Advanced Statistical Process Control of Critical PECVD SiNx Thin Films

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From a process & equipment engineering perspective, maintaining ultra-tight control over Metal-Insulator-Metal Device Capacitor (MIM_CAP) variability, and hence tight wafer-to-wafer and lot-to-lot insulator film property control, is a key challenge. To understand MIM_CAP pF trending, advanced Statistical Process Control (SPC) techniques were applied to critical Plasma-Enhanced Chemical Vapor Deposited (PECVD) Silicon Nitride (SiNx) MIM_CAP thin-films within the GCS high-performance Heterojunction Bipolar Transistor (HBT) product flow.

Thickness & refractive index trend data over large time periods were filtered & analyzed based on Central Limit Theorem considerations, and correlations were made to MIM_CAP. Based on these findings, the SiNx thickness process control limits were fine-tuned and MIM_CAP variation, as calculated using Cpk, showed a marked improvement from 0.47 to 1.02.

Additional sources of variability, e.g. non-linearity in C vs. thickness analysis shown in Fig 2, will be discussed theoretically and directly correlated to low-frequency (LF) oscillations within the refractive index vs. time SPC trend charts.

Breakdown Voltage data correlations (not shown) will also be discussed.

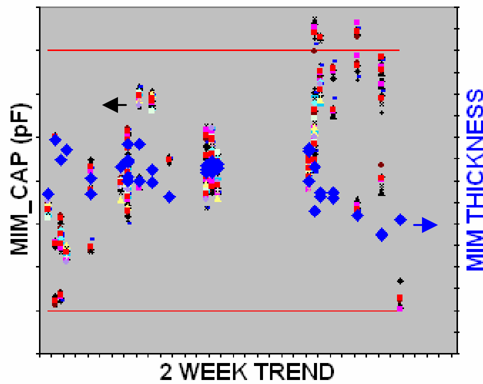

Figure 1. Typical 2-week trend chart showing MIM_CAP within lot scatter left axis and thickness scatter right axis. This data was used as basis for data reduction based on central limit theorem multi-averaging.

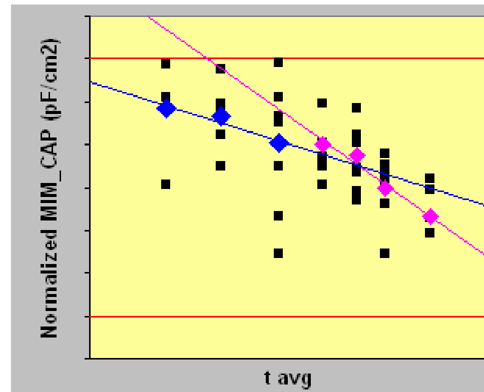

Figure 2. Normalized scatter plot MIM_CAP (pF/cm2) as a function of thickness. Non-linearity is due slight changes in the refractive index from run-to-run & tool-to-tool.

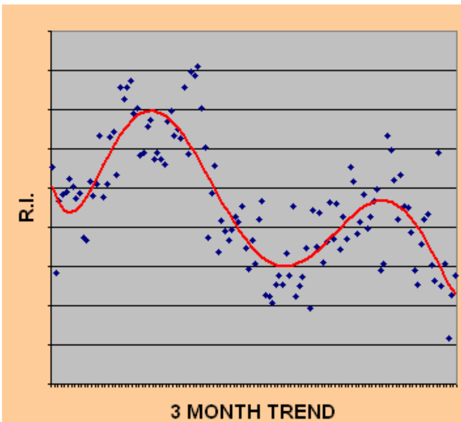

Figure 3. 3-month refractive index trend data.

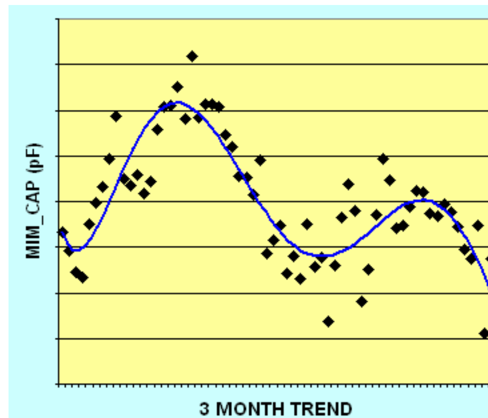

Figure 4. Direct correlation of R.I. to low-frequency oscillation in 3-month MIM_CAP trend data.