An *In-Situ* Reflectance Implementation for High Volume Electronic Device Epitaxial Wafer Production

M. Youngers, P. Rice, G. Yeboah, E. Rehder, O. Laboutin, K. S. Stevens, and W. Johnson
Kopin Corporation, 695 Myles Standish Blvd., Taunton, MA 02780
kstevens@kopin.com, 508-824-6696

In-situ reflectance measurement during epi-layer growth gives data for every epi-layer on every wafer - as it is grown - such that the data is available before the reactor has cooled down [1-3]. As smart phone volumes ramp up and price pressures continue, this in-situ capability is of fundamental importance for continuously driving both yield and quality improvements in device epitaxial wafers (HBT, pHEMT, BiFET, BiHEMT) for use in GaAs based power amplifier and switch circuitry. Although other techniques such as X-ray diffraction, photoreflectance and photoluminescence can also provide detailed epi-layer information, it is available only after long delay from the growth, and therefore it is problematic to achieve sufficient throughput for these techniques.

A key challenge of in-situ reflectance measurement in a production environment is developing an IT system which can convert large quantities of data into easily usable parameters that are clearly linked to the appropriate epi-layer and wafer. The IT solution must include two aspects. First, it must enable and facilitate analysis of data in order to determine, develop and define what parameters are useful for production. Second, it must quickly convert the raw data into these same parameters. This is a continuous process, involving an initial set of parameters, which will be refined and expanded as experience with using the reflectance data in production grows.

Figure 1 presents a schematic of the data flow and analysis for the solution implemented in this work. Highlights include a) uploading the raw reflectance data from the measurement tool into our Oracle production database, b) converting these data into a summary data table using the instructions of a configuration table, c) using a graphing tool to analyze the summary data in order to explore ideas for production parameters, d) converting the summary data into production parameters using the instructions of a spec table., and e) plotting the chosen production parameters in SPC charts.

As one example of the data output and its use in real production control, a plot of growth rate and epi-layer thickness over ~300 production runs (~2100 wafers) is shown in Figure 2. Small growth rate drifts (due to reactor coating) and shifts (due to reactor maintenance) are visible. Because of this greatly enhanced visibility adjustments and/or corrections can be made more quickly. The thickness data in Fig. 2 illustrates one example of the improvements enabled by this data. To the left of the dotted green line, the layer thickness drift tracks the growth rate drift because no adjustments were made to the growth recipe. To the right of the green line, however, the growth rate data is fed back to the growth recipe such that the thickness exhibits much reduced drift, despite the continued slow drift of the growth rate.

As a second example of the data output, Figure 3 shows average surface temperature (normalized) and on-wafer temperature uniformity during growth for ~100 production runs (~700 wafers). The plot shows real wafer temperatures and uniformities can be readily compared before and after reactor maintenance.

In summary, the wealth of these in-situ data allow for rapid detection and correction of any changes, thereby reducing relevant Cpk values over time. Additionally, the added visibility afforded by these data shed light on the mechanisms behind subtle changes, such that the ultimate causes can be better understood and mitigated.

[1] K.P. Kileen, W.G. Breiland, *In situ spectral reflectance monitoring of III-V epitaxy*, Journal of Electronic Materials, **23** (1994) 179-183.
[2] D.E. Aspnes, *Optical approaches to the determination of composition of semiconductor alloys during epitaxy*, IEEE Journal on Selected Topics in Quantum Electronics, **1** (1995), 1054-1063.
[3] E. M. Rehder, K. Tsai, P. Rice, C. R. Lutz, and K. S. Stevens, *In Situ Monitoring of HBT Epi Wafer Production: The Continuing Push Towards Perfect Quality and Yields*, CSMantech, (2009).

