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Application note A147:
Surface Acoustic Wave (SAW)

Advanced metrology tool for surface acoustic wave (SAW) devices

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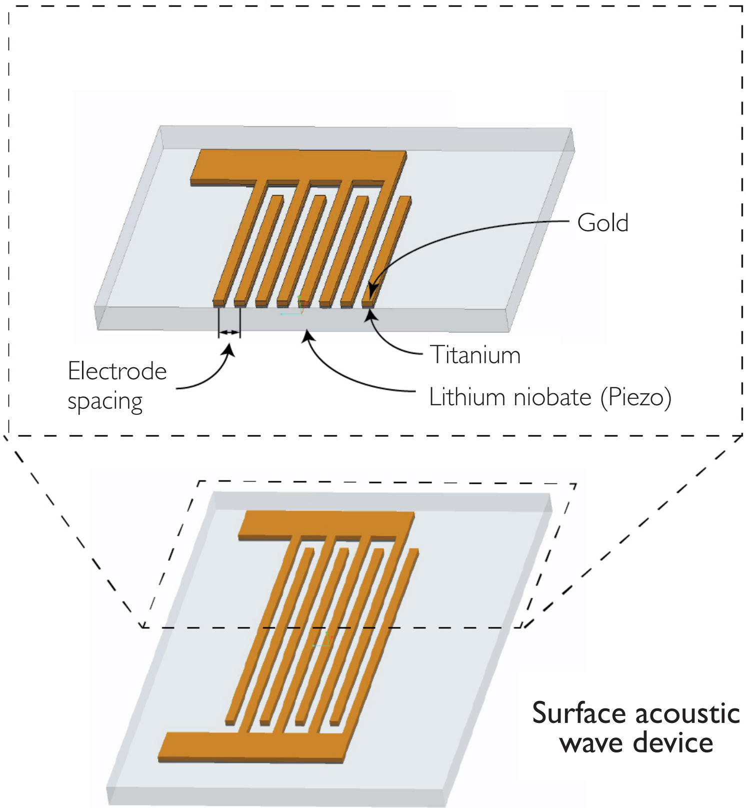
Surface acoustic wave (SAW)

Surface acoustic wave (SAW) devices are based on the transduction of acoustic waves. The transduction from electric to mechanical energy (and vice versa) is accomplished by means of interdigitally structured piezoelectric materials. As filters, oscillators or transformers, these devices are at the heart of a wide range of high-performance commercial and research products, such as mobile phones, telecommunication filters, quality control gas detectors and biomedical sensors. This is because they constitute ultrahigh stable oscillators that also exhibit a strong frequency response as a function of the mechanical properties of the substrate of patterned surface.



Surface acoustic wave device

Importance of controlling SAW devices

These devices typically comprise of two interdigital comb-shaped metal electrodes deposited on the surface of a piezoelectric substrate and coated with a thin insulating film (see figure 1). The finger spacing of the comb-shaped electrodes ranges from 10 microns to less than a micron, while the thickness of the metal layer and thin film coating spans from 1 micron down to few tens of nanometers.

Since SAW devices are resonators, the geometry of the patterns such as the finger spacing, the step heights (between the metal electrodes and the piezoelectric substrate) and their uniformity directly influence the resonant frequency and its bandwidth. Incorrect spacing and step heights may cause higher loss of the stored energy from the resonator

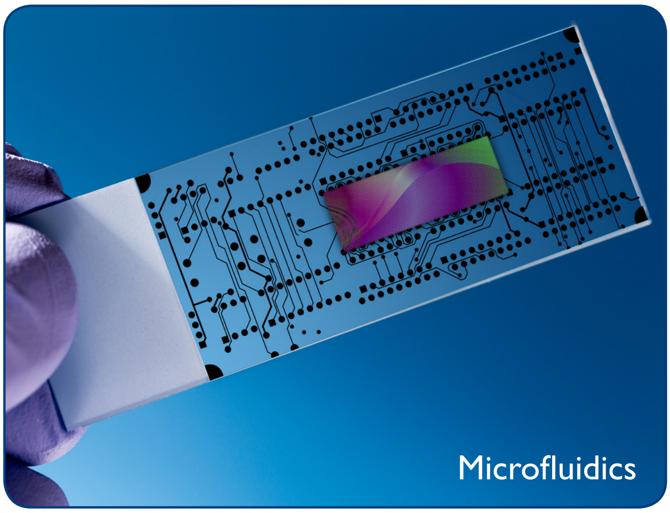
The performance of SAW device is strongly related to these designed parameters, therefore the assessment of the metal layer and insulating layer thickness on the production line is essential.

