APPLICATIONS NOTE

Topography Sensor Technology for Stylus Profilers

Attila Sirovita

Introduction

Stylus profilometry was developed in the late 1920s as a method to accurately measure the topography of a sample. This is typically done to measure a step height, such as the deposition thickness of a film or the etch depth of a feature, as well as to measure the roughness of the surface. The advantage of a stylus profiler is that is a direct technique that is not influenced by the properties of the surface. Over the years the method to make these measurements has continuously improved. One critical area of improvement is the Topography Sensor.

Background

Stylus profilometry sensor design has four main components, shown in Figure 1:

1. Topography Sensor
2. Pivot
3. Force Compensation
4. Stylus

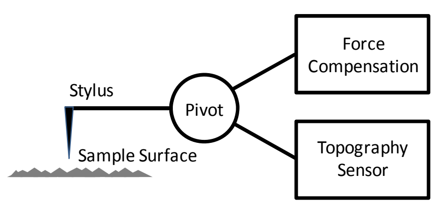

Figure 1 Stylus Profiler Sensor Schematic

The Topography Sensor is used to track the surface of the sample being measured. The design of the LVDT, Optical Lever, and LVDC sensors will be discussed in the next section.

The Pivot connects the stylus to the Topography Sensor, translating the change in motion from the stylus to the sensor. Low mass, frictionless pivots are used so that the signal read by the sensor accurately represents the surface topography.

The Force Compensation mechanism is connected through the pivot to determine the amount of force that will be exerted on the sample surface. This can be applied open or closed loop. Open loop will apply a constant force at the pivot and closed loop will apply a constant force on the sample surface. Force Compensation can be controlled through manual adjustments or through software.

The Stylus is used to track the topography of the surface. It is typically manufactured from diamond and comes in a variety of sizes to support various applications.

Topography Sensor

There are three main sensor technologies that are commonly used with stylus profilers. Each will be reviewed to understand the design and performance.

Linear Variable Differential Transducer (LVDT)

The LVDT sensor technology was first developed in the 1930s and it is the oldest sensor design used for stylus profilometry. Figure 2 shows the AlphaStep-IQ (ASIQ) LVDT sensor schematic.

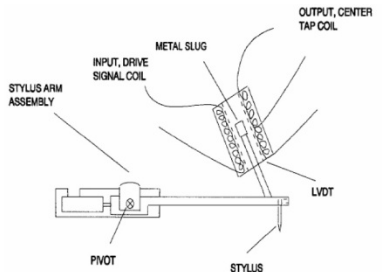

Figure 2 ASIQ Sensor Schematic

The LVDT sensor tracks the surface topography through changes in voltage (Baumeister 1967). This change results from motion within the coil of an arm with a metal slug. The position of the arm changes as the stylus tracks the surface, resulting in changes in the voltage, which is converted to a topography signal.

The advantage of the LVDT design is its large vertical range and has a long history of reliable performance. The weakness is that the motion of the arm will heat over time, which reduces long-term measurement stability.

Optical Lever

The Optical Lever sensor technology was developed on the AFMs in the 1980s (Myer 1988) and was adapted to stylus profilometry in the 2000s. Figure 3 shows the AlphaStep D-Series Optical Lever sensor schematic.

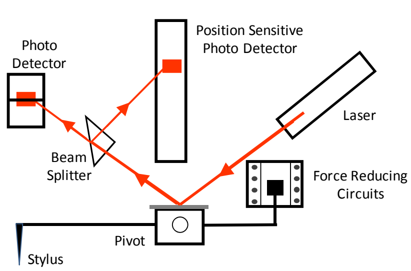

Figure 3 D-Series Sensor Schematic

The Optical Lever sensor tracks the surface topography by using a laser beam reflected off the top surface of the pivot assembly. The reflected beam is then projected on a photo detector. For the D-Series, the beam is split into two components. One side is projected onto a dual cell photo detector while the other side is projected onto a single cell photo detector. This design enables high resolution measurements of smaller steps on one detector and measurement of larger steps on the second detector. The deflection of the laser beam changes as the stylus tracks the surface, which is sensed by the photo detector, which is converted to a topography signal.

The advantage of the Optical Lever is the low mass of the entire assembly, enabling low force measurements. In addition, this sensor has a fast response for tracking changes in the surface topography.

Linear Variable Differential Capacitor (LVDC)

The LVDC sensor design technology was developed in the 1990s to solve the limitations of the LVDT sensor technology (Wheeler 1994 and Eaton et al 1998). Figure 4 shows the P-Series LVDC sensor schematic.

