the process of wet etching with hydrofloric acid was studied. The gases availible for plasma etching were CHF3, CF4 and O2. Reducing the ratio of

encountered. Even the thickness of 1340 Angstroms produced by this 2K is not acceptably thick and therefore three consecutive applications of SOG were used for this experiment. However, layers produced by spin speeds lower then 2k, were highly non-uniform.

The triple application scheme used, resulted in measured SOG thicknesses of 3500 and 2700 Angstroms for the 400'c and 600'c cure respectively. A refractive index of 1.47 was used for the SOG layer. The Nanospec program used was program 1; oxide on Si with a Refractive index of 1.47. A problem was encountered here, in that the Nanospec would not accurately read the 600'c layer. Error messages would be displayed with the output value, and there was no repeatability. Therefore, the 600'c SOG layers had to be read using the Alphastep.

ETCHING AMBIENT ETCH RATES AND SOG/POLY SELECTIVITIES

sccms	Etchant	SOG	Poly (a/min)	PR	SOG/Poly Selectivity
	BHF	>40K	0.0	0.0	***
	10:1 BHF	>40K	0.0	0.0	***
	100:1 BHF	~3k	0.0	0.0	very good
4:1	CHF3:O2	**	**	**	--
5:1.5:1	CHF3:CF4:O2	239	91.5	<10	2.6:1
10:3:2	CHF3:CF4:O2	300	27.8	<10	10.8:1
10:3:1.5	CHF3:CF4:O2	650	44.8	<10	14.5:1

*note the CHF3/O2 gas mixture caused polymerization of all exposed surfaces.

For the above analysis, the 600'c cure SOG was always used. The reason for this is that the 400'c cure was too porous even at the high spin speeds. This caused the SOG to etch non-uniformally and very quickly. The density of the 600'c SOG was high, very little pitting occurred, and the etch rates looked uniform across the wafer.

The wet HF etch at 100:1 produced very good edge profiles and implicitly produces very high selectivity. Without an oxidant, HF will not etch silicon. The batch of acid used in this experiment was made fresh. Therefore, the zero etch rate of Si should be accurate. The concentration greater than 100:1 were far to reactive to be a usable process.

When investigating the plasma etch systems, it was seen that the lower pressure etch of 5:1.5:1 produced poor selectivity etches. This is due to the increase in physical rather then chemical etch mechanism. The 10:3:2 etch mixture produced acceptable selectivities but, had a tendency to polymerize the resist surface. This resulted in the inability to remove the resist layer even with a forty minute O2 plasma ash. By reducing the O2 flow by only 0.5 sccm's, this problem was corrected, and

selectivities of the etch conditions were calculated.

Poly wafers were then imaged and stripped with; KTI820 photoresist, the GCA Wafer Stepper and an SF6:02 etch ambient. THe RIT Factory mask RIT-078-04-01W, NMOS Poly mask, was used to delineate the poly. The wafers were then coated with SOG as per the triple application method described above. The SOG was coated with resist and exposed with the stepper and RIT Factory mask RIT-078-05-01W, NMOS contact cut mask. This mask set was used due to the high contrast of the reticle (as compared to the EMCR 630 NMOS mask set) and the presence of small 4 micron square contact vias. THe hope was to fabricate contact via chains to measure the resistance and try and establish the process.

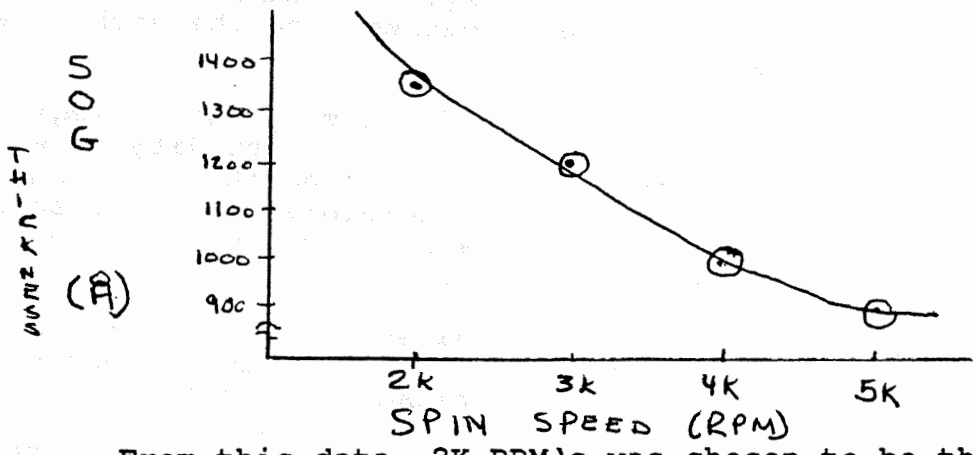
The final analysis was done by submitting wafers to the best wet and dry etch methods as per the prior investigation. Etch times were calculated using the etch rate data for the SOG. The wafers were then plasma stripped to remove the resist and inspected.

RESULTS/DISCUSSION

The very fist task of this experiment was to establish an accurate and reproducible gas delivery system. The existing column displacement flow meters were very inaccurate and insensitive. These crude flow meters were changed to Mass Flow Controllers and a Controller unit. This controller and all MFC's were zeroed and the flows were verified using a simple water displacement test.

A spin speed versus SOG thickness experiment for 20 secs was conducted, the results are plotted below;

Spin speed -vs- SOG thickness(20 sec spin)



From this data, 2K RPM's was chosen to be the spin speed of choice for the rest of the lab. This was based on the acceptable density and the greatest thickness. Thickness is important because as an interlevel dielectric, severe topography could be

the etch rate of the SOG increased. The reason for this could possibly be that the the former gas mixture produced a reaction mechanism very close the polymerization line of figure 1. Small deviations in the process could cause it to go either way.

The final etch profiles were investigated optically at 100X. The profiles of the 100:1 BHF etch were the best. With a 1 minute etch, at 3K/min , the originally square 4micron vias, were rounded and the diameters were increased to about 5.5 microns (measured using the Stage Micrometer and Filar Eye piece). Therefore, a 4 Um via chain seperated by 4 um's would still have 2 um's separation between vias. This is acceptable for the RIT NMOS process.

All plasma etch systems investigated exhibited large lateral etch rates. With the best being the 10 sccm CHF3, 3 sccm CF4 and 1.5 sccm O2. For a 3500A SOG layer, a 4 Um via chain would have the surface openings of consecutive vias touching. This would cause shorts in the deposited metal layer. However, the etch rate of this reaction was much slower and therefore more controllable for thin SOG etches.

SUMMARY

The effect of temperature of cure for ACCUGLASS 104 on etch rates was studied using both plasma etching systems and buffered hydroflouric concentrations. It was seen that a novel 600'c cure for 1 hour for the SOG produced high density pinhole free glasses. A CHF3/CF4/O2 gas mixture at a ratio of 10:3:1.5 was found to be the best plasma etchant. While a 100:1 buffered HF bath produced the best wet etching conditions. The wet etching process produced better image profiles, however the etch rate makes it unusable for thin SOG layers. The slower more isotropic plasma etch was well behaved in terms of etch rates and proved to be easily controlled. However, the profiles were far to degraded for thick film etching. In the future, this process could be optimized with the introduction of pure hydrogen sources, or the possibility of Reactive Ion Etching to increase anisotropy of image profiles.

ACKNOWLEDGEMENTS

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