

A comparison of BCB with Polyimide process in manufacturing HBT devices

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Abstract

This paper reports on the development of BCB (Bisbenzocyclopentene) process at Skyworks Solutions Incorporation - Sunnyvale facility. In this study, we have obtained very promising results demonstrating that the BCB process can readily replace the PI (Polyimide) process without significantly changing process design or reliability. Our study indicates that too much SF₆ will slow down the etch rate of the BCB, while higher chamber pressure will increase the etch rate and uniformity across the wafer. We also able to control the BCB profile by using different RF power levels. Proper adjustment in chamber pressure and RF power setting optimized our BCB process resulting in a very repeatable etch rate uniform and design profile.

Introduction

Throughout the semiconductor industry there has been many papers reporting the significant advantages of BCB (Bisbenzocyclopentene) over the PI (Polyimide). These many advantages include, a lower dielectric constant [1], a lower dissipation factor, reduced water absorption, a shorter cure time and a lower cure temperature. In addition to these improved dielectrics properties, the coating process with BCB has been found to produce a much more planarized layer [2] as opposed to our standard PI process.

Experimental

The profiles of the standard PI etch structure has been the key focus in our HBT design, however the reproducibility remains a sizable challenge. As the InP HBT technology within the industry continues to develop, the curing temperature for the planarization layer is required to be lower than the existing process without significantly changing the design etch profiles.

Taking this into account, an improved process was engineered and evaluated using BCB in an attempt to decrease the cure temperature. In our current HBT design, the PI process or BCB layer is sandwiched between 2 metal layers. It requires certain critical etch profiles to support the top metallic layer. The etch rate, etch uniformity and etch profiles of the BCB (Cyclotene 3022 Dow Chemical) were investigated by DOE methodology (DE-6 software), using RF power, chamber pressure and O₂ + SF₆ gas ratio as variables. An Oxford batch reactive ion etcher with a loadlock was used for this study. The chamber diameter is twelve inches.

Results and Discussion

Three series of experiments were carried out to study the effects of 4 factors (Power, Pressure, and the gases, SF₆ and O₂) with 3 responses (Etch Rate, Non Uniformity, and the Etch Profile) as can be seen in Table 1. The objective of the first 2 series in this study is to perform screening designs for model selection. On these 2 stages, experiments were conducted using blank GaAs wafers. The objective of the last stage is to confirm the prediction of these models and further optimize the processes on the wafers with multiple layers of structures.

Factor 1	Factor 2	Factor 3	Factor 4	Response 1	Response 2	Response 3
Power (W)	Pressure (mt)	SF6 %	O2 %	Etch Rate (A)	Non Uni. (%)	Profile
100	10	72	72	1718	0.19	--
100	80	8	72	2270	0.12	--
200	10	72	8	2505	0.18	78
200	80	8	72	3930	0.05	75
400	10	8	72	5434	0.09	55
400	80	72	8	1366	0.22	45
200	10	72	72	2519	0.16	86
200	80	8	8	2145	0.14	80

Table 1. Factors of DOE

In the case of both PI and BCB processes, the adhesion promoter was first spun, followed by the PI or BCB. The appropriate cure for the given material (280°C for PI and 250°C for BCB) was then completed. Upon evaluation of the DOE matrix we found that a higher SF₆ concentration in the SF₆+O₂ plasma will slow down BCB etch rate (see figure 1) while also producing significantly non-uniformity and steep etch profiles. An increase in the BCB etch rate was obtained by increasing the chamber pressure which also improved the etch uniformity across the wafer (figure 2, and figure3) and wafers to wafers.

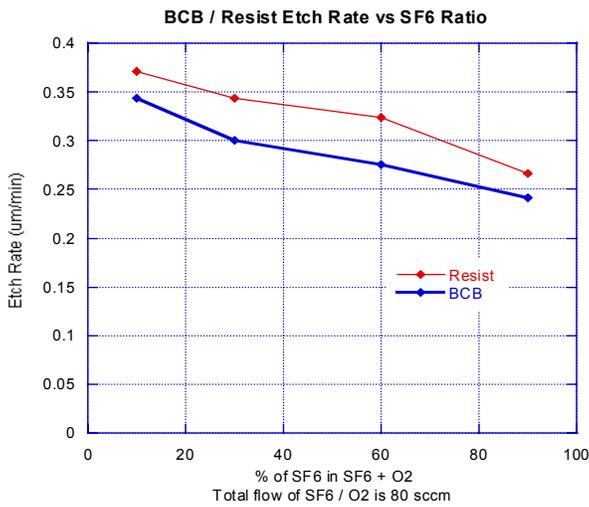


Figure 1. Etch rate of BCB and Resist as a function of percentage of SF₆ concentration in SF₆/ O₂ plasma

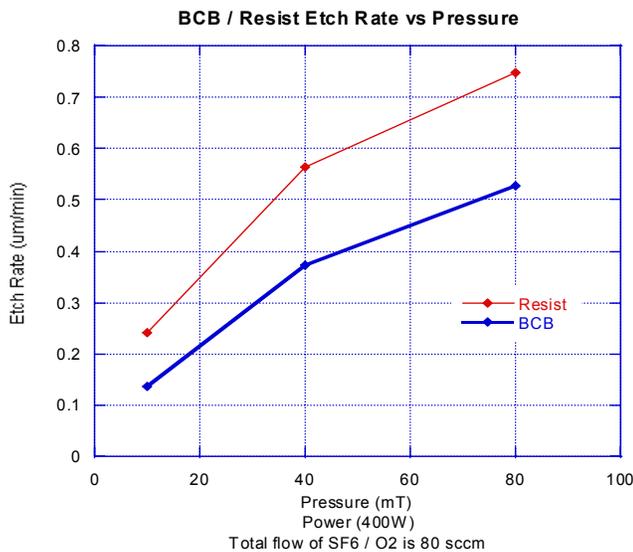


Figure 2. Etch rate of BCB and Resist as a function of chamber pressure at the constant power

