Productive Availability of Non-destructive Thickness Measurement Techniques

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Introduction

"Thickness control" is the most fundamental and essential subject for the semiconductor device fabrication. At the actual production stage, however, the accurate thickness inspection had been hard to be accomplished by the reason of forbidden limitation of wafer destruction. For the effective device production, the enough accurate non-destructive thickness measurement techniques have to be realized. In this paper, we report the productive availability of the specially improved non-destructive thickness measurement techniques of Grazing Incidence X-ray Reflectometer, FTIR, and Spectroscopic Ellipsometer for the wafer process inline inspections.

Thickness Measurement Techniques and The Results

1. Grazing Incidence X-ray Reflectometer

The ledge layer thickness of AlGaAs based HBT after the etching process can be measured by the Grazing Incidence X-ray Reflectometer (Rigaku GXR[2]) as demonstrated in Figure 1. Even with the emitter electrode patterns, the interference fringe shape corresponding to the ledge layer of 500Å thick can be clearly observed in the X-ray reflectance spectrum. The measured thickness given by the fringe shape fitting is in good agreement with the surface profiler's result.

The Pt penetration depth by the alloy annealing of the base electrode (Pt/Ti/Pt) can be also measured by this technique as described in Figure 2. Figure 3 is the TEM photo of the cross section. The bottom Pt layer of 100Å thick was reconstructed to PtGa (125Å) layer and $PtAs_2$ (170Å) penetrated layer by the alloy annealing. The results are in good agreement.

2. FTIR

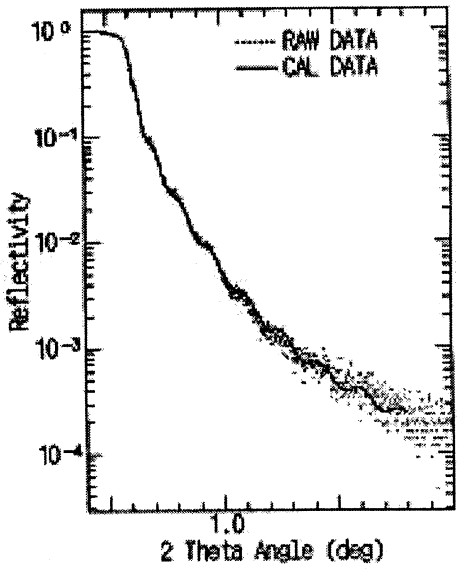
Figure 4 is the interference spectrum of the InGaAs/InP heterojunction of the photo diode by the specially improved FTIR (Jasco FT/IR-610) apparatus to measure the wide wavenumber range from 2,000 cm^{-1} to 16,000 cm^{-1}. The four layer's thickness can be measured simultaneously without wafer cleavage. In comparison with the SEM measurement at the cleaved cross section, the thickness are in good agreement within 0.01μm.

With the microscopic FTIR technique (Jasco MJ-200) , the substrate thickness of the FET chip bonded to the package can be measured. The interference spectrum is shown in Figure 5. Substrate thickness was inspected as 26.5μm with 50μm spatial resolution.

3. Spectroscopic Ellipsometry

The sensitivity of a conventional single-wavelength ellipsometer with HeNe Laser (λ=6,328Å) is low for the films less than 200Å thick and modulo the repeat thickness. For example, SiN (n= 1.85 at 6,328Å) on GaAs of 2,000Å thick, which is correspond to the repeat thickness of 2,002Å at the incident angle of 74 deg, cannot be measured by the HeNe ellipsometer even with 4% change of repeat thickness within the incident angle of 60-80 deg.

The wafer face-up mountable compact configurated spectroscopic ellipsometer (Jasco M-500) is very convenient for the inline inspection of the dielectric film thickness to avoid the repeat thickness problem. The measurement results of the same film by Jasco M-500 at 5,000Å are thickness=2,042 Å, n=1.82, Δ=129.6, and Ψ=38.9.



Curve Fitting Results

Layer	δ (x10^{-6})	β (x10^{-6})	Thickness[Å]	Roughness[Å]
1	3.8860	2.9567	20.14	10.0800
2	14.0305	0.2474	480.55	5.5006
Base	14.5000	0.4200	10000.00	5.0000

< R-Value = 2.937%, SSQ-Value = 3.81155 >

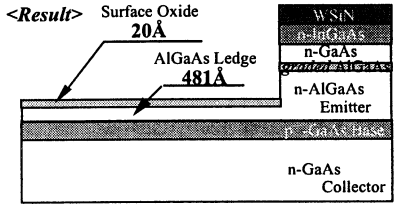


Figure 1 Ledge layer thickness measurement of AlGaAs-HBT by GXR[2].

