RIE PLASMA ETCHING OF GaAs IN $SiCl_4$ and CCl_4 GASES WITH DIFFERENT RESISTS AS ETCH MASKS

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1. Introduction

Etching of substratesfor microelectronics in chlorine plasma requires masking materials (resists) with both high etch resistance as well as with good sensitivity[1]in lithographic processes.We have chosen several commonly used resists which we tested in CCl_4 and $SiCl_4$RIE plasma[2]. As a substrate material for these tests we used GaAs.In the tests with CCl_4plasmawe examined eight types of masking materials (Tab. 1and Fig. 1), including a polyimide (PI 2525). However, only for five masking materials reasonable etch rates (E.R.) have been achieved. In the tests with$SiCl_4$plasmawe concentrated on twelve different resists (cf. Tab. 2 and Fig. 1).The decrease of resist thickness was measuredby profilometric measurements (AlphaStep).

2. Experimental part

RIE etching in CCl_4 plasma

The masking resist layers were spin-coated and patterned by using the EBDW lithography on the ZBA 21 (20keV, *Carl-Zeiss, Jena*; currently *Vistec, Ltd.*)variable shaped e-beam pattern generator in II SAS.In order to optimize the etching process it was necessary to estimate the

Resist type	**Thickness** before etching [nm]	**Thickness** after etching [nm]	**Total etched thickness** [nm]	**E.R.** [nm/min]
AZ 5214E	955	848	107	26.75
HSQ FOX-25	1141	912	229	57.25
SU-8 2002	510	392	118	29.50
UV-5	628	512	116	29.00
PI 2525	2668	529	139	34.75

Table1:*Etch ratesof selected resists (and a polyimide) in CCl_4plasma.*

resistance (etch-rates) of the resist layers. The etch-rates of the selected resists etched in CCl_4 plasma are shown in Table 1.
The PI 2525 polyimide is mentioned for its good etch-resistance, however its sensitivity was not sufficiently suitable.In these experiments the material with the lowest E.R. was the image reversal(IR) photoresist AZ 5214E, and the resist with the highest E.R. turned out to be the HSQ FOX-25. The ma-N and ARN 7520 resists (not shown in the table) degraded in the plasma

so that their structure was changed after RIE and their final thickness after the etching was even higher than that before the etching.With the AZ 5214E resist some problems occurred during its removal after the RIE inCCl_4.

RIE etching in SiCl4 plasma

In order to estimate the E.R. of the resists in $SiCl_4$ plasma, we have chosen twelve resists listed below. The viscosity of some of them was very low (ma-N 2410, XR-1541-006, PMGI SF 2) and thus also their coated thickness; that is why they were etched only for a short time (3 min).The results of the etching are summarized in Table 2. Out of these resists the lowest E.R. was achieved with the XR-1541-006 and ma-N 2410 resists, while the highest E.R. was achieved with the ma-N 1420 resist.

Resist type	**Thickness** before etching [nm]	**Thickness** after etching [nm]	**Total etched thickness** [nm]	**E.R.** [nm/min]
ARN 7520	546	494	52	17
AZ 1514 H	1720	1665	55	18.3
AZ 5214 E	1082	1082	-	-
HSQ FOX-25	1131	1106	52	17
ma-N 1420	2120	2010	110	36.6
ma-N 2405	503	451	52	17
ma-N 2410	309	292	17	11.3
PMGI SF 2	69	44	25	16
PMMA	1199	1093	106	35
SU-8 2002	520	484	36	12
UV-0.8	895	722	73	24
XR-1541-006	151	141	10	6.6

Table2: *Etch rates of selected resists in $SiCl_4$ plasma.*

In the following analysis we will concentrate on the ma-N 2405negative-tone e-beam resist (by *MicroResist Technology*) which turned out to be a sensitive resist with good etch resistance, andwith which we achieved a 300-400nm periodof the patterns. It is a resist reported to have a high wet and dry etch resistance, good thermal stability, which is useful as a mask for etching various materials and as well as an easy-to-remove resist [3].

3. Results and Discussion

Figure 1 shows a comparison of the etch rates of selected resistsin $SiCl_4$ and CCl_4 plasma.

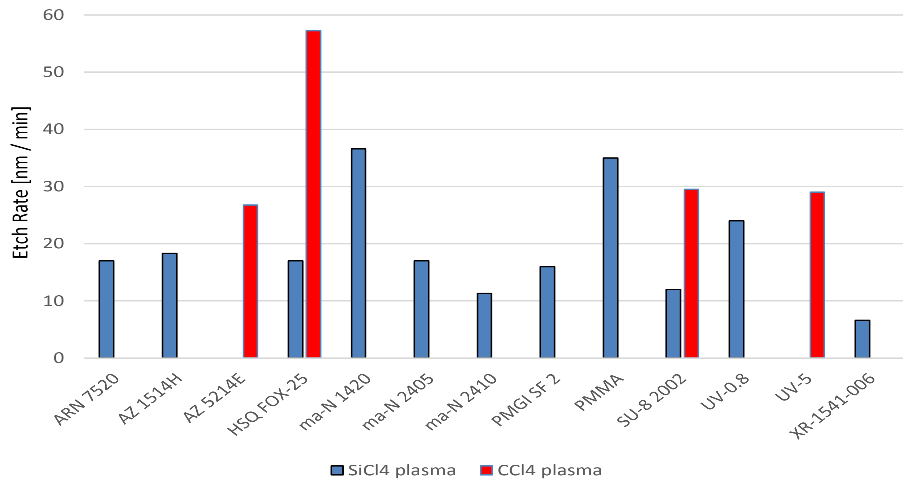

Fig.1: *Comparisonof the etch rates in $SiCl_4$ and CCl_4plasmafor selected resists.*

