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Short Title of Work:	

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NVL Summary

13 Nov 83

Plasma Passivation of Selected MCT Samples

PRELIMINARY COMPARISON by EER Analysis

Included are summary reports and data for similar plasma oxides grown on x=.32 LPE p-type, x=.295 bulk n-type, and two x=.2 LPE n-type. Also included is each samples detailed descriptive data. Results are given in the format of X (composition), gamma (related to crystal quality), and theta (related to carrier concentration.

Summary:

1. Mercury depletion of the plasma oxidized surface region (first 600Å) appears to be common to all samples except 3b which was much more defective (gamma erratic and layer average value is 160). Here the surface of the bulk sample, 2, is shown to be the most impoverished.

Sample			Composition X			Epilayer/Substrate
No.	Variety	Type	Surface (<600Å)	Near Surface (>600A to 3000Å)	Bulk (>1μm)	Interface Width, μm
* 1	LPE	p	.29	.28	.32	5
2	Bulk	n	.37	.29		-
* 3a	LPE	n	.20	.16	.20-.25	2
* 3b	LPE	n	.14	.18-.20	.20-.22	3

* Show "usual" Hg enrichment of the surface in LPE materials.

2. (See enclosed gamma vs depth plots.) Damage at the plasma MCT interface appears similar to that throughtout the surface region, first μm. That is, gamma in the surface region is 140 to 170 with a bulk value of 130 except for sample 3b where bulk and surface value is erratic from 140 to 170.

3. Theta with respect to type (0-n type, ¶-p type)

No.	Sample Variety	Type	Surface	Theta, Radians Near Surface	Bulk
1	LPE	p	2(type masked)-------------------		2.5(masked or tends to p)
2	Bulk	n	†0(n-type)	1.5(type masked)-----------------------------	
3a	LPE	n	†0(n-type)	2.2(type masked)	2.5(masked or tends to p)
3b	LP	n	1.5(type masked)	2.2(type masked)	1.5 to 2.7(erratic)

† Seem to have a low enough defect content to exhibit the effects of oxide passivation.

Tentative Conclusion:

Composition: Plasma deposition may induce Hg depletion within the oxidized region.

"Bulk region of LPE sample #1 could be considered state-of-the-art."

"The lateral uniformity of sample #2 was found to be uniform in composition to within $\pm$ .015 which is clearly better than the stated $\pm$ .05."

Damage: "The only thing that can be said is that plasma deposition has not introduced more damage than was already there."

Type: Unambiguous determination of type by EER at room temperature may have been obtained for samples 2 and 3a only perhaps because of positively charged interface effects masking charge defects to EER.

Recommended Follow Up: Provide for similar EER comparison sections from single bulk and Epi samples in which each has had the following treatment.

Section 1, as received.

Section 2, least defect generating surface treatment.

Section 3, plasma oxide after surface treatment.

Section 4, wet anoidzation after surface treatment.

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SAMPLE DATA

Plasma Conditions: 60 watts RF power
+40 VDC sample bias
.5 torr O_2

Samples:

#1 488Å Plasma oxide on LPE
6 min. growth time
Rockwell #5-271B LPE - (111), $\lambda = 3.87$ μm, 25-28 μm thick
p-type, $4.8 \times 10^{16}/cm^3$ @ 77K
mobility $238 cm^2 v^{-1} s^{-1}$ @ 77K
$x = .32 \pm .01$ (by EER)

#2 445Å Plasma oxide on Bulk
5 min. growth time
Cominco #15(321)-10B - (111), Bulk
n-type, $-2.7 \times 10^{15}/cm^3$ @ 300K
$-1.7 \times 10^{14}/cm^3$ @ 77K
mobility $5.6 \times 10^3 cm^2 v^{-1} s^{-1}$ @ 300K
$6.4 \times 10^4 cm^2 v^{-1} s^{-1}$ @ 77K
$x = .295 \pm .05$

#3 a 237Å Plasma oxide on LPE
2 min. growth time

b 363Å Plasma oxide on LPE
6 min growth time
Fermionics #4318 LPE - (111), $\lambda = 12.5$ μm, 20 μm thick
n-type, $-1.1 \times 10^{14}/cm^3$ @ 77K
mobility $1.4 \times 10^5 cm^2 v^{-1} s^{-1}$ @ 77K
$x = .2$

Quarterly Progress Report for the First Quarter, April - June, 1983

NVL # DAAK 70-83-K-0047

Report of N.V.L. Sample 1, 2, 3A, and 3B

Complete Report Prepared by

Dr. Paul M. Raccah

FINAL REPORT ON N.V.L. SAMPLE # 1

Prepared by Pr. Paul M. Raccah

Technical Program Manager :

Dr M. Martinka

PRELIMINARY INFORMATIONS

Preliminary informations on this sample are limited to the fact that it is an L.P.E. material and that 488 Angstroms of oxide have been plasma deposited on it.

RESULTS AND DISCUSSION

Our results are presented hereafter in six consecutive figures. These are subdivided into two groups of three, the first group presents the results pertaining to a high resolution profile in the neighborhood of the interface and the second group deals with the normal resolution profile of the entire epilayer. In both cases X , Γ , θ vs. depth are presented in succession.

Here again the high resolution composition profile shows that there has been a Hg depletion of the surface albeit not as extreme as in the case of sample 2. It could be that the usual Hg enrichment of the surface in L.P.E. materials has compensated for the loss imposed by the plasma deposition. Also, as can be seen in figure 2, here again, there does not seem to be anymore damage at the interface than anywhere else. Finally the average value of θ hovers around 2 as always for L.P.E. materials. Hence the minority carriers type is masked by the strong interaction of the thermalized electrons and holes.

The Hg enrichment in the first 5 μ in figure 4 is no surprise and is usually associated with growth termination in L.P.E. materials. In the bulk region the material is reasonably well behaved and could be considered state of the art with an average composition $X = 0.32 \pm 0.01$. The substrate/epilayer

interface region is about 5μ and is larger than in materials where a non-contact polish method has been used. As shown in figure 5 the linewidth does not change much in the bulk of the material but is higher both near the surface and at the substrate interface. The latter is consistent with poor substrate surface preparation. Finally figure 6 shows that over most of the bulk region the value of θ is close to π and therefore the material would tend to be p-type. However charge interface defects generate a region around 26 μ which is almost n-type.