Issues of conventional techniques

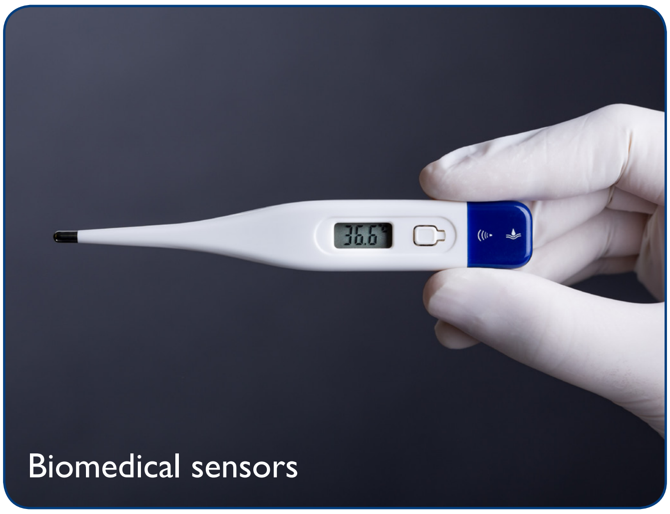
Performing these measurements with a stylus profilometer requires firstly the metal layer to be inspected prior the deposition of the insulating overlay, and secondly the etching of part of the device to enable investigation of the coating process. This is an invasive method.

This issue can be overcome by CSI optical profilometry that provides non-destructive testing of high aspect ratio structures with nanometric vertical dimensions and submicron lateral scale. A well-known challenge in optical profilometry is the measurement of the step-height between two dissimilar surfaces; this is the case in surface acoustic wave quality control as there are metal electrodes deposited on top of a piezoelectric substrate, subsequently buried under a thin transparent film.

Mobile SAW filters



Microfluidics



Biomedical sensors

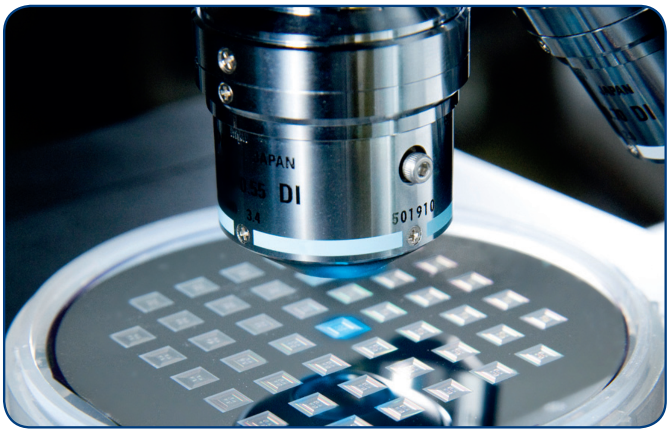
Telecommunications

Advanced non-contact measurement technique – CCI [1]

The non-contact Coherence Correlation Interferometry (CCI) instrument is an advanced coherence scanning interferometer which provides fast and accurate high-resolution 3D surface measurements and film thickness measurements.

Through the knowledge of thin film structure and Taylor Hobson's patented 'Films and Materials' technique [2, 3], the DC shift (shift of the fringe envelope) due to the phase-change on reflection (PCOR) for both dissimilar material step and thin film step can be compensated so that the 'true' step-heights are determined. Therefore it has become the ideal method to obtain not only film thicknesses and interface information but also true step heights for dissimilar material steps and thin film steps.