The ma-N 2405 resist was spin-coated ontoGaAs substrate and patterned. As developer, ma-D525was used for 60s, then the resist was rinsed in water for 60s. The nominal thickness of the resist was 503nm. The resist was subsequently RIE etched in CCl_4plasma (0.8Pa, 100W, 4 min) in order to examine its etch-resistance. As can be seen in Figure 2 (left), this resist degraded in CCl_4 plasma and could not be removed in combination of O_2 plasma (for 30min) and acetonestripping(Fig. 2, right). The same phenomenon was observed also with other investigated ma-N and AZ series resists.

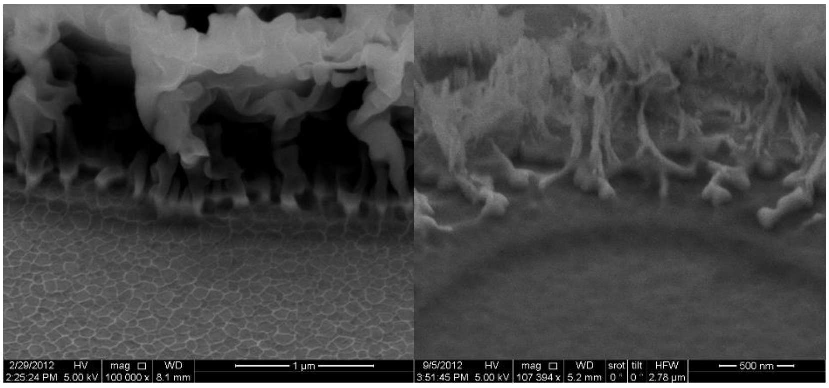

Fig.2: *SEM picture of ma-N 2405 resist etched in CCl_4plasma. Left: resist degradation; right: remnants of the resist after O_2 plasma and acetone stripping.*

The RIE of the ma-N 2405 in $SiCl_4$plasma (2Pa, 40W, 3min), however, showed nice results, as can be seen in Figure 3 (on the left: 700nm lines, on the right: ~1.2µm dot; etch depth ~70nm).After an hour in acetone there were no residuals of the resist left on the surface of the etched patterns. Similar quality of the patterns after the RIE in $SiCl_4$ was also observed with other investigated resists.

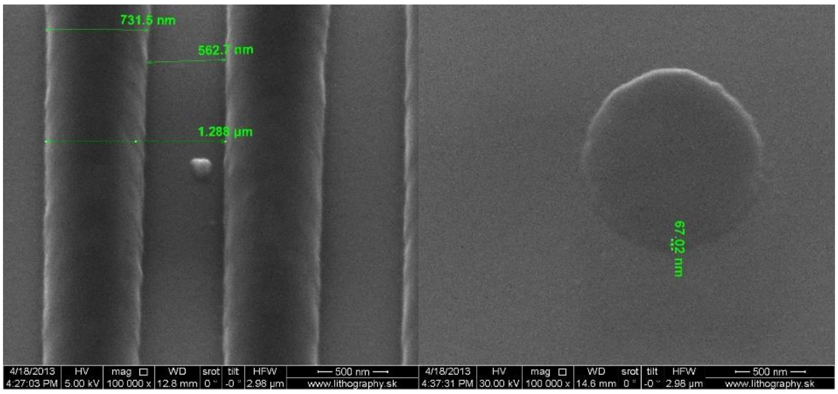

Fig.3: *SEM picture of ma-N 2405 resist etched in $SiCl_4$plasma.*

4. Conclusion

Several chosen resists were examined in order to find their etch-resistance in both CCl_4 and $SiCl_4$ plasma. It has been shown that the etch quality depends on the quality of the resist layers.Most of the investigated resists showed bad quality after the RIE in CCl_4 plasma. On the other hand, the $SiCl_4$ plasma turned out to be more suitable for etching of GaAs through resist mask layers with nicer results achieved. After the RIE in $SiCl_4$ the resists could easily be removed in acenone and O_2 plasma leaving no resist residuals.

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References

[1] K.R. Williams, K. Gupta, M. Wasilik, Etch Rates for Micromachining Processing II. *Juornal of MEMS*, 12, 6 (2003) 761-778.

[2] *Negative e-beam resists as masking layer in dry etching of semiconductor thin films*, Internal Technical Report 2014-25-1, UISAV, Bratislava.

[3] *ma-N 2400 series Product Data Sheet*. www.microresist.com