CONCLUSIONS

This material is a fairly typical L.P.E. material, with the usual Hg enrichment of the surface, and is too imperfect to lend itself to an accurate analyzis of the physics of plasma deposited oxides. In particular the effect of the oxide/epilayer interface charges cannot offset the interaction of thermalized electrons with the associated holes. This effect was observed in sample 2 but cannot be seen here because of the excessive density of ***defects. The only thing that can be said is that Plasma*** **deposition has not introduced more damage than was already there.**

SAMPLE N.U.L. #1 DEPTH VS. % AT TOP OF LAYER

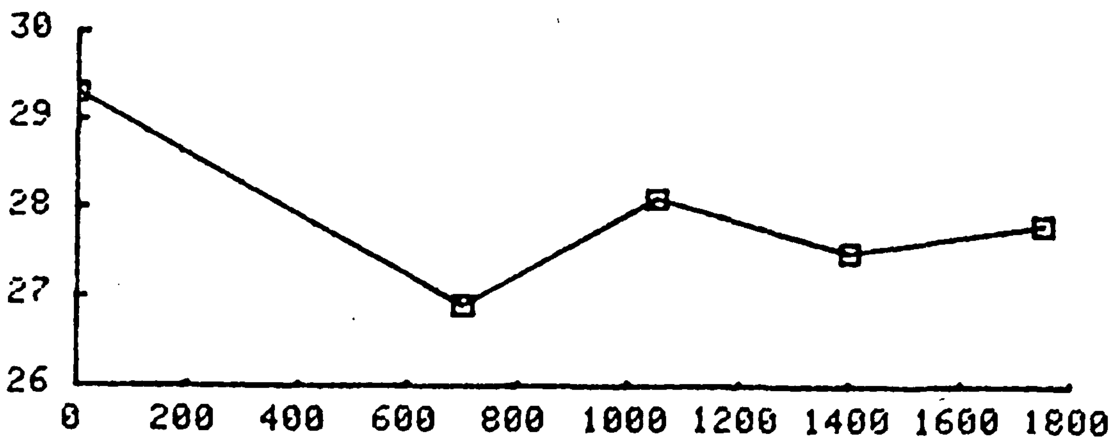

Figure 1

SAMPLE N.V.L. #1 DEPTH VS. GAMMA AT TOP OF LAYER

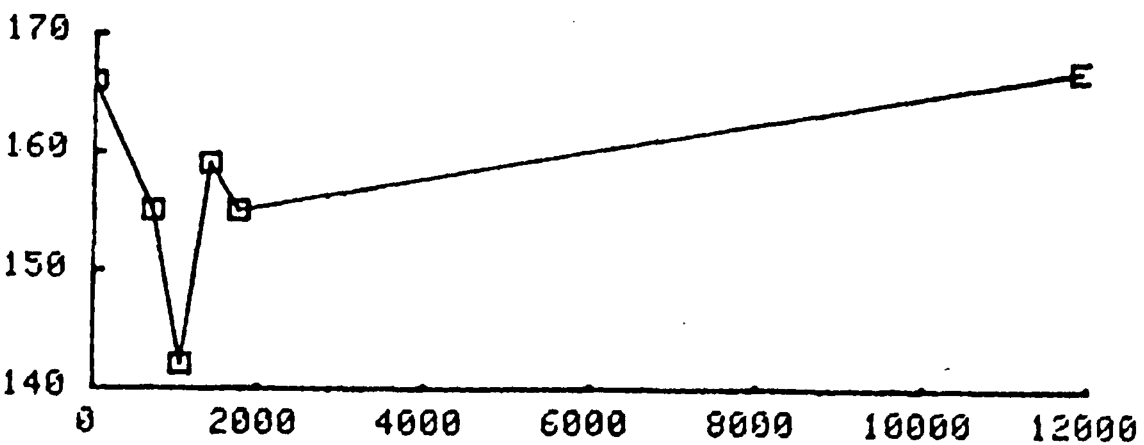

Figure 2

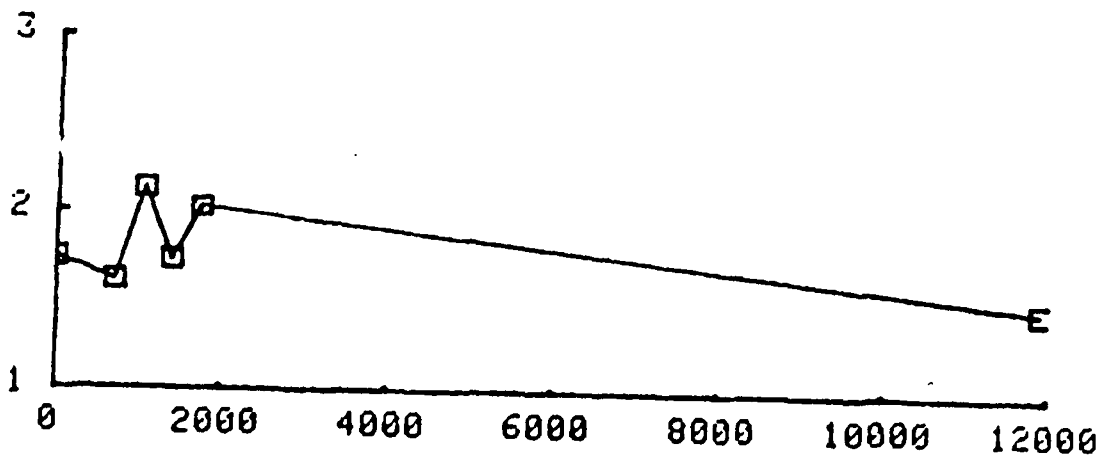

Figure 3

SAMPLE N.V.L. #1 DEPTH VS. X / TOTAL PROFILE

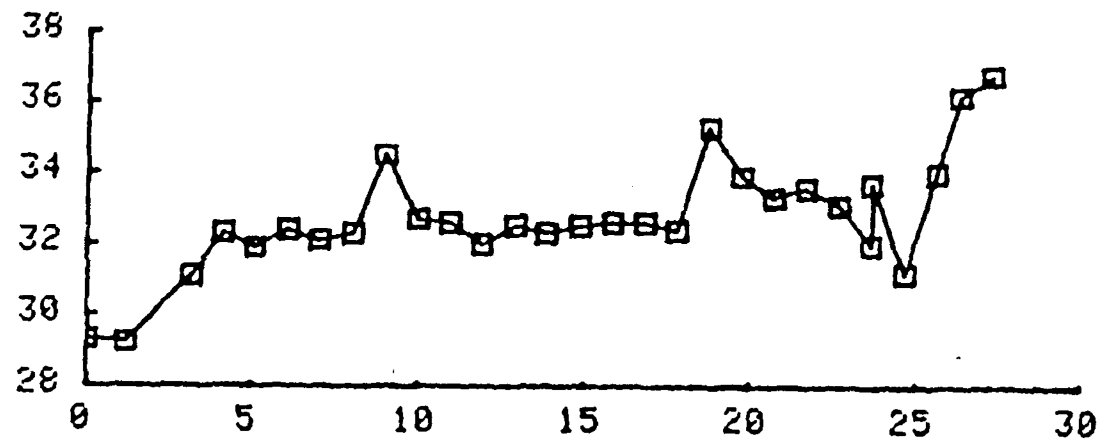

Figure 4

SAMPLE N.V.L. #1 DEPTH VS. GAMMA / TOTAL PROFILE

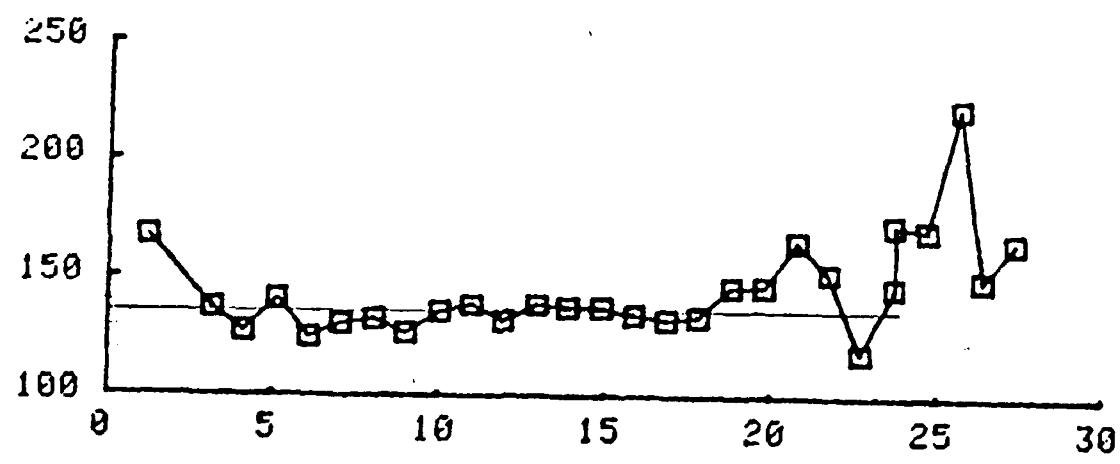

Figure 5

SAMPLE N.U.L. #1 DEPTH VS. THETA / TOTAL PROFILE

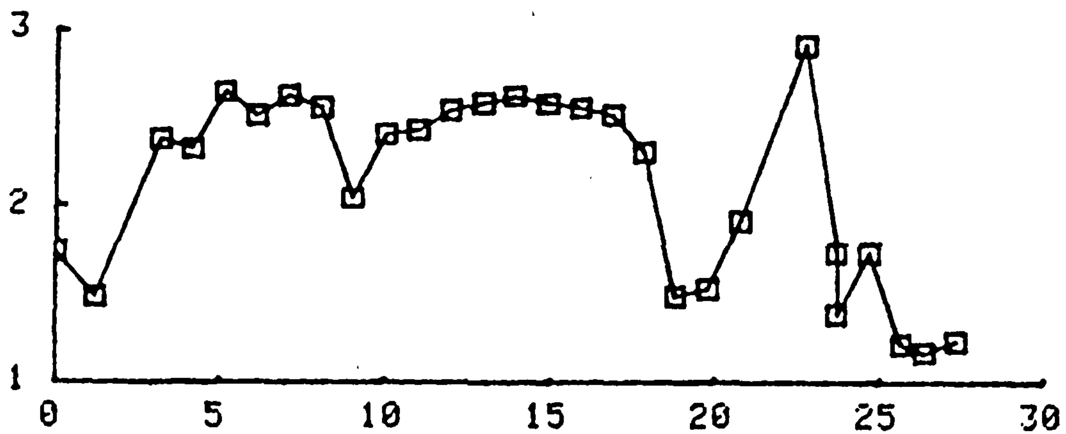

Figure 6

SAMPLE N.V.L. # 2

Complete Report prepared by

Pr. Paul M. Raccah

Technical Program Monitor

Dr. M. Martinka

PRELIMINARY INFORMATIONS

Sample #2 is a bulk sample with nominal composition X reported to be equal to 0.295 ± 0.05. It is n-type and has a carrier concentration at room temperature N = -2.7×10^{15}

RESULTS AND DISCUSSION

The lateral uniformity of the sample was first checked and it was found to be uniform in composition to within ± 0.015, which is clearly better than the stated nominal uniformity.

The purpose of our measurements was to study the interface between the material and the plasma deposited oxide. The results shown in figure 1 indicate clearly that the interface has been impoverished in Hg since the value of X is 0.37 compared to an average value of 0.29 ± 0.01 in very good agrement with the reported composition. The depth of the impoverished region is less than 600 Angstroms.

The results shown in Figure 2 display Γ in function of the depth. It is clear that the value of Γ is not larger at the interface than it is at 3000 Angstroms and therefore that *there is no more damage at the interface than anywhere else.* On the other hand the average value of Γ is clearly excessive and the surface of this bulk material is not state of the art. It seems that it was not prepared with sufficient care to remove "as received " damages. Further evidence can be found in figure 3, where θ is displayed in function of depth. The average value is

 almost exactly π/2 except at the surface where it is zero, consistently with the reported type .

