

Measuring What Matters: Using Picosecond Ultrasonic Technology for SiCr Film Thickness Control in BCD Devices

By Huayuan Li, Alex Hong, Johnny Mu, Timothy Kryman, and Priya Mukundhan, Onto Innovation

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Bipolar, CMOS, and DMOS (BCD) devices are among the most widely used semiconductor technologies today. Capable of handling increasingly complex electrical demands, BCD devices play a vital role in powering automotive, consumer, and medical systems.

Automotive systems must simultaneously manage power, control signals, and safety-critical functions like braking and airbag deployment. Consumer devices demand high performance with minimal power consumption. Medical platforms require both precision and reliability. Delivering across all these dimensions requires a level of integration that few semiconductor technologies can achieve.

So what makes BCD uniquely suited to this task?

The answer lies in its architecture. BCD devices integrate three complementary transistor types—bipolar, CMOS, and DMOS—onto a single chip. The integration of these transistors enables the simultaneous handling of analog, digital, and power functions within a compact and high-performance platform, with each transistor type contributing unique strengths:

- Bipolar transistors offer high current handling and precise analog control.
- CMOS transistors provide low power consumption and high integration density for digital logic.
- DMOS transistors are optimized for high-voltage and high-current power applications.

For BCD devices to meet performance expectations, proper process control measures are needed, especially in the case of silicon-chromium (SiCr) thin films where even small variations impact device performance and reliability.

SiCr films play a critical role in BCD technology, primarily as precision resistive elements within analog and power management circuits. SiCr resistors offer high stability, low temperature coefficient resistance (TCR), and excellent linearity, making them ideal for applications requiring accurate voltage and current control. Given the stringent reliability standards for BCD technology as demanded by the automotive industry and others, SiCr deposition must exhibit high reproducibility and minimal defectivity to support high-yield manufacturing and robust device performance under thermal and electrical stress. Variability in these films can introduce parametric drift and reliability risks that must be tightly managed during manufacturing and qualification.

Uniformity across the wafer and repeatability between lots are critical. Even minor thickness or compositional variations can lead to resistance drift which impacts analog accuracy and long-term reliability. Tight process control during the deposition step, including

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chamber stability, target conditioning, and plasma uniformity, ensures consistent film morphology and stoichiometry. Maintaining consistency requires tight control over deposition conditions throughout the process.

During SiCr sputtering, the precise regulation of specialty gas flow is critical as their partial pressures influence plasma chemistry and the kinetics of silicide formation on the substrate. These reactions influence nucleation behavior and grain growth, which can directly affect grain boundary spacing and, consequently, TCR. Variations in gas flow can alter the stoichiometry and microstructure of the SiCr film, leading to shifts in TCR behavior, including the onset of a pronounced negative coefficient if the process is not tightly controlled. These variations can be difficult to detect without high-sensitivity, in-line monitoring capabilities.

Given these requirements, manufacturers need high-sensitivity, in-line metrology capable of monitoring critical process parameters and identifying variations before they impact device performance. In this two-part blog series, we will discuss the application of picosecond ultrasonic technology, first as a robust thickness metrology solution for qualifying SiCr deposition processes and then as excursion monitoring tool in BCD devices.

About Picosecond Ultrasonic Technology

Picosecond ultrasonic technology (PULSE™ technology) is a non-contact, non-destructive pump-probe laser acoustic technique for the measurement of metal film thickness. It is a proven workhorse in semiconductor fabs around the world.

When using picosecond ultrasonic technology, a 0.1ps laser pulse (pump) is focused to a small ($\sim 8 \times 10 \text{mm}^2$) spot onto a wafer surface to create a sharp acoustic wave. The acoustic wave travels away from the surface through the film at the speed of sound. At the interface with the material, a portion of the acoustic wave is reflected and comes back to the surface while the rest is transmitted. The probe pulse detects this reflected acoustic wave as it reaches the wafer surface. Engineers can detect the change in optical reflectivity that is caused by the strain of the acoustic wave (REF mode) or alternatively detect, using a position sensitive detector (PSD mode), the deflection of the reflected probe beam that is caused by the deformation of the surface due to the acoustic wave. Both modes are used in characterizing metal films. By knowing the speed of sound in the material and the arrival time of the echoes, engineers are able to readily extract film thickness using a first principles technique. This enables non-destructive, high-resolution measurement of film thickness directly on the wafer.

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Film Thickness

With background on picosecond ultrasonic technology out of the way, let's dive into how this approach enables the application of this technology in process control for BCD devices. To demonstrate this, we measured the nominal thickness of SiCr thin films using picosecond ultrasonic technology.

Figure 1a shows the raw data from the SiCr thin film. The acoustic echoes identified in the figure are used to calculate the thickness of the film using the speed of sound and round-trip transit time through the film. Nominally, textbook values for the longitudinal speed of sound would be used. In the case of SiCr films, the longitudinal speed of sound will vary from the bulk material and depend on the deposition process and specific film composition. Because the acoustic velocity in SiCr films depends on deposition conditions and film composition, a one-time TEM calibration was used to establish the appropriate velocity for this process.

As a one-time calibration, we used cross-section transmission electron microscopy (TEM) to obtain SiCr film thickness and calculated the speed of sound for this specific process to be 69.7Å/ps. The modeled fit to the measurement is shown in Figure 1b.

