

# CHARACTERIZATION OF SOLID SOURCE PHOSPHORUS DOPING DIFFUSION

by

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## ABSTRACT

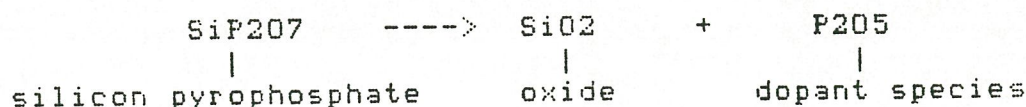
Phosphorus solid sources for doping of silicon wafers were characterized by keeping the temperature constant and varying the diffusion time. Sheet resistances and junction depths were measured using a four-point station and the groove and stain method, respectively. The results were contrasted with the SUPREM II predictions.

## INTRODUCTION

There are several methods used to achieve phosphorus doping (n-type) of a silicon wafer: phosphorus gas sources, ion implantation, spin-on sources, and solid sources (1). The method presently used at RIT involves spin-on sources, which are more cost efficient and less hazardous compared to gaseous sources. Solid sources, which are fairly new, may even be better.

The advantages in using solid sources are ease of handling, better uniformity on larger diameter wafers, no capital expense to convert system, and decreases manufacturing downtime, mainly tube maintenance. The two main disadvantages in using solid sources are storage of the wafers and pre-fabrication process predictions, such as SUPREM II modeling. Lack of moisture is the most important item in storing the solid sources. There are various methods of storage. One is a "dry box" where the bottom of a sealed container contains a dessicator and a dry nitrogen ambient is maintained. The second method is to store the sources in a dry nitrogen ambient @ 475 - 700 C. These two methods are good if the sources are used on a regular basis. The other problem presents more difficulties. To predict the sheet resistance and the junction depths, SUPREM II, a modeling program, was used. The problem with this is that the SUPREM II output is based on gaseous sources, not solid sources.

Phosphorus solid sources were used in this experiment. There are no corrosive or toxic materials since the only by-product is SiO<sub>2</sub>, which stays on the source wafer. (2)





## EXPERIMENTAL

The planar diffusion sources used were PDS Phosphorus PH-1025 n-type.++ The silicon wafers were Wacker, p-type, 3 inch (111) wafers with a thickness of 500 microns. The initial resistivity was 10-20 ohms-cm.

The source wafers were annealed at 1000 C for 4 hours. This is done to activate the source prior to the diffusion process. A single diffusion process was used which is outlined in Appendix I and summarized as followed. The temperature was kept constant at 1000 C for 15, 30, 45 and 60 minutes. A constant flow of nitrogen was used to prevent any back flow of contaminants, from the clean room, into the diffusion furnace. The storage of the sources was not a problem because they were only used for brief intervals. Therefore the source wafers were stored in a wafer box and re-annealed before each use.

The four-point probe was used to obtain sheet resistance. The measurements were taken at five different points on the wafer to check uniformity. The junction depths were obtained by using a Sigatone Model S-1100 Automatic Angle Lapping Machine.(3) The stain used was the "orange" version of Saf-T-Stain by Philtec Co.(4)

## RESULTS/DISCUSSION

The data in Table 1 shows the uniformity of the sheet resistance across the wafer for the various diffusion times. The standard deviation is lower at the intermediate times, but it is hard to determine if this is a valid point with just one run.

The comparison of SUPREM II predictions and the experimental values can be observed in Figures 1 and 2. The curves follow the same trend with a slight deviation. When this data was used on the Irvin graph the surface concentration,  $N_{sur}$ , was approximately the same for both the SUPREM II and experimental results. ( $N_{sur} = 1e21/cc$ ) The graphs show that the trend is there but some fine tuning of SUPREM II must still be done.