This last fact is most interesting since the material seems to be normal at the interface where one would anticipate the maximum of damages. The explanation is that the surface of this particular wafer was damaged prior to the plasma deposition and, as stated earlier, the damage was not sufficiently removed. The plasma deposited oxide has a positively charged interface and it is the field from these charges which in the immediate neighborhood of the interface compensate the for the effects of the charged defects and masks them to electroreflectance. *This is consistent with the common experience that oxide passivation decreases surface recombination etc...* . According to these results this is not because of the removal of damages but because the interface charge minimizes charged defects scattering.

CONCLUSIONS

Even though the surface of this sample does not seem to have been optimally prepared the effects of oxide passivation seem to have been achieved. *The plasma deposition of the oxide does not generate any more defects than was already present* . It would appear logical to prepare another sample in the same fashion but with a better preliminary surface treatment and to compare it to a sample treated similarly but where the oxide would have been deposited by the more conventional anodic method.

SAMPLE N.V.L. # 2 DEPTH IN ANGSTOMS VS. COMPOSITION %

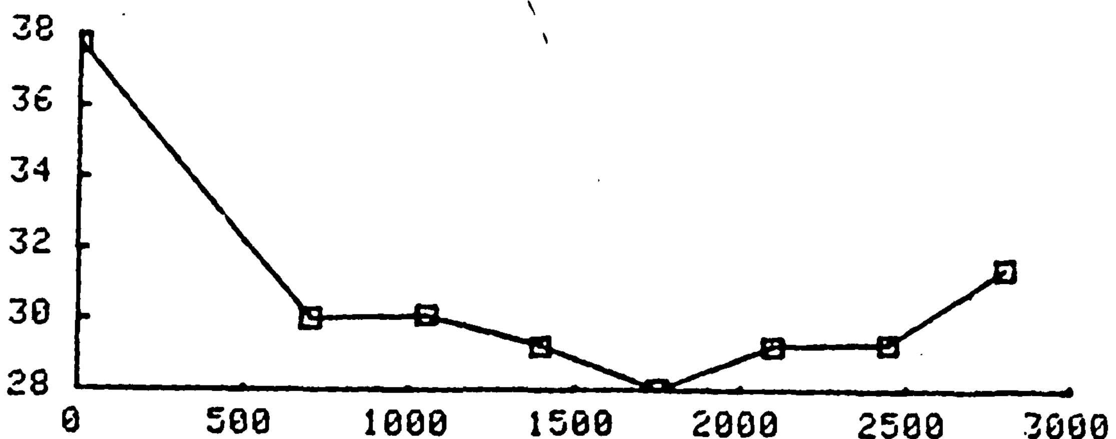

Figure 1

SAMPLE N.V.L. # 2 DEPTH IN ANGSTROMS VS. GAMMA IN MVS

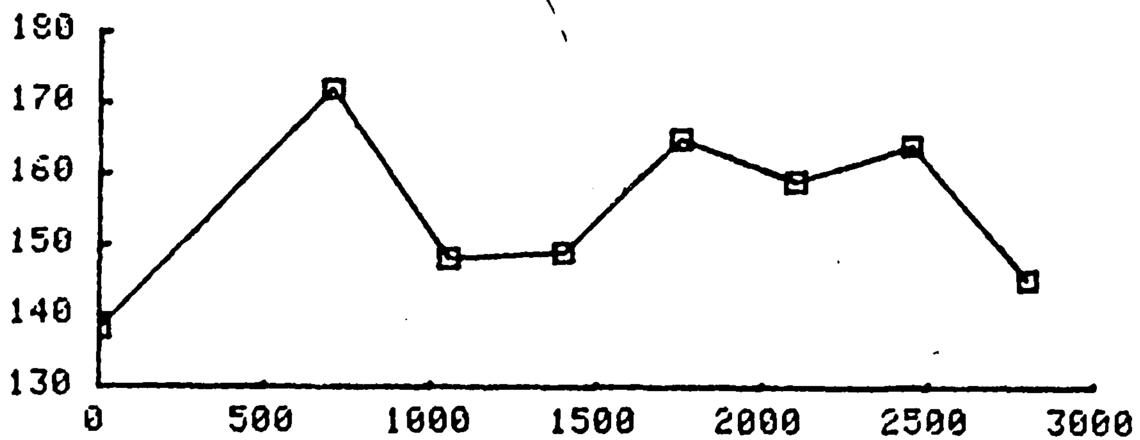

Figure 2

SAMPLE N.V.L. # 2 DEPTH IN ANGSTROMS VS. THETA

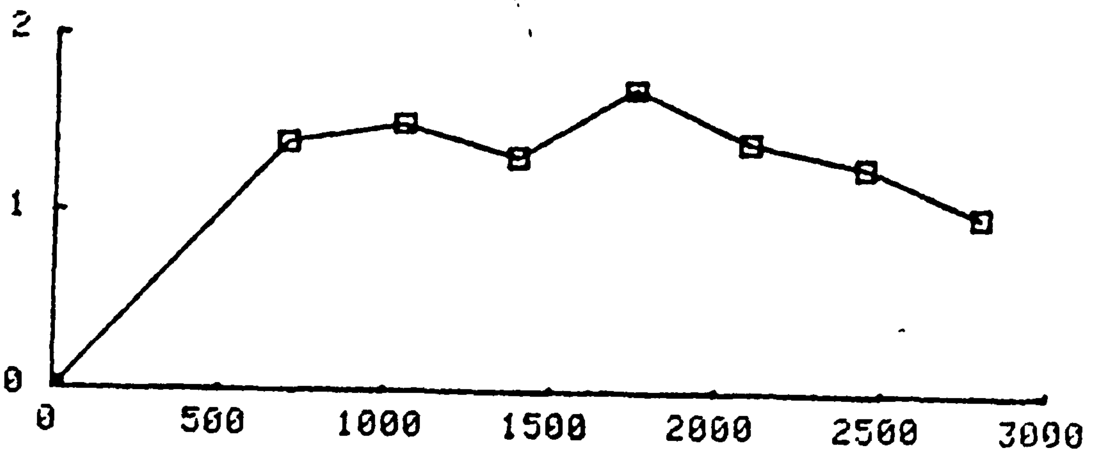

Figure 3

FINAL REPORT ON N.V.L. SAMPLE 3A

Prepared by Pr. Paul M. Raccah

Technical Program Monitor

Dr. M. Martinka

PRELIMINARY INFORMATIONS

Sample #3A is an L.P.E. material nominally n-type. It has received 237 Angstroms of plasma deposited oxide while two other samples from the same wafer, sample #3B and sample #3C, have received 363 and 188 Angstroms respectively. This sample is therefore the one with the intermediate oxide thickness.