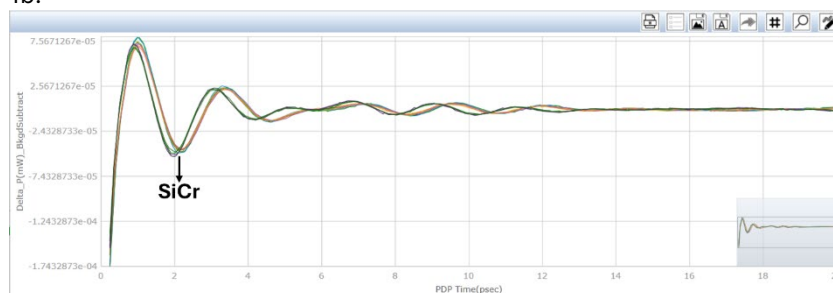


Figure 1a. Raw data of reflectivity change vs time shown. The cross-wafer variation is identified by the shift in acoustic echoes.

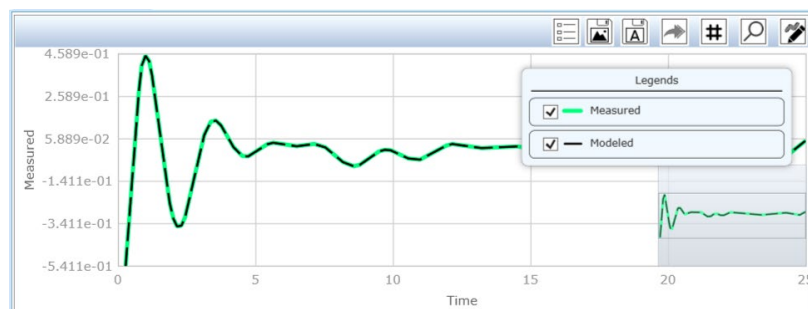


Figure 1b. Modeled fit to measured data shown. The green curve represents the measurement, and the black curve represents the fit.

In Figure 2, raw data from the design of experiments (DOE) skew is shown. The shift in echo position between the different wafers demonstrates the sensitivity of the technique for monitoring the

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process. Within wafer uniformity profiles from 13 points across the wafer also show consistent trends.

Given the critical function of SiCr films in BCD device architecture, it is imperative to maintain highly uniform deposition with stringent process control to meet electrical and reliability specifications. As part of chamber qualification, more extensive sampling across the wafer, including to the edge, was performed. Those profiles are also consistent across the thickness skew window.

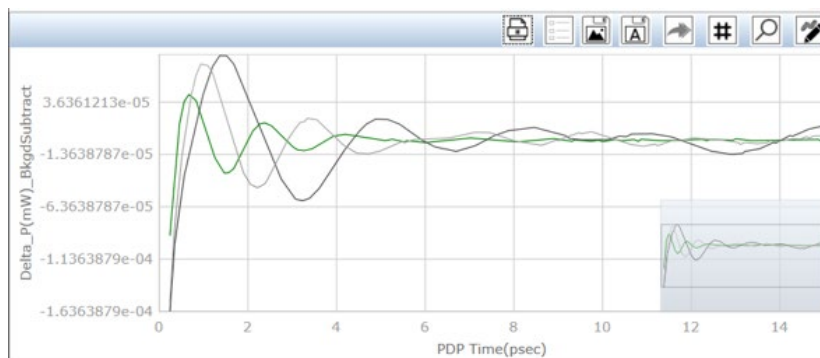


Figure 2. Raw data from the DOE thickness skew. Delta represents the skew in thickness from the target. The shift in echo position demonstrates the sensitivity for process monitoring

Repeatability is a key metric in SiCr thin film metrology for ensuring robust process control and consistent device performance. Poor repeatability can obscure true process shifts, leading to incorrect corrective actions and potential yield loss. Gage capable repeatability measurements ensure compliance with automotive industry standards and are critical for long-term reliability. The dynamic repeatability data indicates performance is better than $0.5\text{\AA}$ (1σ) and is more than sufficient to meet the process monitoring needs. High repeatability helps reduce false alarms and unnecessary process adjustments, improving overall manufacturing efficiency.

For manufacturers, the value extends beyond thickness measurement itself. The sensitivity and repeatability of picosecond ultrasonic technology support earlier detection of process variation and greater confidence in chamber qualification, process optimization, and ongoing production monitoring.

Summary

As demonstrated, [picosecond ultrasonic technology](#) provides a precise, non-destructive method for measuring film thickness, validated against TEM calibration. The technique also offers exceptional repeatability and sensitivity, enabling manufacturers to monitor wafer-to-wafer and within-wafer uniformity with high confidence and actionable insight. This capability is critical for

maintaining tight process windows, as even minor deviations in thickness can lead to resistance drift and compromise analog precision. By integrating this metrology into chamber qualification and process monitoring, fabs can ensure consistent SiCr deposition, optimize yield, and meet stringent reliability standards.

Please join us next month for our second installment in this two-part blog series. In the following blog we will examine how picosecond ultrasonic technology can provide additional insight. By leveraging simultaneously collected reflectivity data alongside thickness measurements, the same platform can be used to detect process excursions, monitor the effects of gas-flow variations during sputtering, and provide a more comprehensive view of SiCr film quality.

We hope you join us as we continue our discussion.

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Biography

Huayuan Li is a Manager, Applications Engineering, at Onto Innovation.

Alex Hong is an Applications Engineer at Onto Innovation.

Johnny Mu is Head of China Applications Engineering at Onto Innovation.

Timothy Kryman is Product Marketing Senior Director at Onto Innovation.

Priya Mukundhan is Senior Director of Product Marketing at Onto Innovation.