Step height measurement errors caused by dissimilar materials and thin films

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When a surface step also involves a change in material, interferometric techniques may fail to measure the step correctly. This is because different materials may cause a different 'phase change on reflection' (PCOR). This technical note explains the issues involved.

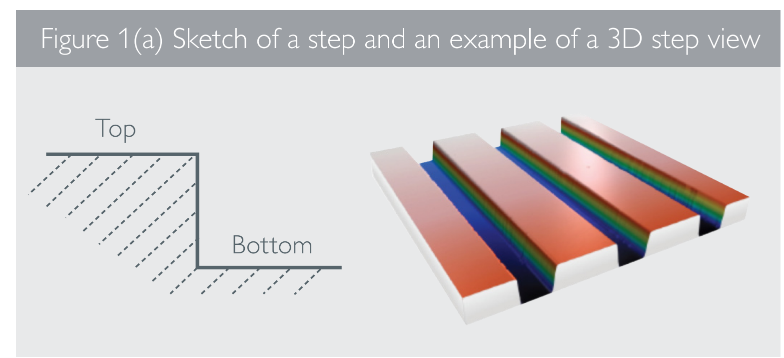
Technical note T154 shows how Taylor Hobson's CCI systems provide the solution for accurate measurement of 'different material step heights'.

1 Phase Change on Reflection (PCOR) (Figure 1b)

Phase change on reflection occurs, for example, when the top surface of a step is constructed of an absorbent metal or a semiconductor and where the bottom surface is constructed of a non-absorbent dielectric material. In addition, when either the top or bottom surface has a semi-transparent thin film coating, the difference in phase change on reflection may result in a considerable step height error.

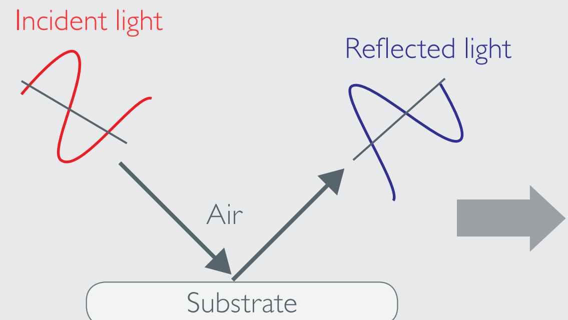
These two primary scenarios – dissimilar material step and thin film step - both lead to a variable phase-change on reflection, resulting in an incorrect measurement of step height.

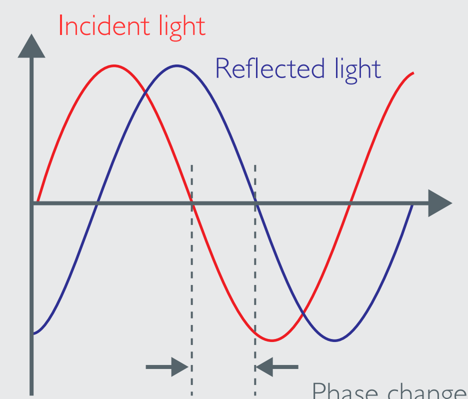
Figure 1(a) Sketch of a step and an example of a 3D step view



Notes: all dielectric (low absorption) materials are optically similar, even when the real refractive index is not the same. Therefore, a step comprising different types of non-absorbing dielectric material is not a 'dissimilar material step'.

Figure 1(b) PCOR – Phase Change on Reflection





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2 Step height measurement error (Figure 2)

n&k

Briefly considering these two scenarios, all metals, semi-conductors and dielectrics have a refractive index which is a function of wavelength and which consists of a real and imaginary component (n and k respectively); whilst n relates to the speed of light within the medium (and hence refraction), k relates to absorption (and hence such a PCOR).

Step height measurement error

These two scenarios of thin film steps and dissimilar material steps both give rise to a wavelength dependent phase-change on reflection. This inevitably distorts the interference pattern and leads to a DC-shift in the measured topographical surface, resulting in a step height measurement error.

Traditional error correction methods

The DC shift for a dissimilar material step is usually constant for a given material when using the same objective lens (NA) and light source (wavelength). It is possible to use a theoretical or empirical error correction for interferometric step height measurement; however, this may not be accurate due to the complexity and inconsistency of some materials. Taylor Hobson's CCI system deploys a more advanced method and this is described in Technical Note T154.

Large dissimilar material steps

Measurement step height errors due to phase-change on reflection are normally quite small for dissimilar material steps. These errors can be negligible when large steps of dissimilar materials are measured.

