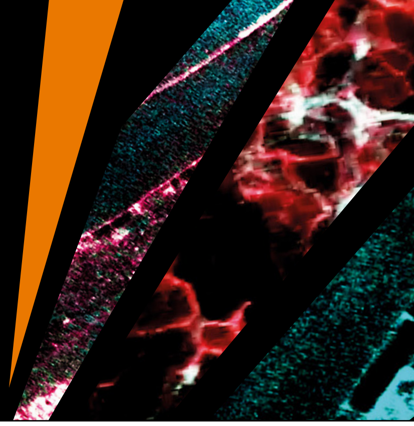
Chromacity™

CHARACTERISING THIN FILMS USING PICOSECOND LASER ULTRASONICS

Advanced semiconductor metrology making use of the Chromacity 520

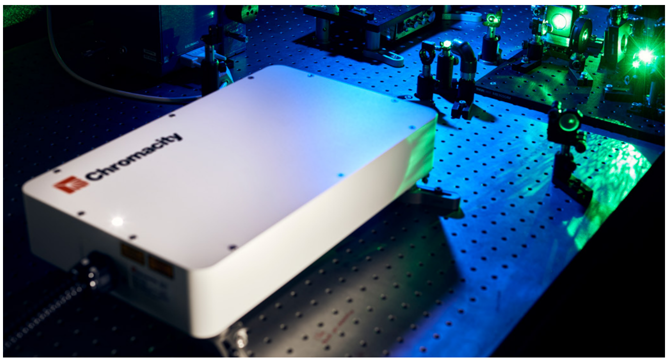


Introduction

Picosecond ultrasonics has become a widely used metrology tool in the semiconductor device industry. It provides an accurate method for the measurement of the thickness of thin films, can determine the quality of the bonding between a film and a substrate, and gives information about the mechanical properties. The overlay and alignment of a lithographically defined pattern on top of an underlying layer is fundamental to device performance.

There are a wide variety of optical techniques that are used to monitor this alignment in conventional production flows. Typically, either an ultraviolet, visible, or infrared light is coupled through a top photoresist layer or an etched hard mask to be aligned to the bottom layer. However, in some production flows there may be an opaque layer that interferes with the measurement. In such cases, conventional methods of alignment using light fail. To overcome this issue, extra patterning operations may be used to open areas around the alignment features, but these operations add significant process cost.

The picosecond laser acoustics (PLA) technique has been widely used in thin metal film metrology because of its unique advantages such as being a rapid, non-contact, non-destructive technology and its capabilities for simultaneous multiple layer measurement (even through opaque layers). Measuring velocity and thickness simultaneously for transparent and semi-transparent films offers the ability to not only monitor the growth process but offers insight into device performance.



Ultrasonic Technique

PLA is a well-established technique with an extensive publication history. Briefly, an ultra-fast laser generates light pulses of duration 100 to 200 fs with a repetition rate typically around 80 MHz. Each pulse is divided by a beam-splitting mirror to give a "pump" pulse and a "probe" pulse. The pump pulse is focused onto a selected area of the surface of the sample, and the absorption of the light results in the generation of a sound pulse. The sound propagates through the sample and when it reaches an interface is partially reflected back to the sample surface.