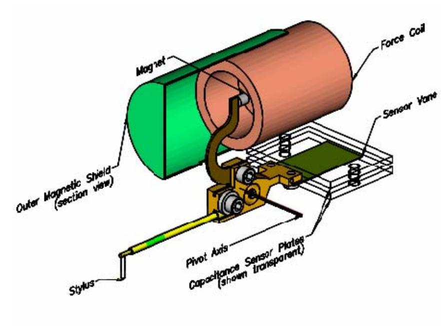

Figure 4 P-Series Sensor Schematic

The LVDC sensor tracks the surface topography by using a change in capacitance. This change results from the motion of a thin metal sensor vane moving between two capacitor plates. The position of the sensor vane changes as the stylus tracks the surface, resulting in changes in the capacitance, which is converted to a topography signal.

The advantage of the LVDC design is the low mass of the entire assembly enabling low force measurements. In addition, the change in capacitance is very stable over time and provides very high vertical resolution.

KLA-Tencor Profilometers

The stylus profilers from KLA-Tencor use different Topography Sensors, with the choice depending on our customer's surface topography measurements requirements.

AlphaStep-IQ Stylus Profiler

Figure 5 shows the ASIQ stylus profiler. This is the latest generation stylus profiler that was originally developed in 1975. This design uses the LVDT senor technology.

Figure 5 ASIQ

The LVDT sensor on the ASIQ is able to measure features up to 2 mm in height or depth, offering the largest vertical range within the KLA-Tencor product family. The design uses a mechanical adjustment of the force, which results in a constant force on the pivot, enabling stable measurements. The weakness of this force control design is that it results in a changing force on the substrate as a function of the height of the step. This generally only impacts a subset of low force applications. This is a common limitation of the LVDT sensor designs. The ASIQ design allows for a force between 1 to 100 mg.

D-100 and D-120 Stylus Profilers

Figure 6 shows the D-100 and D-120, D-Series stylus profilers. These profilers were designed in 2000 and utilize the Optical Lever sensor technology.

Figure 6 AlphaStep D-100 and D-120

The Optical Lever design on the D-Series profilers is able to measure features up to 1.2 mm in height or depth. The design uses an electronic force compensation circuit which enables software control of the applied force. The force applied is open loop, resulting in a constant force on the pivot. The disadvantage of this force control is that it results in a changing force on the substrate as a function of the step height. The D-Series design allows for a force between 0.03 to 15 mg.

P-6 and P-16+ Stylus Profilers

Figure 7 shows the P-6 and P-16+, P-Series stylus profilers. This the latest generation of the P-Series stylus profilers originally developed in 1990. This design uses the LVDC sensor technology.

Figure 7 P-6 and P-16+

The LVDC sensor on the P-Series is able to measure features up to 1 mm in height or depth. The design uses an electronic force coil which enables software control of the force. The force is applied closed loop resulting in a constant force on the substrate; the force on the pivot changes as a function of the step height. The closed loop design enables application of low force, regardless of the step height, which is critical for accurate measurements of soft samples. The P-Series is the only stylus profiler on the market with constant force control. The P-Series design allows for a force between 0.03 and 50 mg. A similar sensor design is also employed on the automated HRP-250 and HRP-350 stylus profilers.

Conclusion

With the three different Topography Sensor technologies KLA-Tencor has the necessary range of capabilities to address the surface metrology challenges faced by our customers, whether in a R&D or production environment. With over 35 years of experience and a long history of success in the stylus profilometry industry, KLA-Tencor stands confident that we can help our customers with their current and future surface metrology requirements.

References

Myer, G, et al (1998) *Novel Optical Approach to Atomic Force Microscopy.* Applied Physics Letters, 53, 1045-1047

Baumeister, Theodore, et al (1967) *Standard Handbook for Mechanical Engineers.* McGraw-Hill, LCCN 16-12915

Wheeler, William (1994) *Profilometer Stylus Assembly Insensitive to Vibration*, US Patent 5309755

Eaton, Steven, et al (1998) *Constant-Force Profilometer with Stylus-Stabilizing Sensor Assembly, Dual-View Optics, and Temperature Drift Compensation*, US Patent 5705741

KLA-Tencor
GEM – Candela Division

www2.kla-tencor.com/profiler_inquiry
info@kla-tencor.com
www.kla-tencor.com

One Technology Drive
Milpitas, CA 95035
408-875-3000