++ Donated by      Standard Oil  
                      Engineered Materials Company  
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                      Niagara Falls, N.Y. 14302

Fig. 1

COMPARISON OF SHEET RESISTANCES

— — SUPREM

— Solid Source

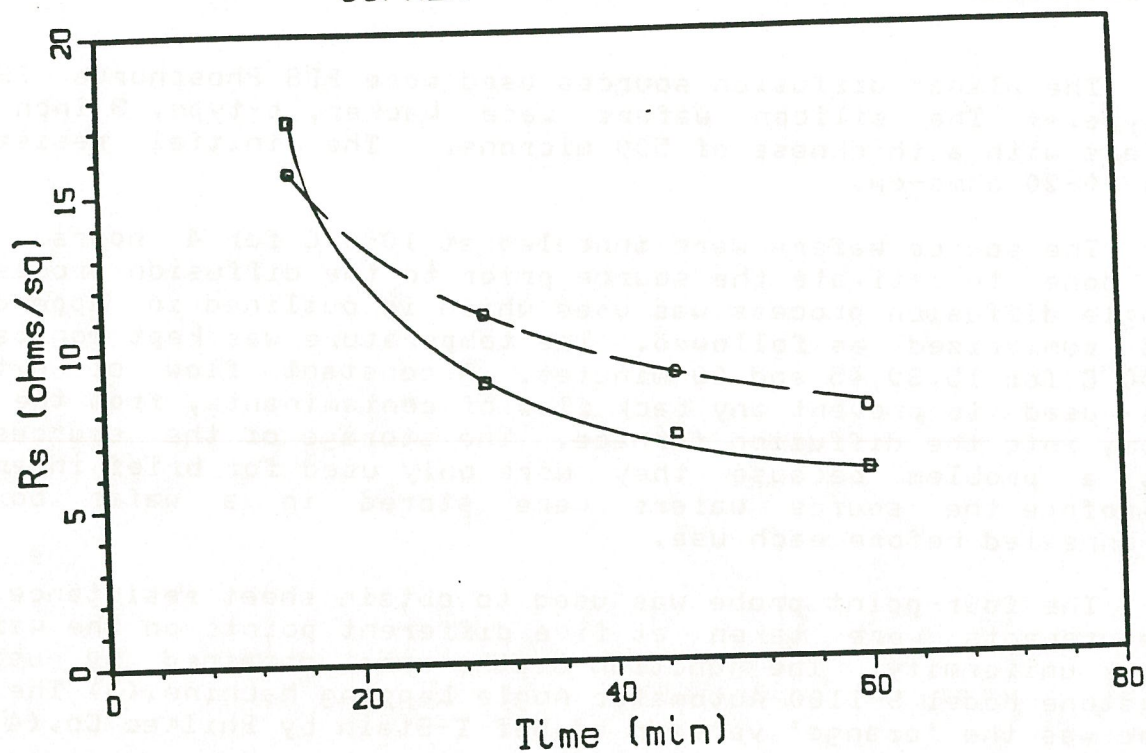
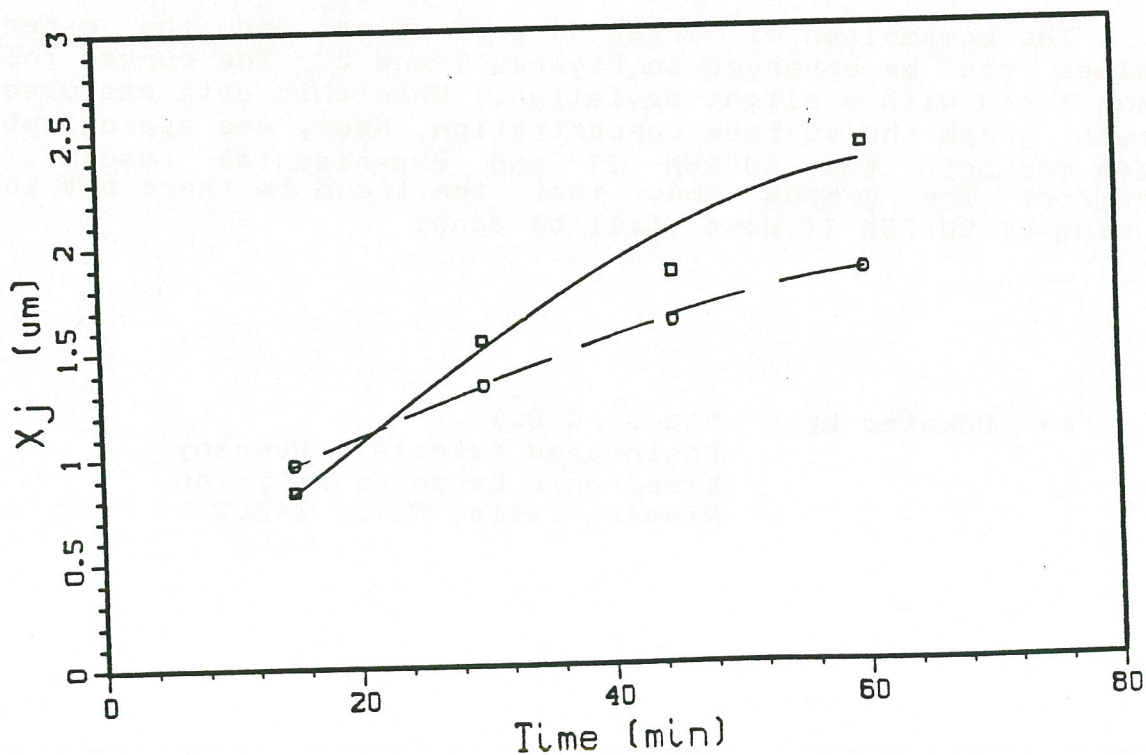