RESULTS AND DISCUSSION

Here again our results are presented in six figures subdivided into two groups of three. The first group presents a high resolution depth profile in the neighborhood of the oxide/epilayer interface while the second group presents a normal reasolution depth profile of the entire epilayer. In each case the order of presentation is X , Γ and θ .

The first figure shows that while the first ½ μ of the layer is Hg enriched the immediate surface is clearly depleted, confirming that plasma deposition induces Hg depletion over a depth of about 500 Angstroms. A comparison of figure one with figure 4 shows that the low X values ($X \approx 0.16$) reached between 0.1 and 0.3 μ are significantly lower than the bulk average in this region. This result seems to indicate that the plasma deposition drives the Hg inward generating a Hg accumulated region adjacent to the Hg depleted region at oxide/epilayer interface.

The second figure shows, one more time, that *the plasma deposition has not introduced new damage.* The third figure, on

the other hand, clearly shows that the reported n-type of the material prevails only at the immediate oxide/epilayer interface while in the rest of the depth of the layer the material appears to be of mixed conduction type. It does show, however, that the type is unmasked , by the interface charges , at the interface oxide/epilayer.

Turning now to the results describing the properties of the entire layer we see in figure 4 that composition control is insufficient. The composition reaches a maximum of $X = 0.25$ around 6 μ and decreases on each side to $X = 0.20$. This accident is not associated with a corresponding accident in the linewidth, indicating that it is due purely to poor control of the growth parameters and not to defects mediated diffusion. The fifth figure shows, here again, that the linewidth is fairly constant throughout most of the layer indicating that the defect density is essentially uniform and not too high (≈ 125 meV) for an L.P.E. material. The interface region is rather narrow (≈ 2μ) and indicates that this epilayer was grown on a substrate which was probably prepared by a non contact method. Finally Figure 6 shows that θ has an average value hovering around 2.2 radians. This result is fairly typical of L.P.E. materials and the reported n-type is observable only at the oxide/epilayer interface when the field of the charged defects is neutralized by the interface charge.

CONCLUSIONS

Even though this material is a fairly typical L.P.E. material it does seem to have a low enough defects content to exhibit the benefits of oxide passivation. This is important because it shows that passivation is a viable approach to device technology in L.P.E. materials . Another interesting result obtained with this sample is that the oxide/epilayer interface Hg depletion seems to be accompanied by an enrichment in Hg of the region immediately adjacent to the surface. In other words *the plasma deposition seems to be truly passivating in that the Hg does not leave the surface but rather diffuses inward.*