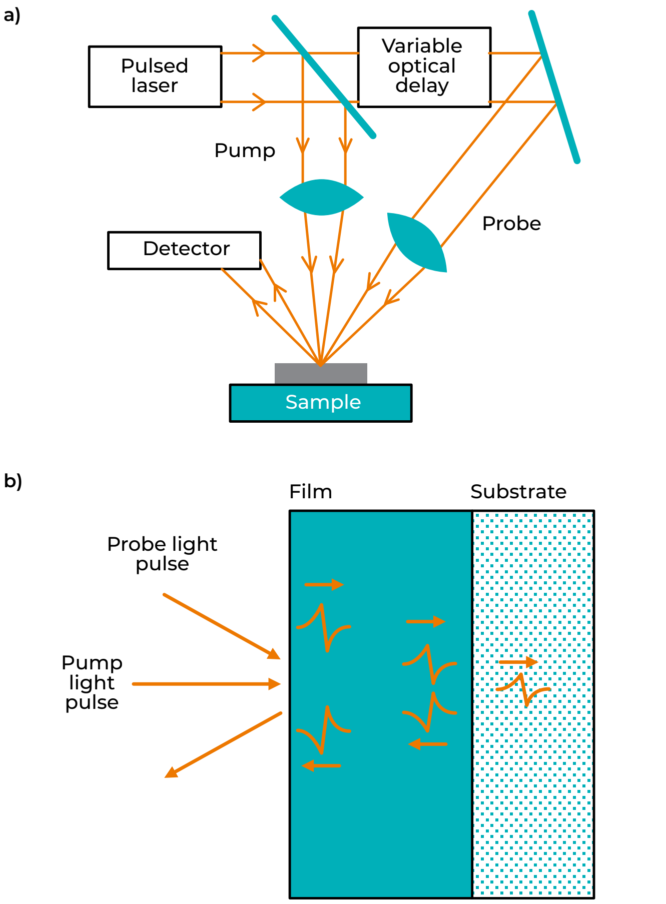


FIGURE 1. a) Block diagram of typical setup. b) A strain pulse is generated by the pump, is reflected at the interface between the film and the substrate, and is detected by the probe pulse when it returns to the free surface.

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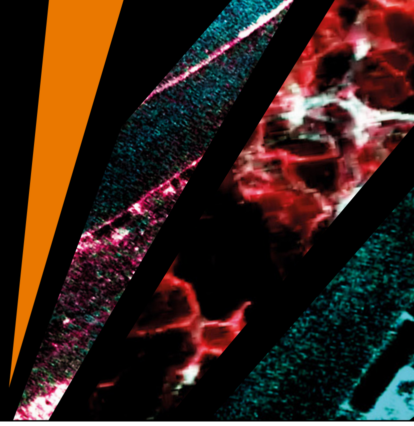


The returning sound causes a small change in the optical reflectivity of the sample and this change is measured with the probe light pulse. The time of arrival of the probe pulse relative to the time of application of the pump is adjusted through the use of a variable optical path.

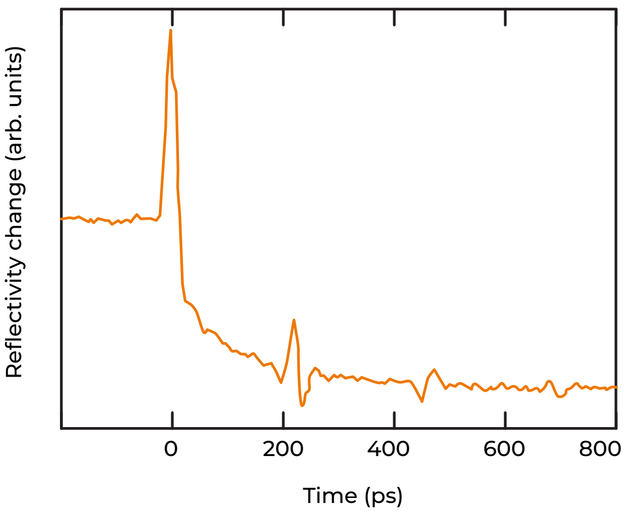
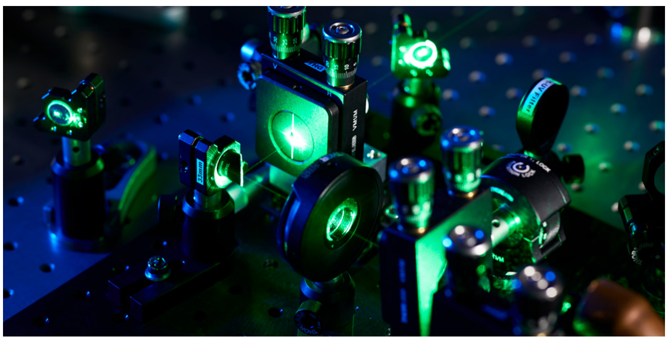


FIGURE 2. Example of acoustic echoes detected in a film of As_2Te_3 of thickness 2200 Å.* These echo signals can provide a high-resolution measurement of the thickness of the layer.