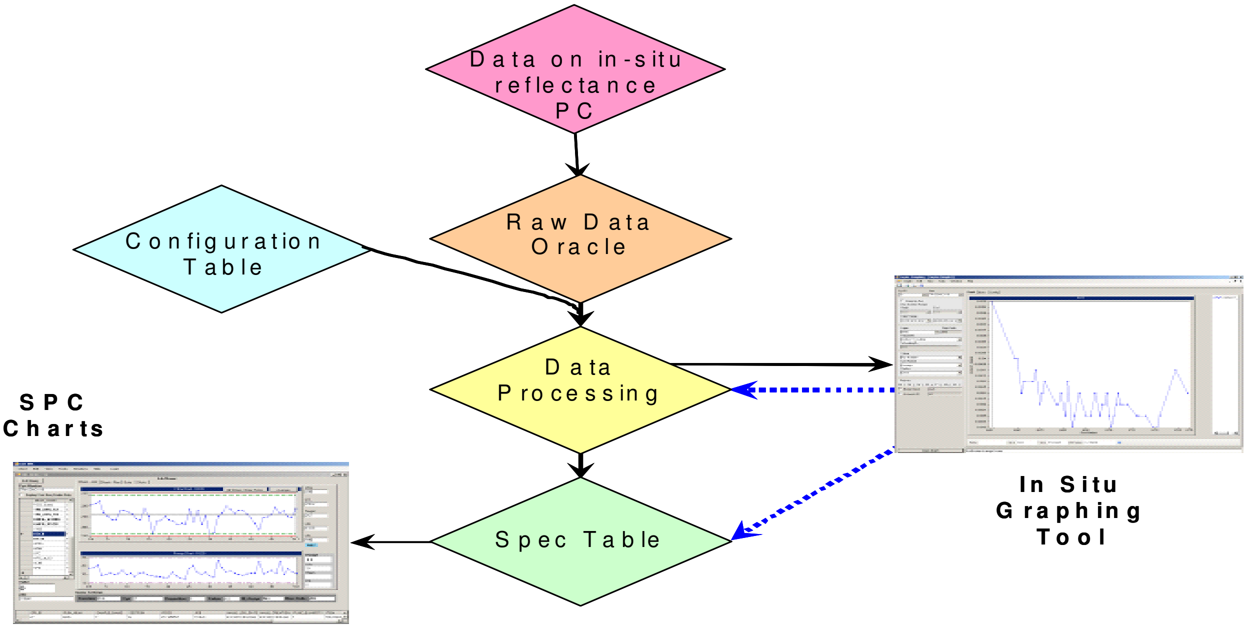

Figure 1: Schematic of the data flow and analysis for an IT system designed to convert large quantities of in-situ reflectance data into parameters suitable to a production environment where key data is linked to the appropriate epi-layer and wafer