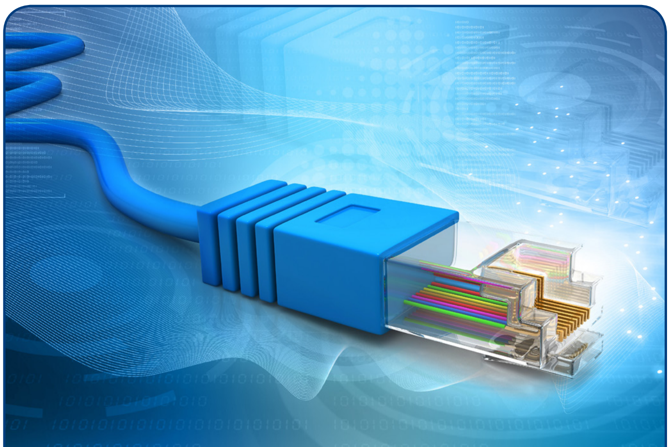
A SAW based device having application in microfluidics [5, 6] has been studied using different techniques and the correlation study results are shown in this note. In addition, this note also includes some correlation study results by means of six reference thin film steps.



Applications

- Mobile SAW filters
- Gas detectors
- Biomedical sensors
- Telecommunications
- Microfluidics…

Gas detectors



Telecommunications

Coherence Correlation Interferometry (CCI)

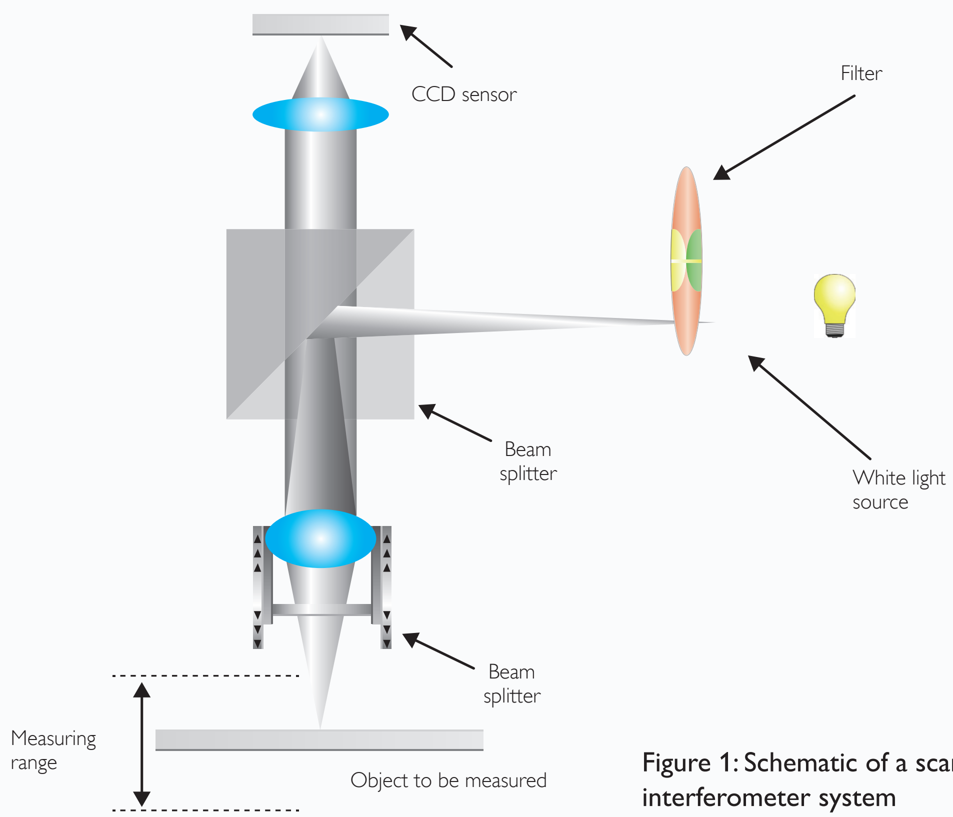


Figure 1: Schematic of a scanning interferometer system

"The wide variety of industrial applications mean that Coherence Correlation Interferometry is increasingly important"

Dr Mike Conroy, Business Development Manager, Taylor Hobson Ltd.

