Novel Passivation Ledge Monitor in an InGaP HBT Process

Cristian Cismaru and Peter J. Zampardi
Skyworks Solutions, Inc., 2427 Hillcrest Drive, Newbury Park, CA 91320
cristian.cismaru@skyworksinc.com, 805.480.4663

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InGaP/GaAs heterojunction bipolar transistors (HBT) are widely used for wireless applications since they have excellent features such as high power density and high efficiency. The performance and reliability of the HBT is greatly influenced by the effectiveness of the emitter ledge [1,2,3]. This ledge reduces the recombination current providing better device scaling and improved reliability.

Given the importance of the HBT ledge thickness and quality, monitoring these allows for better in-line quality control and wafer screening. Previously, in an AlGaAs HBT process, a ledge monitor was successfully demonstrated by using the first interconnect metal layer as the top electrode [4,5]. The metal layer, a Ti/Pt/Au stack was deposited directly on the AlGaAs passivation ledge to form a metal insulator semiconductor (MIS) capacitor between M1 and the HBT p^+ base. In-line capacitance measurements of this structure allowed for the monitoring of the ledge thickness and quality. However, with the switch to the current InGaP HBT processes, this original structure no longer works, since this metal applied to InGaP does not form a high quality Schottky contact. To our knowledge, there are currently no simple in-line electrical tests to monitor ledges in an InGaP HBT process.

In this work, we propose a new ledge-monitoring structure similar to the previous implementation which is valid for InGaP ledges. Our solution is to use Tantalum Nitride (TaN) as a barrier between first metal (M1) and the InGaP layer. Figure 1 shows a diagram of the structure. This results in improved Schottky behavior for the top electrode leading to the desired MIS capacitor formation (Figure 2). The measurement of the structure as a diode I-V provides information on the InGaP ledge thickness/quality. If the ledge is too thin, the structure will behave almost like a tunnel diode (with very low turn-on voltage due to the thinner InGaP barrier) between the TaN layer and the p-type base.

For production control, an in-line device is more suitable for implementation in the process control monitor (PCM) since it provides a capacitance of approximately 10 pF with no applied bias using an LCR meter with a 1 MHz, 10 mV signal.

Figure 3 shows the distribution of the capacitance density of the measured device across an experimental sample. The average capacitance density is approximately 3 fF/um^2. Using the simple capacitance relationship:

$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}, \qquad \textbf{(Equation 1)}$$

we can then calculate the InGaP ledge thickness by using a value of 11.75 for the InGaP relative permittivity. Figure 4 shows that the average ledge thickness for this sample is 340 A, while Figure 5 shows the average ledge thickness distribution across the wafers.

In conclusion, with this work we report on a measurement technique/structure for monitoring the emitter passivation ledge based on the use of TaN as a barrier between the InGaP ledge surface and the top metal contact. The technique is suitable for the manufacturing environment and it allows for the assessment of the passivation ledge thickness and quality. It also serves as early screens for potential reliability or process related device degradation.

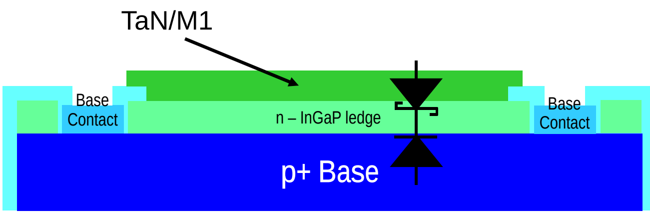

Figure 1. Schematic of the ledge diode.

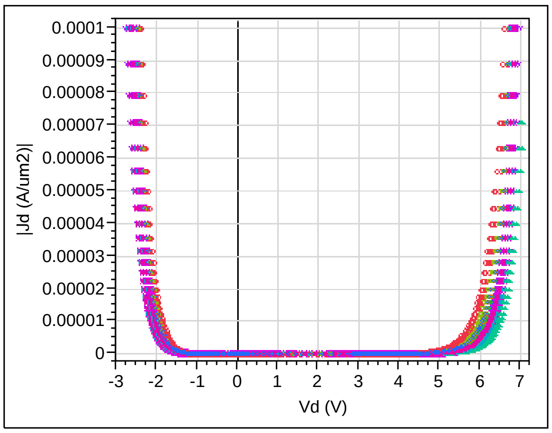

Figure 2. Forward and reverse I-V curves of the TaN ledge diode (absolute value).

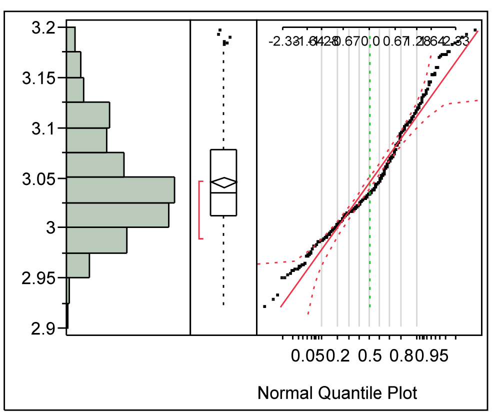

Figure 3. Distribution of measured ledge capacitance density (fF/um^2) across a wafer lot.

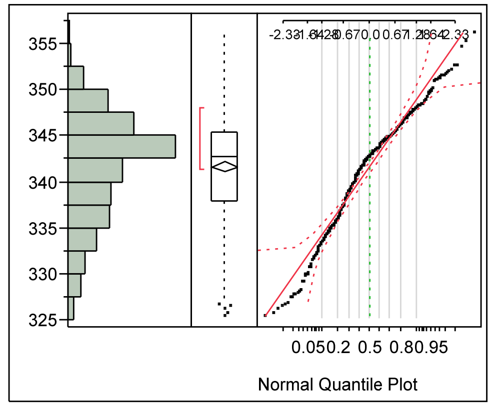

Figure 4. Distribution of calculated ledge thickness (A) across a wafer lot.

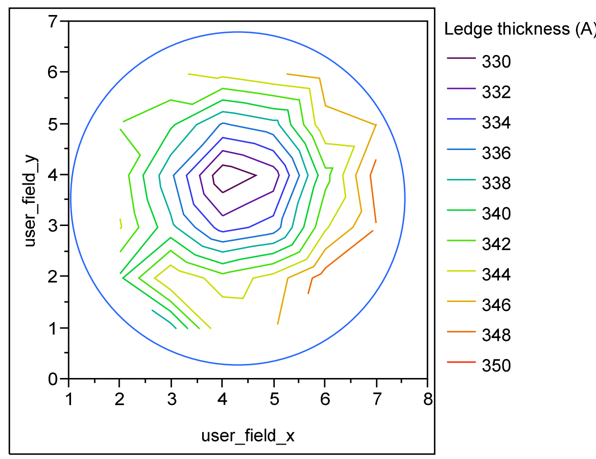

Figure 5. Averaged ledge thickness variation across wafer.

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