Fig. 2

COMPARISON OF JUNCTION DEPTHS

— — SUPREM

— Solid Sources





Wafer	Diffusion Time	Resistivity (initial)	Rs(diffusion)		Xj (u)
A) 1	15 min	12.55 ohm-cm	17.58		
2	.	.	17.49	mean 17.26	
3	.	.	17.21	SD .27	0.84
4	.	.	17.08		
5	.	.	16.94		
B) 1	30 min	11.30 ohm-cm	8.83		
2	.	.	8.88	mean 8.85	
3	.	.	8.83	SD .05	1.54
4	.	.	8.79		
5	.	.	8.92		
C) 1	45 min	13.04 ohm-cm	7.02		
2	.	.	7.07	mean 7.10	
3	.	.	7.16	SD .07	1.85
4	.	.	7.20		
5	.	.	7.07		
D) 1	60 min	13.49 ohm-cm	5.66		
2	.	.	5.93	mean 5.89	
3	.	.	6.02	SD .15	2.44
4	.	.	6.02		
5	.	.	5.84		

TABLE 1 - Experimental data of sheet resistance and junction depths

## CONCLUSION

A further study of planar sources must be done to accurately evaluate the data and compare it to SUPREM II. The data obtained in this experiment combined with future data will give a better understanding of what happens in the phosphorus diffusion using solid sources. If a correlation between SUPREM II and the planar sources can't be found, all is not lost. The graphs of sheet resistance and junction depths could be used to determine a diffusion process.

## ACKNOWLEDGMENTS

The author would like to thank Jim Dalcin and John Tworek of Standard Oil Engineered Materials Company for donating the diffusion sources, quartzware and source literature. They were also very helpful in answering all my questions. I would also like to thank M. Jackson for his valuable advice and support.

## REFERENCES

1. "Solid Source Phosphorous Doping", K. Wolf Jr., SOHIO Carborondium Co., Nov.1986
2. "PDS Phosphorous PH-1000N n-type Planar Diffusion Source" Form A-14,041, Nov., 1985, The Kennecott Corporation
3. "Signatone Model S-1100 Automatic Angle Lapping Machine" Signatone Corporation
4. "Saf-T-Stain", Philtec Instrument Co.

## APPENDIX I

## PROCEDURE USED:

- 1) all wafers will go through an initial cleaning step:
  - RCA clean
- 2) Prepare all wafers for solid source method of diffusion
  - this is done by placing the solid source wafers in the specially designed boat that was supplied with the solid sources. Place the boat in the N-type diffusion furnace @ 1000 C for 4 hours (PH-1025) with nitrogen flowing at 2.5 slpm.(2)
- 3) Diffusion
  - each lot will have a drive-in temperature of 1000 C but times will vary.
    - 1 for 15 min
    - 1 for 30 min
    - 1 for 45 min
    - 1 for 60 min
- 4) Four-point probe all wafers
  - before doing this, dip the wafers in buffered HF to remove any oxide.
- 5) Groove & stain
  - the groove time used was 8 minutes, the stain was activated while looking at the groove-n-stain under the microscope.