A schematic of a scanning interferometer system is shown in Figure 1. Light from the light source is directed towards the objective lens by the upper beam splitter and the light is then split into two separate beams by the lower beam splitter.

One beam is directed towards the sample and the other is directed towards an internal reference mirror. The two beams recombine and are sent to the detector. As the interferometric objective is scanned in the z direction, interference occurs when the path lengths of the two beams are the same. The detector measures the intensity, taking a series of snapshots as the sample is measured.

This creates an intensity map of the light being reflected from the surface, which is then used to create a 3D image of the surface being measured. Different techniques are used to control the movement of the interferometer and also to calculate the surface parameters. The accuracy and repeatability of the scanning white-light measurement are dependent on the control of the scanning mechanism and the calculation of the surface properties from the interference data.

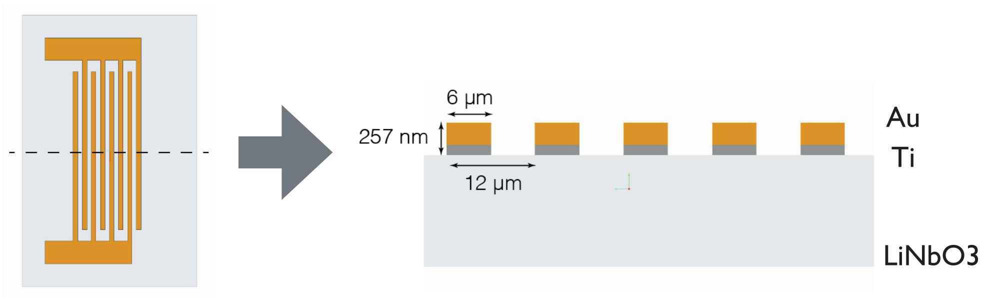
Coherence Correlation Interferometry[1] is becoming increasingly important for measurements in many applications, providing:

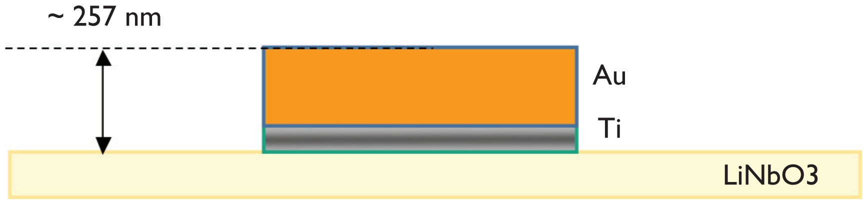
- Fully automatic non-destructive measurements
- Accurate and quantitative characterization of surfaces
- Sub-angstrom resolution regardless of the scanning range used
- Fast and convenient sample loading and set-up
- Capability of measuring a wide range of materials
- Highly repeatable measurements
- Roughness and step-height analysis in one measurement
- Film thickness and interfacial surface measurement capability
- Real dissimilar material correction

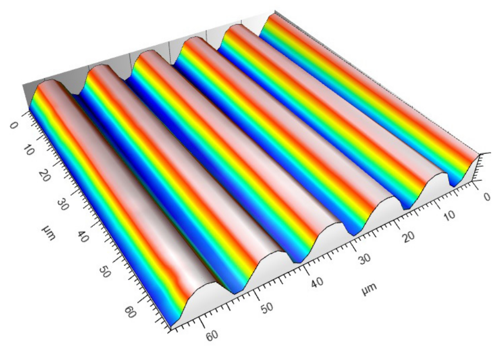
Case 1 – A typical SAW sample with dissimilar material steps

A typical sample used for SAW device, comprises of comb-shaped metal electrodes deposited on the surface of a piezoelectric substrate prior the deposition of the insulating film was studied using different techniques. The step height result using 'Films and Materials' technique on CCI HD was compared with CCI standard step measurement and stylus profilometry method.