Technology Fit

One of the unique advantages of PLA technology is that it offers a first-principle approach to modelling the measured data. Thickness measurements rely on locating the echoes and transit time of the acoustic pulse through the films. Using the known speed of sound from literature, the thickness of a particular layer can be readily calculated without the need for additional calibration. Competing technologies like X-ray metrology require daily or weekly standards and cannot measure repeating layers in a multi-layer stack.

The PLA technique can measure metal films with thicknesses ranging from 50Å to 35 µm. Measurements take a few seconds per site and the high throughput allows mapping of a whole wafer in minutes.

Over the years the technique has been refined to the point that it has also show sensitivity to detect concentration changes by monitoring the changes in velocity of the sound wave.

Chromacity laser for ultrasonic technic

The Chromacity 520 offers characteristics in line with the requirements to execute PLA and flexibility to progress towards better metrology equipment performance:

Chromacity 520 core specifications:

Wavelength	520 nm
Pulse duration	100 – 200 fs
Repetition rate	50 – 200 MHz
Pulse energy	Up to 80 nJ if required

* C. Thomsen, H.T. Grahn, H.J. Maris and J. Tauc, Phys. Rev. B34, 4129-4138 (1986)

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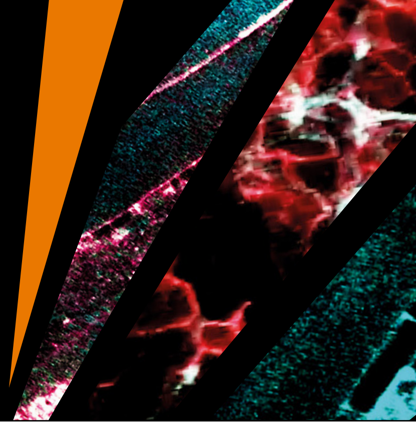

The Chromacity 520 offers characteristics in line with the requirements to execute PLA and flexibility to progress towards better metrology equipment performance.

Wavelength

Aluminium has largely been replaced by copper which has lower resistivity. It turns out that at the light wavelength generated by the first generation of compact ultrafast laser (800 nm), the piezo-optic coefficient of copper is extremely small. Thus, the change in optical reflectivity due to the returning sound echo is too small to measure accurately. To overcome this difficulty, it has been necessary to frequency double the light from these near-IR lasers. This is why fixed wavelength sources operating at ~520 nm are the ideal candidates for this technique.

Pulse Duration

To create an acoustic wave within a device the pump pulse must be of the order of 100 – 200 fs. This allows the creation of a kW peak power pulse within the device without generating unwanted thermal expansion. Shorter pulses, allowing thinner layer measurements, become critical considering the year-on-year reduction of film thickness. The Chromacity 520 offers stable and clean ultrashort pulses guaranteeing accurate results for metrology equipment measuring today's films but also the next generation to come.

Repetition Rate

Pulse repetition frequencies of 63 – 80 MHz have been cited in the literature. The higher the repetition rate the quicker the measurement. 80 MHz is the typical repetition rate used for the first generation of ultrafast lasers emitting at 800 nm. Chromacity technology platform allows an access to higher repetition rates (up to 200 MHz) that could, in the near future, be more appealing for PLA to reduce the time required to perform measurements, thus increasing the efficiency and cost of metrology equipment.

Pulse energy

Pulse energies for PLA are of the order of a few nJ at the sample plane (the literature indicates typically pulse energies ~0.5 nJ). This fits well with the high repetition rate nature of the Chromacity laser systems. With higher pulse energy, measurements of thicker films can be achieved, which is well within the Chromacity 520 capabilities. Our unique patented laser platform can achieve up to 80 nJ pulse energy (depending on repetition rate and pulse durations) with no compromise on the laser stability over time.

Chromacity 520 offers stable and clean ultrashort pulses guaranteeing accurate results for metrology equipment measuring today's films but also the next generation to come.

For more information about Chromacity capabilities for semiconductor applications: https://chromacitylasers.com/applications/lasers-semiconductor-failure-analysis/

For more information about the Chromacity 520 ultrafast laser: https://chromacitylasers.com/ultrafast-lasers/chromacity-520/

Learn how our ultrafast lasers can enable you to discover more.
For more information, email: sales@chromacitylasers.com