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# Using Picosecond Ultrasonics To Measure Trench Structures In SiC Power Devices

By: Nick Keller,
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The road to the future is not always a smooth, trouble-free drive. Along the way, there may be unforeseen detours, potholes and accidents, each one capable of setting progress back. But for those behind the wheel, those obstacles are just a part of the journey.

Such is the case for the automotive industry as it continues to steer away from gas-powered vehicles and turn toward hybrid and electric vehicles. To accomplish this, manufacturers of power devices are opting to use wide-bandwidth compound semiconductors like SiC and GaN. The reason: compound semiconductors accommodate higher voltages, faster switching speeds and lower losses than traditional silicon-based power devices.

For the purpose of our three-part series, we have been focusing on SiC power devices, the challenges presented by trench-based architectures that reduce on-resistance and increase carrier mobility, and the need to accurately measure epi layer growth and the depth of implant layers. Before we move onto the details of this blog, let's take a quick look back at the previous two blogs.

In the first, we explored how using an FTIR-based system allows for the direct modeling of carrier concentrations and film thickness, thus enabling SiC power device makers to better measure epi layer growth, implant layers and composition. In the second, we examined how high-volume manufacturers of SiC power devices address this important matter by using an optical critical dimension (OCD) metrology system designed specifically for specialty devices.

With this, our third and final blog, we explore how manufacturers are using picosecond ultrasonics to optimize the performance of SiC power device with trench architectures.

## Using Picosecond Ultrasonics

Picosecond ultrasonics (PULSE™ technology) is a pump-probe technique that uses ultrafast laser pulses – at approximately 200fs – for metal film metrology; this includes metal film metrology for trench-based SiC power devices. By using this non-destructive technique, manufacturers can measure multi-layer metal films simultaneously, while also being able to discriminate between individual layers of repeating metal. In the case of SiC power devices, picosecond ultrasonics offers a non-destructive solution to measuring film thickness and roughness.

Because of the advantages of picosecond ultrasonics, it is rapidly replacing more traditional methods, such as four-point probe

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methodology. For one, these conventional measurements are destructive; picosecond ultrasonics is not. Two, traditional methods do not offer direct thickness information and cannot detect missing layers or misprocessed wafers. In the case of SiC power MOFETS with trench architectures, picosecond ultrasonics can be used for metallization process control; this application includes monitoring the contact barrier (Ti/TiN), trench metallization (W-based contacts), and both frontside and backside metallization (Ti/NiV/Ag) stacks.

In our study, we measured ohmic contact and conduction metal layer thicknesses for both source and drain contacts in SiC power devices with trenches. These measurements are important because they have a direct impact on contact resistance; a power device with poor contact resistance will not perform properly. Metal thickness uniformity also has an impact on the reliability of the end device.

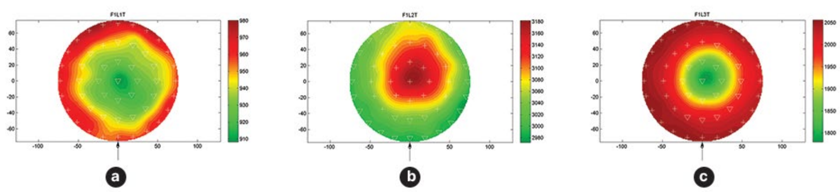


Figure 1: Forty-nine point maps of (a) Ti 1000 Å, (b) NiV 3000 Å, and (c) Ag 1500 Å.

Using picosecond ultrasonic technology, we measured a multi-layer metal stack; in this specific case, the layers were Ti/NiV/Ag. Because of the small spot size (8µm x10µm) and the rapid measurement times (<4s per site), we were able to characterize full wafer uniformity. In addition, the use of picosecond ultrasonics in our study shows excellent precision of 3 sigma < 0.25% standard deviation.

As previously noted, one of the key advantages of the picosecond ultrasonics is to be able to measure repeating metals in a multi-layer stack. In this case, we measured a stack of Ti/Al/ox/Ti/Al, with Ti repeating. The raw data generated by this technique showed an excellent signal-to-noise ratio, with echoes from each of the layers clearly resolved. Competing techniques such as X-ray metrology cannot provide individual layers in such a stack, and measurements on blanket films are not representative of product performance. Additionally, the recipes can be set up to flag missing layers or detect misprocessing.

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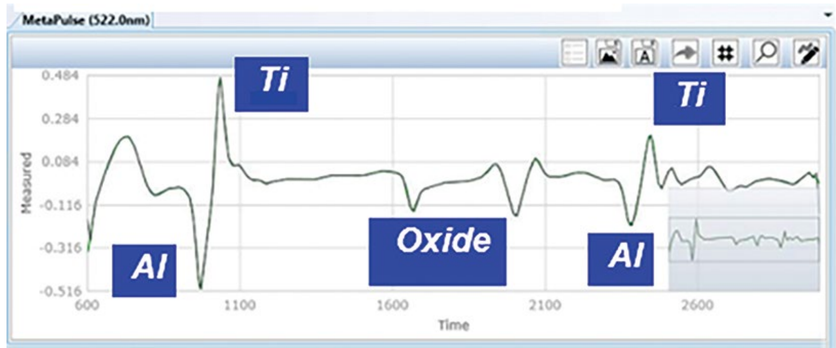


Figure 2: Multi-layer metallization stack measurement.

In addition to thickness, picosecond ultrasonics can be used to monitor roughness, especially for thick metal films (1,000s of Angstroms to micron range). Roughness serves as a qualitative indicator to monitor a well-established process. Figure 3 shows measurements from an aluminum film that was used to validate this capability. Correlation of this measurement to transmission electron microscopy (TEM) and atomic force microscopy (AFM) reference was excellent at $R^2$ ~f 0.99.

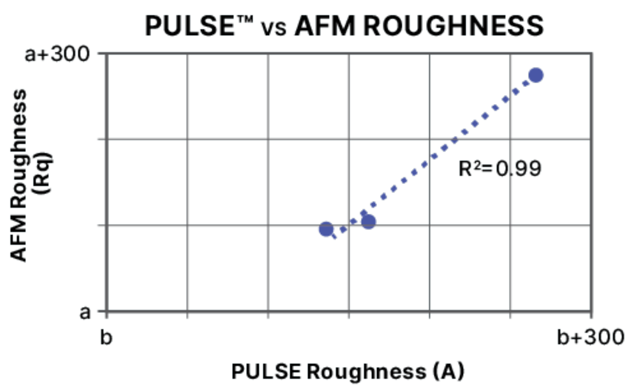


Figure 3: The correlation of PULSE measurement to transmission electron microscopy (TEM) and atomic force microscopy (AFM).

## Conclusion

Silicon-carbide (SiC) power devices are destined to be one of the major drivers enabling the growth of hybrid and electric vehicles, among other green innovations. But due, in part, to the trench-based structures of these SiC power devices, manufacturers need to be prepared to avoid many of the process control obstacles in their way. With FTIR, OCD and picosecond ultrasonics metrology, SiC power device makers have several options capable of addressing these challenges – and clearing the road to the future in the process.

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**About the author**

Nick Keller has been with Onto Innovation since its founding in 2019 and prior to that Nanometrics, which merged with Rudolph Technologies to become Onto, since 2007. Keller is now a Director of Applications Development and has been instrumental in developing infrared critical dimension technology and providing pathfinding simulations in support of other new products at pre-initiation phases. He has seven issued patents and over 25 publications.