Sample information





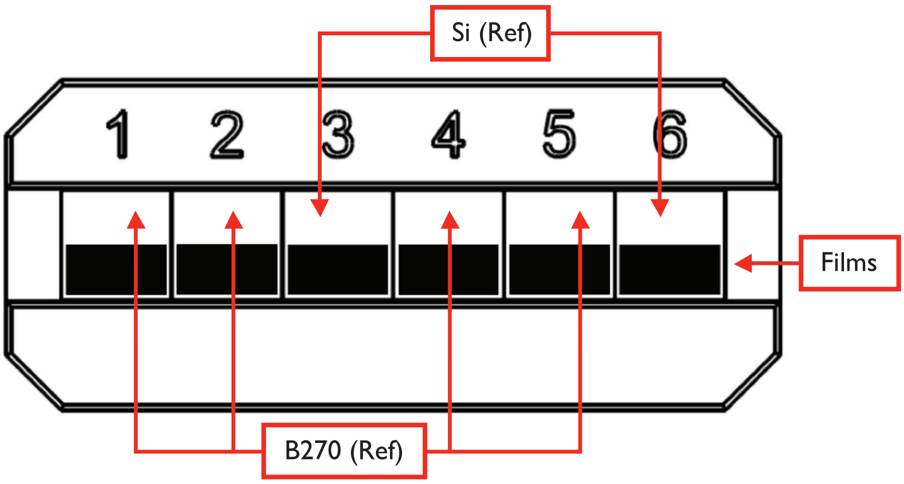


A 3D image from the CCI measurement

Measurement technique	Step-height results	
CCI standard step	227 nm	✘
CCI (Films and Materials)	~259 nm	Best
Stylus Profilometry	~257 nm	OK

Case 2 – Thin film step measurements

The 6 reference thin film steps were used in this study, the thin film step height results using 'Films and Materials' technique on CCI HD were compared with other techniques include spectrophotometry and film thickness measurement.



Step height comparison results

Thin film step (reference films)

	Film 1	Film 2	Film 3	Film 4	Film 5	Film 6
Film/substrate	Ta205/ B270	Ta205/ B270	Si02/Si	Ta205/ B270	Ta205/ B270	Si02/ Si
Film thickness (spectrophotometer) (nm)	48.8	98.5	311.1	504.6	1002.2	994.5
Mean film thickness (film thickness measurement) (nm)	52.5 ± 0.6	99.1 ± 0.3	312.8 ± 0.3	505.1 ± 0.6	1003.4 ± 1.2	996.9 ± 1.2
Mean step height (dissimilar material step measurement) (nm)	**56.1 ± 0.7**	**97.3 ± 0.3**	**315.9 ± 2.1**	**514.1 ± 1.1**	**994.8 ± 1.6**	**1014.6 ± 1.6**

Good correlation results

The study results showed that the patented 'Films and Materials' technique can provide accurate and reliable dissimilar material step height results