SAMPLE N.V.L. #3A DEPTH VS. X AT THE TOP OF THE LAYER

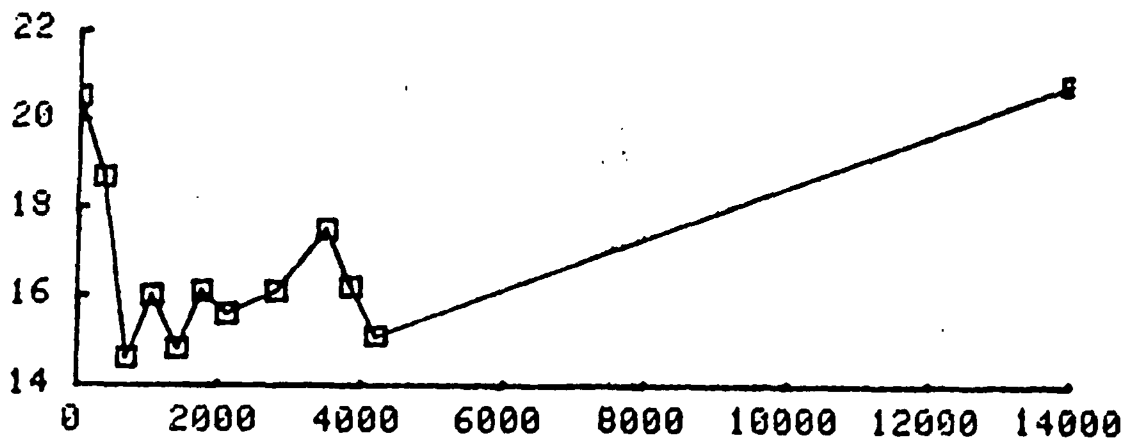

Figure 1

SAMPLE H.V.L. #3A DEPTH VS. GAMMA AT TOP OF LAYER

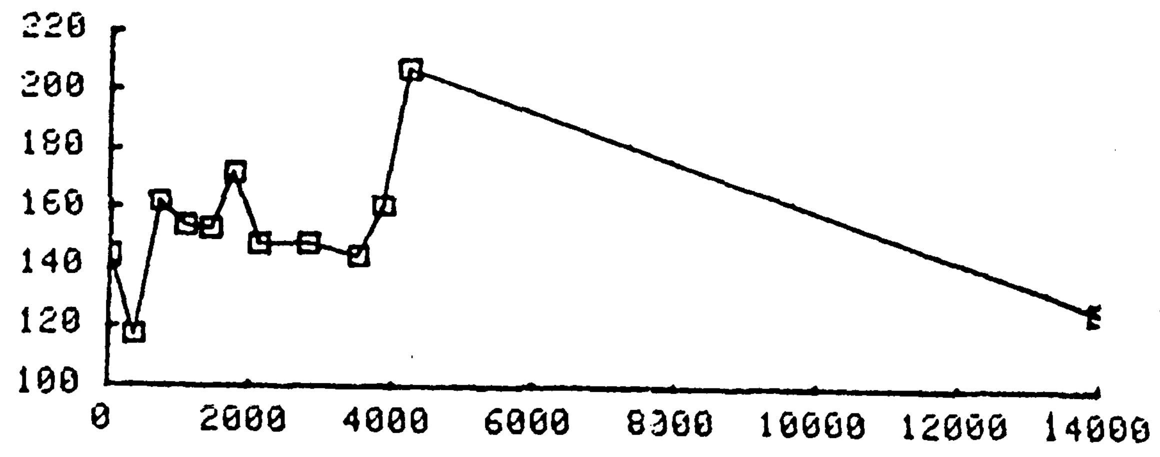

Figure 2

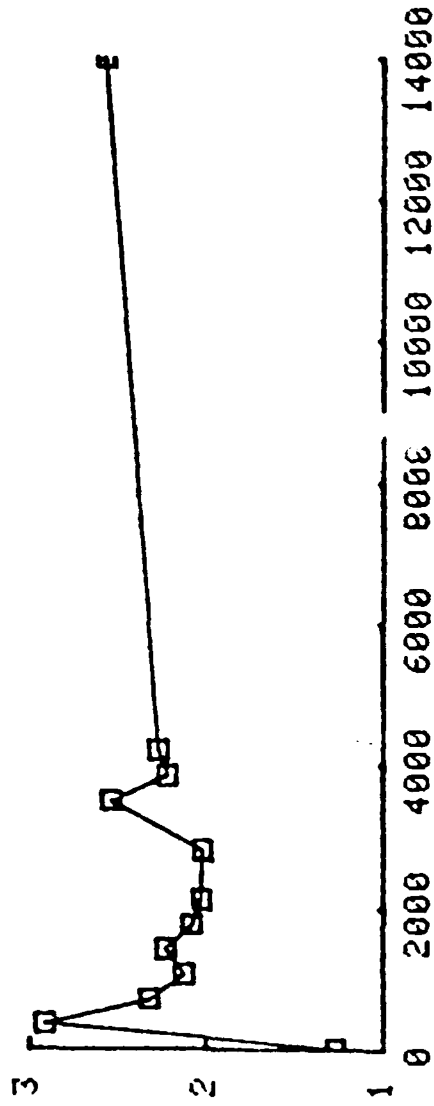

Figure 3

SAMPLE N.V.L. #3A DEPTH VS. X/TOTAL PROFILE

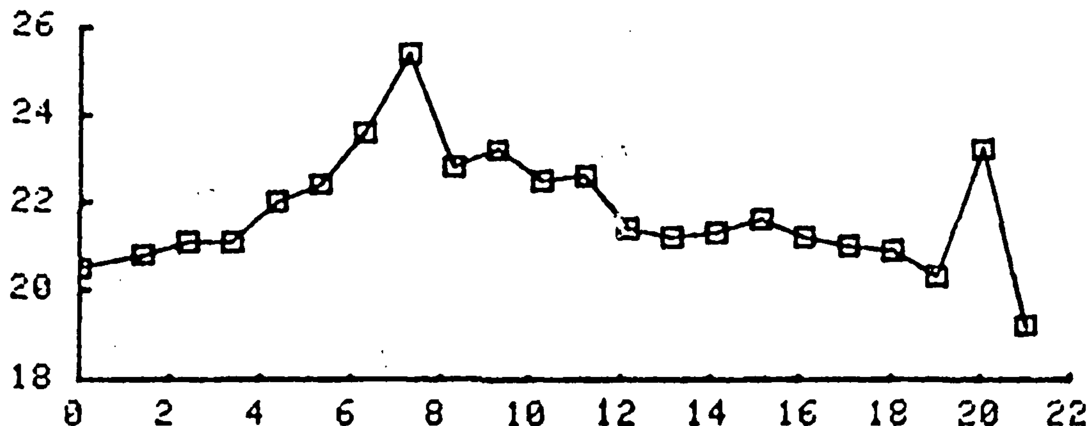

Figure 4

SAMPLE N.V.L. #3A DEPTH VS. GAMMA/TOTAL PROFILE

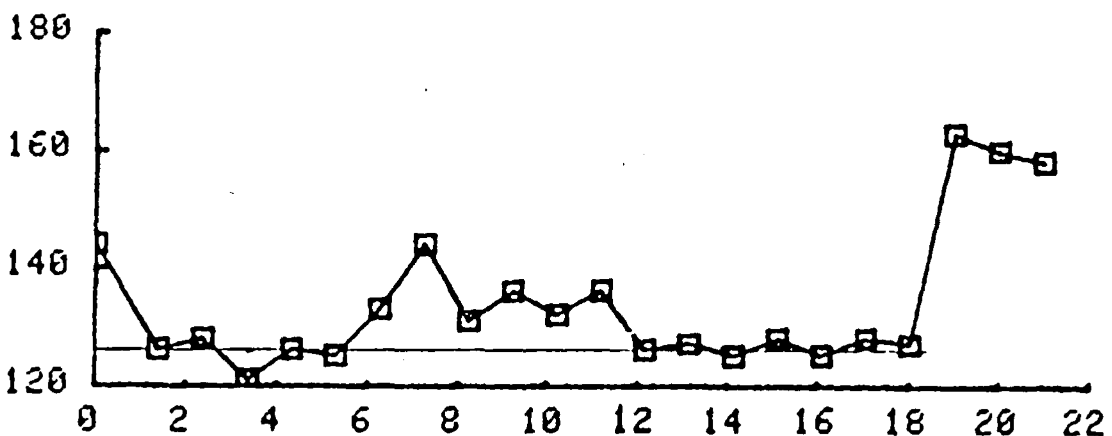

Figure 5

SAMPLE N.V.L. #3A DEPTH VS. THETA/TOTAL PROFILE

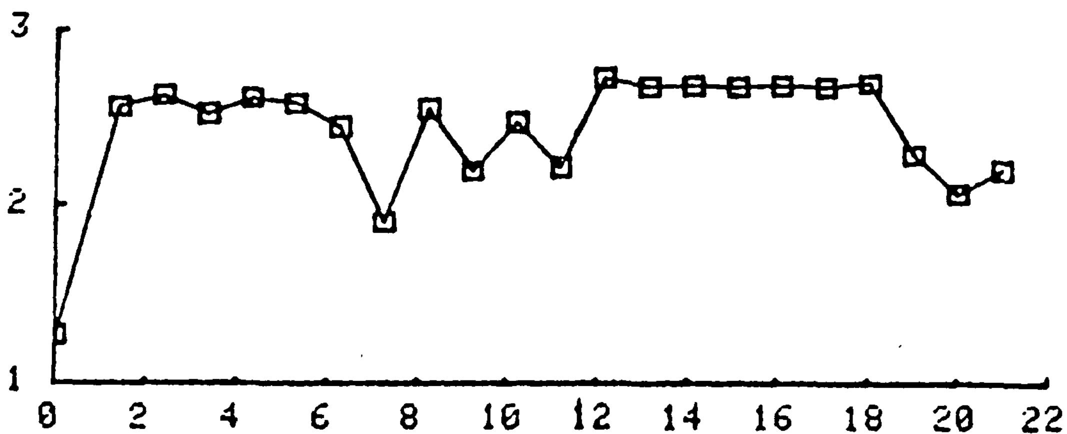

Figure 6

FINAL REPORT ON SAMPLE N.V.L. 3B

Prepared by Pr. Paul M. Raccah

Tecnical Program Monitor

Dr. M. Martinka

PRELIMINARY INFORMATIONS

This sample is an L.P.E. material reportedly n-type on which an oxide layer of 363 Angstroms has been plasma deposited. It is a parent of sample 3A (see separate report).

RESULTS AND DISCUSSION

Here again our results are presented in six figures subdivided into two groups of three. The first group presents a high resolution depth profile in the neighborhood of the oxide/epilayer interface while the second group presents a normal reasolution depth profile of the entire epilayer. In each case the order of presentation is X , Γ and θ .

A rapid look at figure 5 , which shows Γ vs. depth for the entire epilayer, is a good starting point to begin this discussion. Clearly this epilayer is more deffectuous than Sample 3A. It could be that it has been treated differently or maybe it comes from a more imperfect area of the wafer.

Figure 1 shows that the immediate oxide/epilayer interface in sharply lower in composition ($X \approx 0.14$) than the bulk which averages 0.21. The results in Figure 3 show mixed minority conduction type consistently with a high defects density.

The results shown in the normal resolution profile are similar. All in all this is , somehow, a poor sample it has an average compostion $X = 0.21 \pm 0.01$, which is slightly below standards and likewise an epilayer/substrate interface of 3μ which

also is not as good as that of Sample 3A.

CONCLUSIONS

This sample serves only to demonstrate that materials where the etch pits density is higher than 3×10^4 / cm^2 are not usable for device construction. In contrast to sample 3A or of sample 2 this sample does not show the effects of passivation on the intrinsic charged defects because the latter dominate completely.