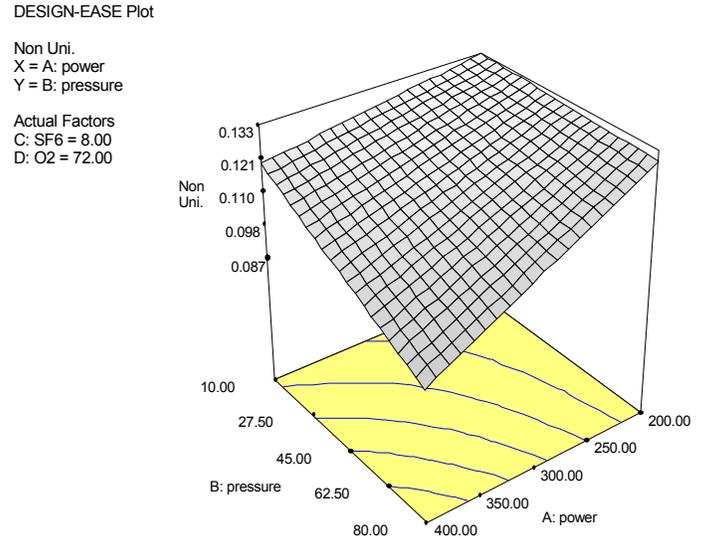


Figure 3. A design-ease plot to show the uniformity across the wafer at different power and pressure

In order to achieve the needed design profile, we found that the RF power played a very important role as different RF power levels affected BCB profile. When RF power was set too high, we noted a much too quick erosion in the resist resulting in a great deal of difficulty in controlling the BCB profile (figure 4). Conversely, a much lower RF power setting produced an odd BCB shape (figure 5). With average RF power and high chamber pressure, we achieved the design profile with repeatability uniformity across wafer and wafers to wafers.

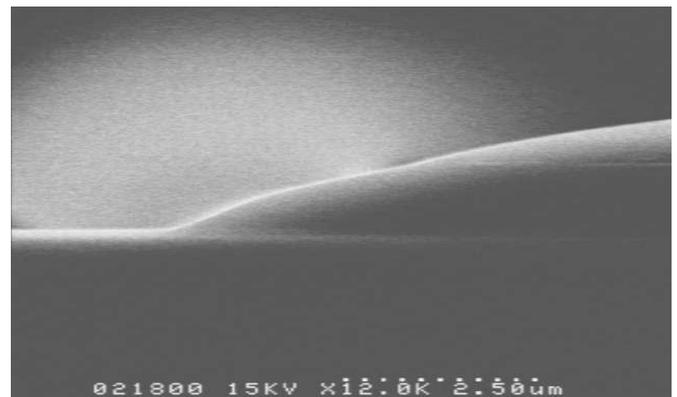


Figure 4. A SEM picture of BCB profile at high RIE power



Figure 5. A SEM picture of BCB profile at low RIE power

We determined a number of optimal process conditions with which we produced a quantity of multiple layered structured prototype wafers. An autoclave (121°C / 100%RH) test on the individual die was then performed to study overall device function and reliability. The results indicated that the device failure rate of the BCB process was less than that of the standard PI process. The DC burn-in Test also confirmed that the BCB process does not detrimentally affect the lifetime of the device (figure 6). More extensive tests are being conducted to confirm these preliminary findings.

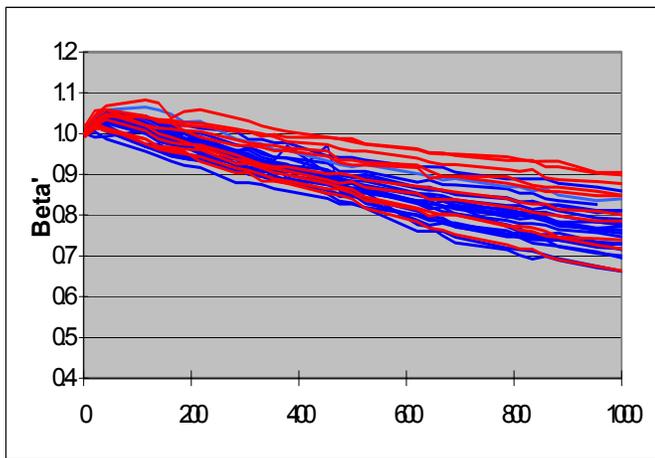


Figure 6. Beta drifts of BCB and PI coated devices vs time at bias 3.3V and 25 KA DC burn-in test

Summary

We have obtained very promising results demonstrating that the BCB process can readily replace the PI process without significantly changing process design or reliability. With the same DOE methodology, we were able to achieve the desired etch profile with excellent uniformity at high RF power with a high chamber pressure recipe. Proper adjustment in chamber pressure and RF power setting optimized our BCB process resulting in a very repeatable and uniform process that has all the dielectric advantages that BCB has to offer while enjoying a lower cure time and temperature.

Acknowledgements

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References

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