Conclusions

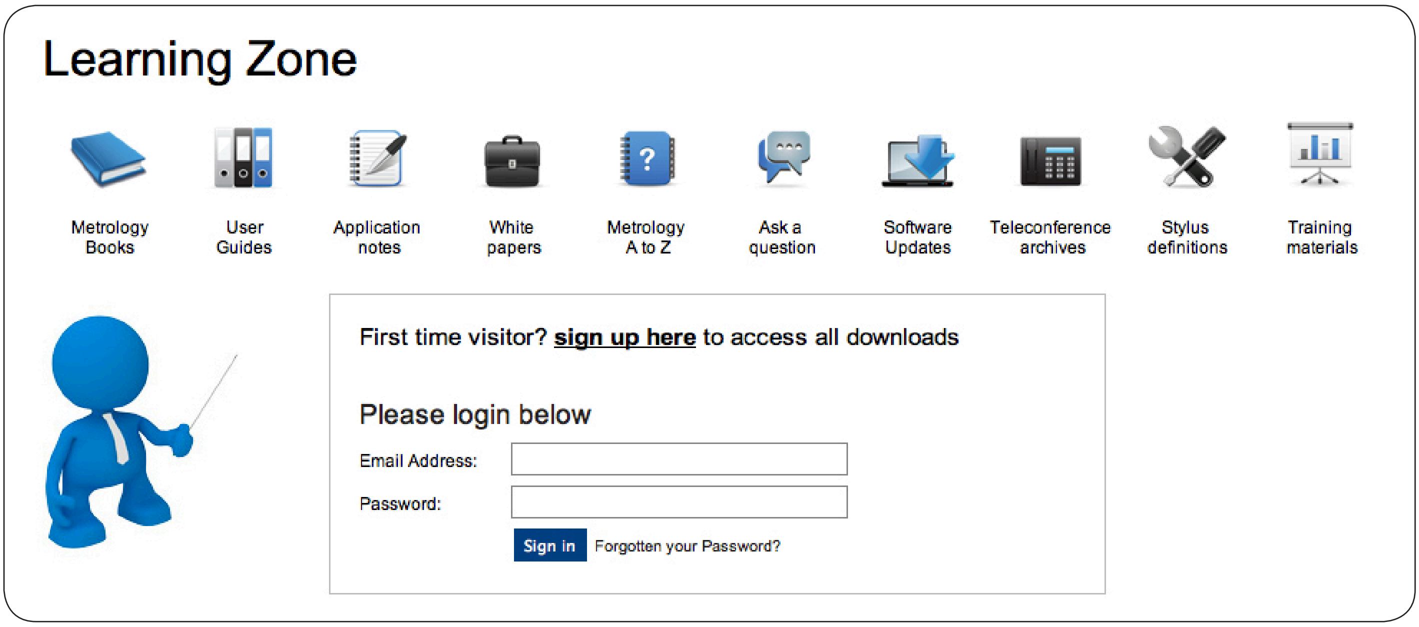
'Films and Materials' technique can eliminate the step height measurement errors caused by the distortion of the fringe series due to PCOR (phase change on reflection) from both thin film steps and dissimilar material steps.

Through the development of 'Films and Materials' technique, coherence correlation interferometry (CCI) has become the ideal method to obtain not only film thicknesses and interface information but also true step heights for dissimilar material steps and thin film steps. It allows us to precisely measure the important geometrical parameters of SAW device such as the step heights, finger spacing and their uniformity, ensuring high quality of SAW device production.

References

1. A. Bankhead et al, Interferometric Surface Profiling, GB2390676, 2004
2. Mansfield, D., 'The distorted helix: thin film extraction from scanning white light Interferometry,' Proc. SPIE vol6186, 2006
3. Mansfield, D., US7755768, 'Apparatus for and a method of determining a characteristic of a layer or layers', 2010
4. A125 Precise measurement of photoresist film thickness; A130 Accurate measurement of optical coating thickness; A131 Advanced metrology for anti-reflection coatings used in photovoltaics devices; A145 Accurate measurement of Diamond-Like Carbon (DLC) coating thickness; T153 Step height measurement errors caused by dissimilar materials and thin films; and T154 Error correction in different material step height mesurement using Coherence Correlation Interferometry.
5. Shilton, R. J., Travagliati, M., Beltram, F., Cecchini, M. "Nanoliter-droplet acoustic streaming via ultra high frequency surface acoustic waves". Adv. Mater., 26(29), 4941-4946, 2014
6. Travagliati, M., De Simoni, G., Lazzarini, C. M., Piazza, V., Beltram, F., Cecchini, M. "Interaction-free, automatic, on-chip fluid routing by surface acoustic waves". Lab Chip, 12(15), 2621-2624, 2012.

Application notes are available for download at www.taylor-hobson.com/learning-zone



Some other relevant application notes

A125 Precise measurement of photoresist film thickness

A130 Accurate measurement of optical coating thickness

A131 Advanced metrology for anti-reflection coatings used in photovoltaics devices

A145 Accurate measurement of Diamond-Like Carbon (DLC) coating thickness

T153 Step height measurement errors caused by dissimilar materials and thin films

T154 Error correction in different material step height mesurement using Coherence Correlation Interferometry

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