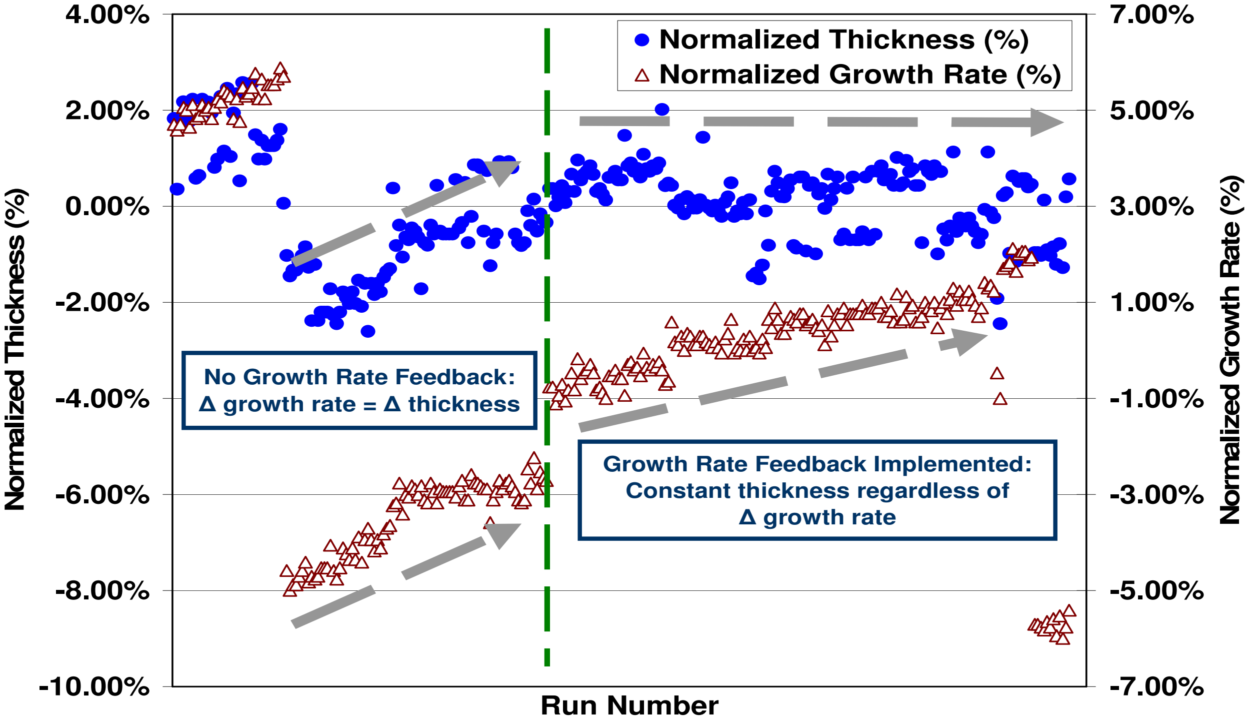

Figure 2: Growth rate and epi-layer thickness over the span of ~300 production runs (~2100 wafers). To the left of the dotted green line, the layer thickness drift tracks the growth rate drift. To the right of the dotted green line, the growth rate data is fed back to the growth recipe such that the thickness exhibits no drift, despite the continued slow drift of the growth rate. Grey arrows are a guide to the eye. Bimodal nature of the thickness data is an artifact of measurement, which will be corrected in the future.

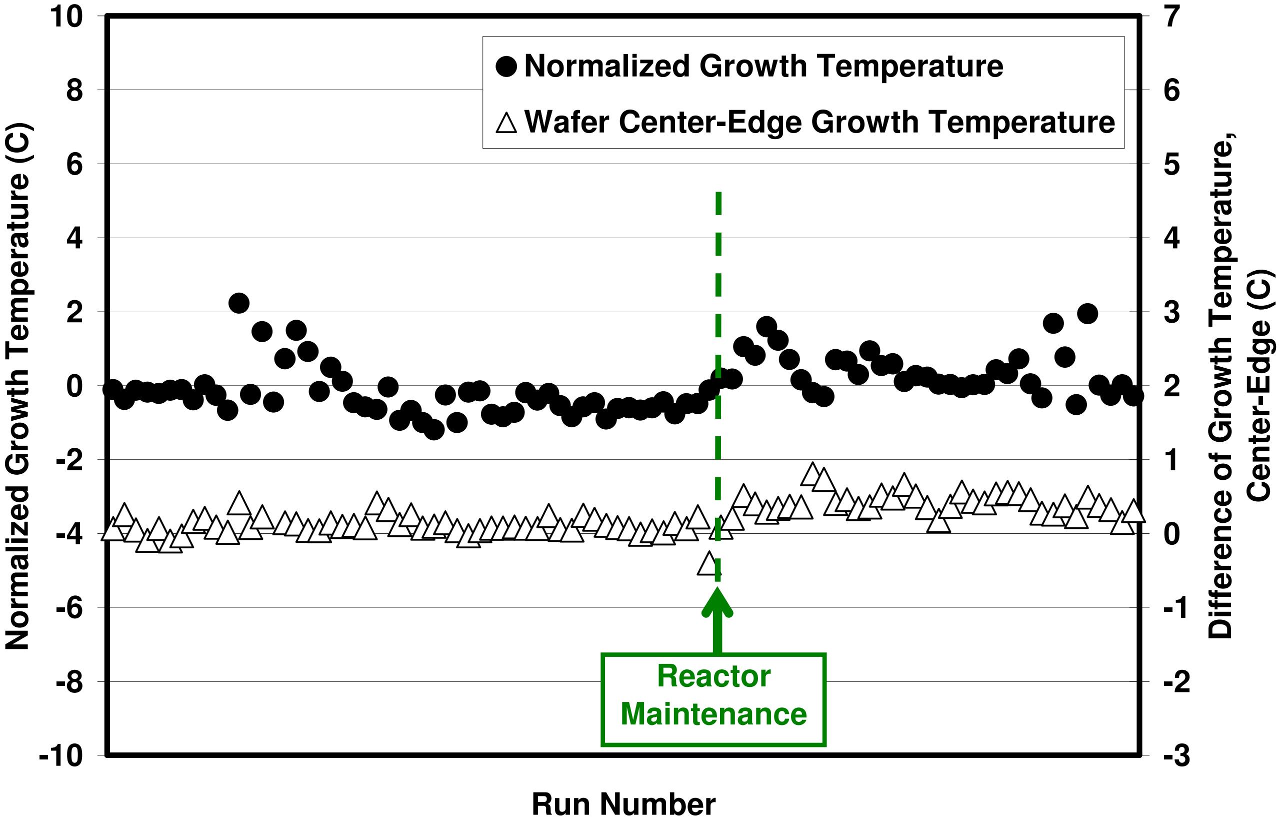

Figure 3: Epi-wafer average surface temperature (normalized) and on-wafer temperature uniformity over the span of ~100 production runs (~700 wafers). Wafer surface average temperature and on-wafer temperature uniformity during growth are readily compared before and after routine reactor maintenance.