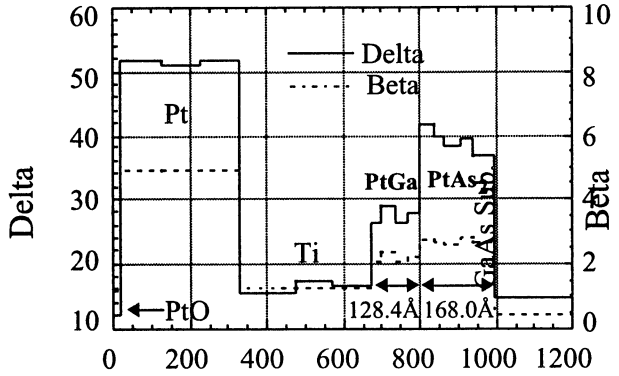


Figure 2 Structural analysis result by GXR[2] of the Pt penetrated base contact of Pt/Ti/Pt electrode.

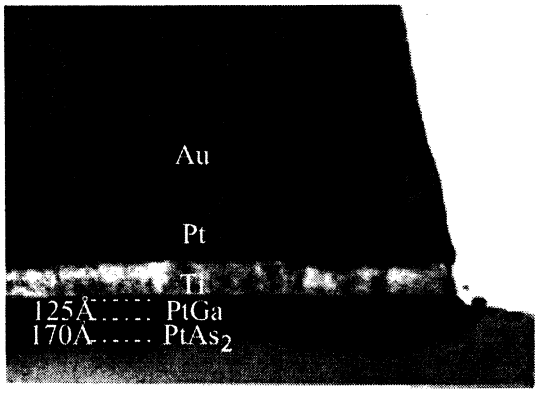
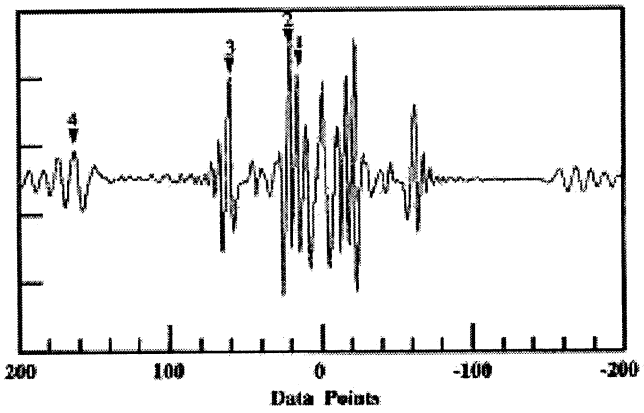


Figure 3 TEM photo of the cross section of the Pt penetrated base contact.



Layer	FTIR	SEM
(1) InP	0.80	0.81
(2) InGaAs	0.23	0.22
(3) InP	1.91	1.94
(4) InGaAs	4.36	4.52

Figure 4 The interference spectrum of the InGaAs/InP photo diode epi. structure.

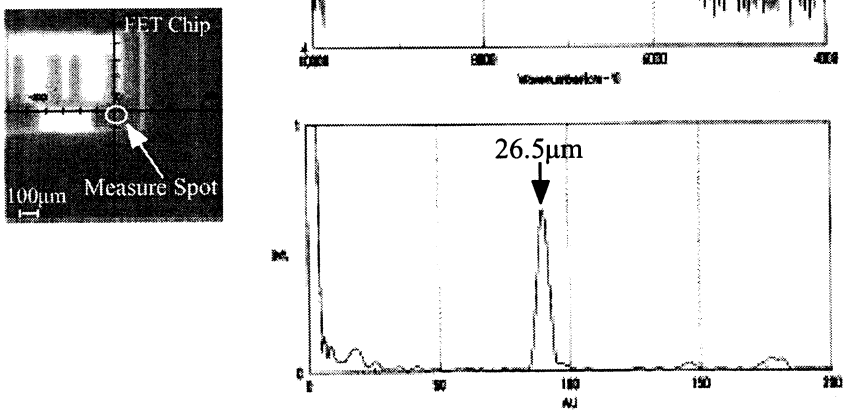


Figure 5 The interference spectrum of the FET chip of 26.5μm thick substrate bonded on a package.