SAMPLE N.U.L. #3B DEPTH VS. X AT THE TOP OF THE LAYER

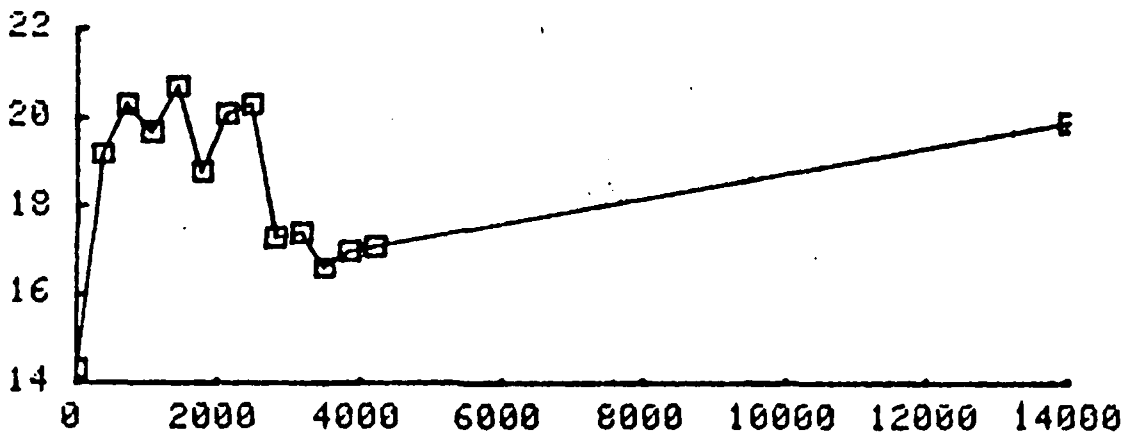

Figure 1

SAMPLE #3B N.V.L. DEPTH IN ANGSTROMS VS. GAMMA IN MVS AT THE TOP

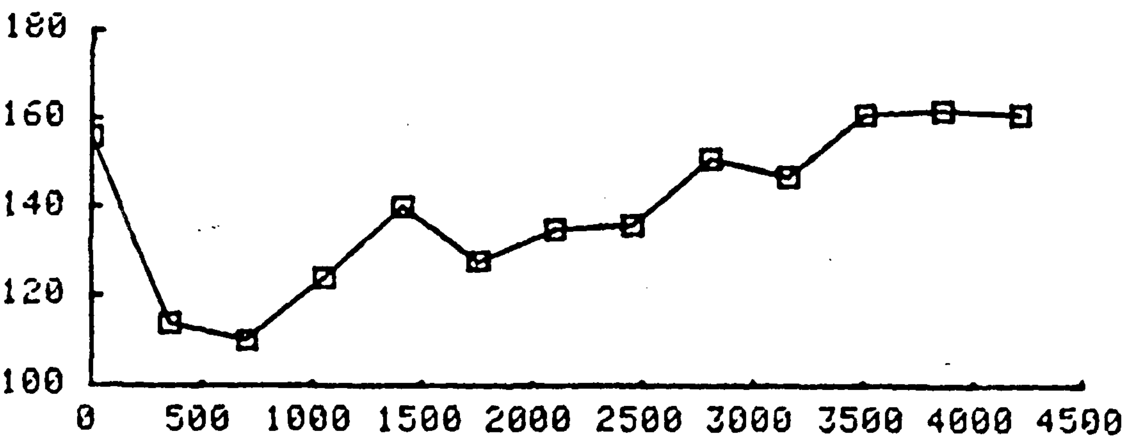

Figure 2

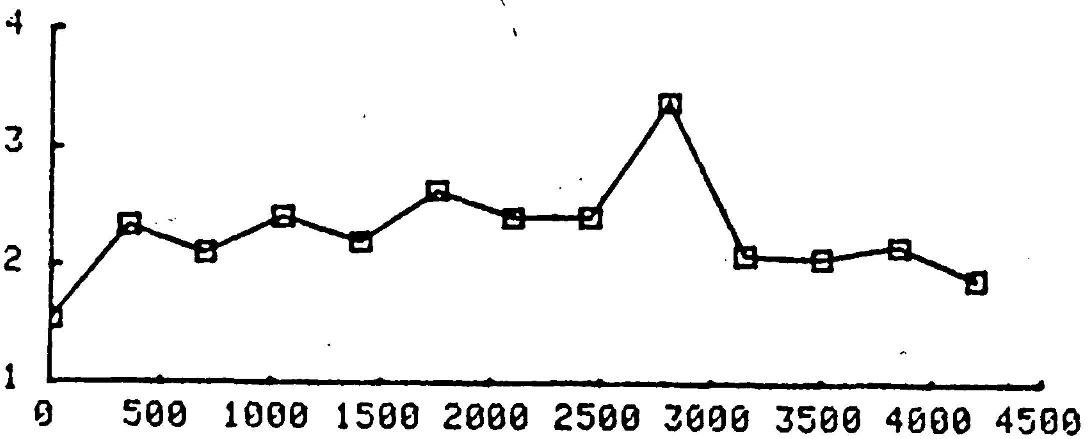

Figure 3

SAMPLE N.V.L. #3B DEPTH VS. % TOTAL PROFILE

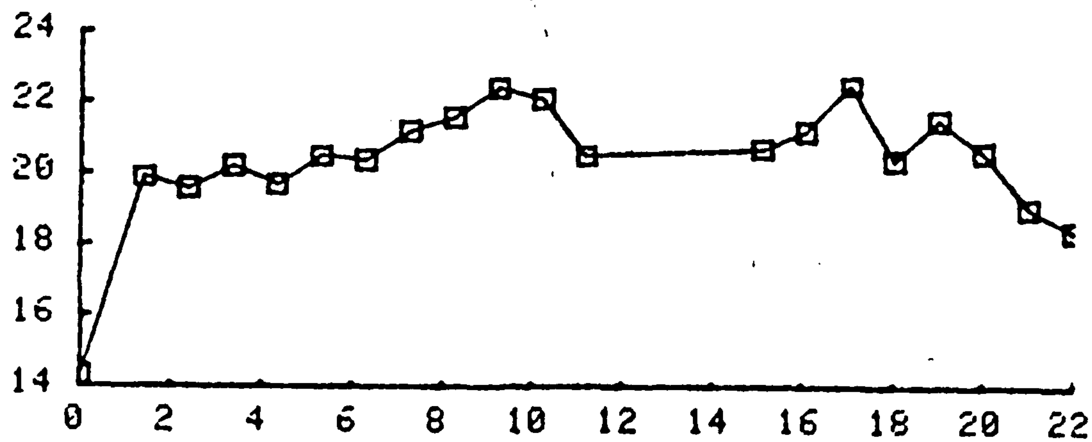

Figure 4

SAMPLE #3B N.V.L. DEPTH VS. GAMMA/TOTAL PROFILE

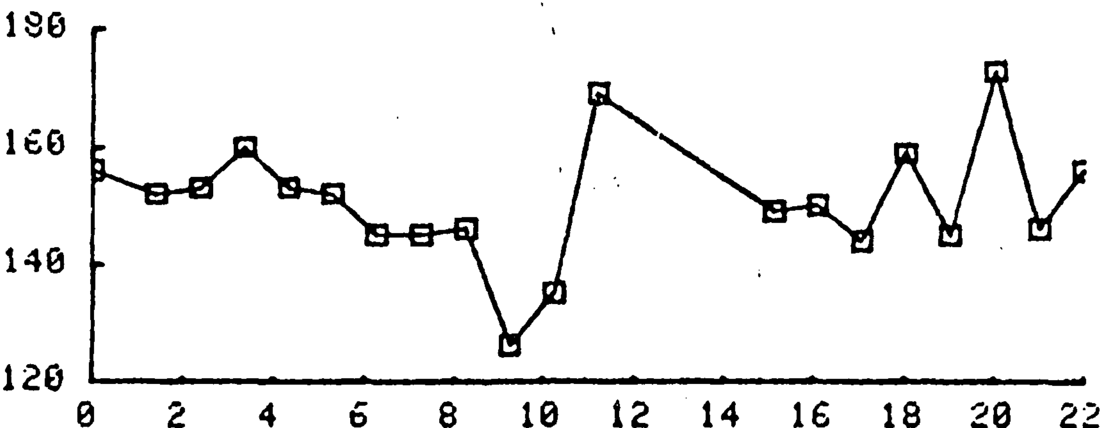

Figure 5

SAMPLE N.V.L. #3B DEPTH VS THETA TOTAL PROFILE

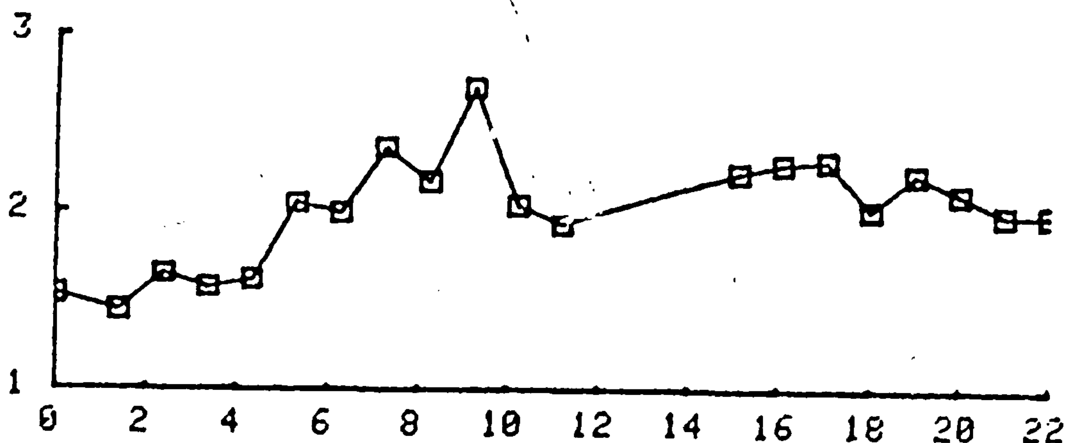

Figure 6