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Measuring Multi-Layer Ultra-Thin Critical Films

By Jiangtao Hu,
Onto Innovation

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Artificial intelligence is one of the driving forces in today's semiconductor industry, with more traditional market drivers like high performance compute and smart phones continuing to play important roles. This situation is unlikely change in the years ahead as chip makers continue their quest to create the most advanced nodes. With 3nm nodes in production and 2nm nodes on the horizon, the importance of film measurement only grows in significance as fabs seek to maintain the performance and reliability of cutting-edge devices.

Film metrology is an essential part of semiconductor manufacturing, whether you are dealing with material discovery, technology development, equipment or process control. In a typical semiconductor device manufacturing cycle, there are hundreds of film deposition and removal steps. In addition, film deposition and removal are also commonly used to monitor equipment health. Many of these steps use film measurement tools to ensure that equipment and processes are meeting production requirement.

Films are generally divided into two categories: common film or critical film, based on film thickness, complexity and process control requirement. Critical films are generally ultra-thin (e.g., less than 20Å) and are used for the most critical process steps. They require very tight control limits for precision and long-term stability. Common films, on the other hand, are relatively thick and require less strict control.

For the purpose of this blog we are going to focus on a specific critical film: gate oxide.

As you know, gate oxide is the most critical components of a transistor. The quality and effective thickness of gate oxide largely determines the speed, power consumption and reliability of the transistor.

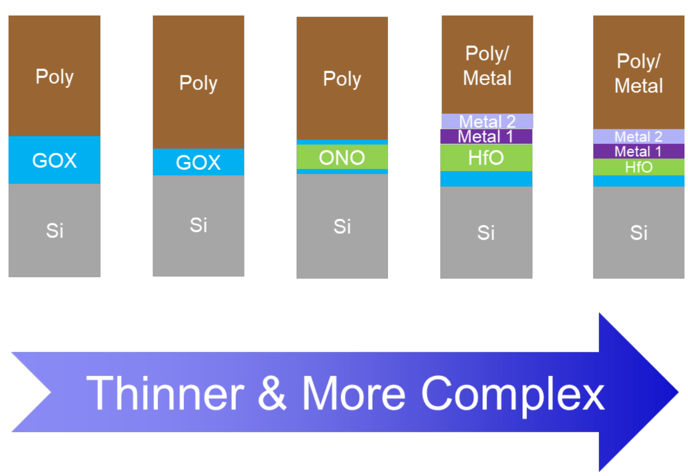

Figure 1: Films are becoming thinner and more complex

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Over the years, the film thickness of gate oxide has become thinner, more complex and materially more diverse. These changes have led to a number of metrology challenges, including:

- Common spectroscopic ellipsometry doesn't meet long term stability of gate oxide measurement.
- Single wavelength ellipsometry (SWE), which is currently used for ultra-thin film measurement, only works for single layer films and is relatively slow.
- Multi-layer high-K metal gate (HKMG) film stacks require the adoption of a feedforward process.

Spectroscopic ellipsometry is widely used for film thickness measurement. It is a non-destructive, noncontact, and non-invasive optical technique capable of measuring a wide variety of films used in the semiconductor process. However, due to the complexity of the spectroscopic ellipsometry system, it is prone to change over time and difficult to meet the strict long-term stability requirements of critical films.

Alternatively, single wavelength ellipsometry (SWE) is used for single layer critical film measurements. SWE is capable of meeting the long-term stability requirement of critical film measurement. However, with limited information from single wavelength, SWE is incapable of measuring the complex multi-layer films used as gate films in advanced transistors. As a result, manufacturers are limited to measuring only one layer of these critical films at a time. This reduces efficiency and increases operation cost.

To meet the challenges of the leading-edge devices including the measurement of multi-layer ultra-thin critical films, we propose using an advanced thin film system that combines deep ultraviolet spectroscopic ellipsometry with a laser ellipsometry technology.

While deep ultraviolet spectroscopic ellipsometry provides rich high precision measurements for complex film stacks, laser ellipsometry enhances long term stability and provides additional information to decouple multi-layer films. The benefits of this new technique only increase when they are combined with common film applications on a single platform. Not only does a single platform offer customers the flexibility to optimize cost of ownership and performance based on their needs, a single platform simplifies fleet management and fab operations while reducing overall capital investment.

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Conclusion

The integration of deep ultraviolet spectroscopic ellipsometry with laser ellipsometry technology is a novel advancement in the measurement of multi-layer ultra-thin critical films, one that offers a versatile solution for both critical and common film applications. Metrology innovations such as these will be crucial in maintaining the performance and reliability of leading-edge devices as the manufacturers march toward more advanced nodes.

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About the author

Jiangtao Hu is Senior Director of Product Management at Onto Innovation.