Figure 2(a) Step height measurement error source diagram

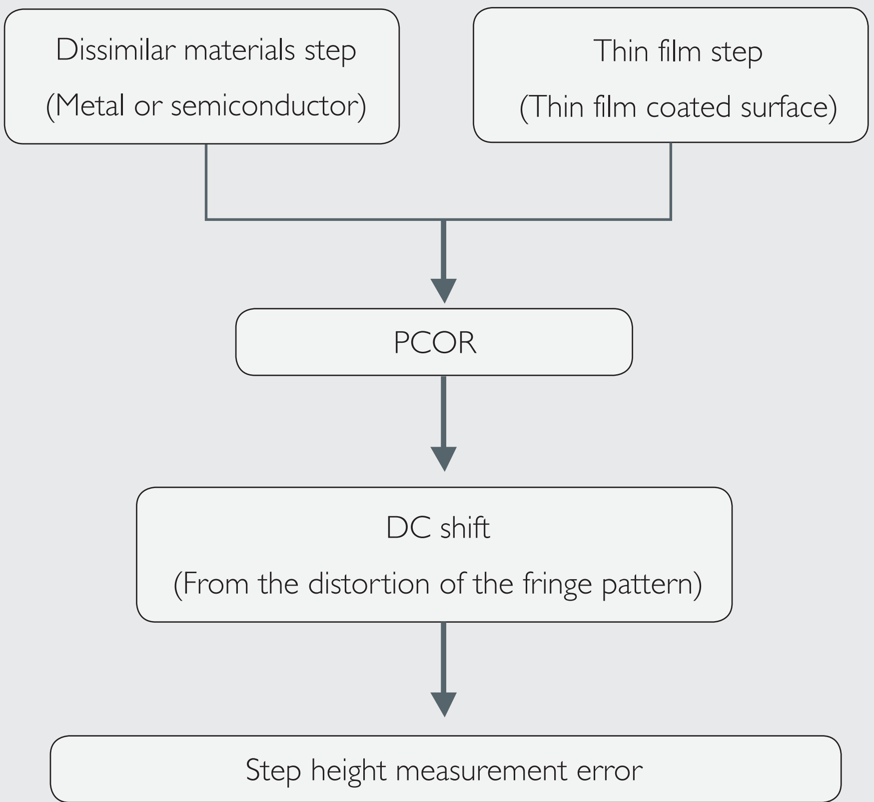

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Figure 2(b) Sketch of DC shift (shift of the fringe pattern)

Reflected light from sample surface

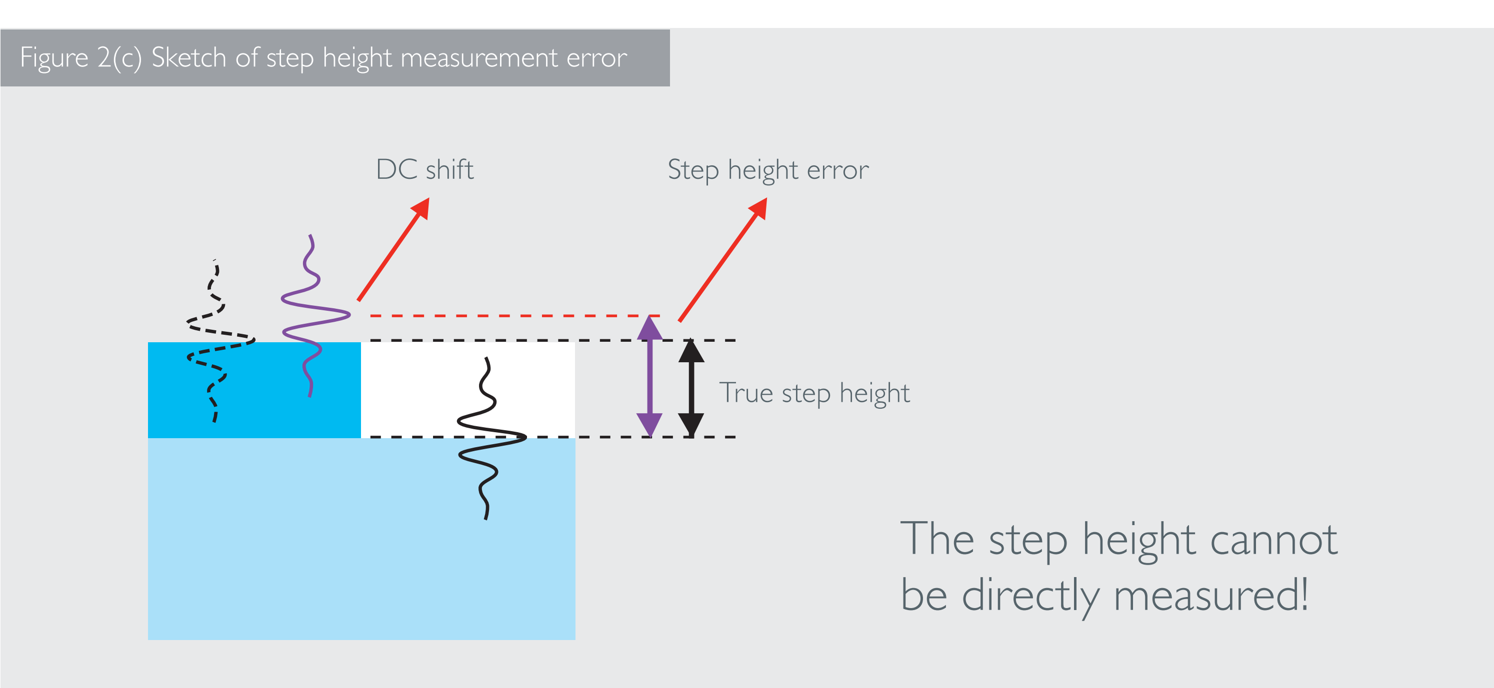
+

Reflected light from reference mirror

Interference

DC shift (led by distortion of the fringe pattern

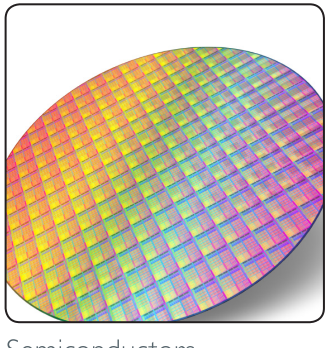
Figure 2(c) Sketch of step height measurement error

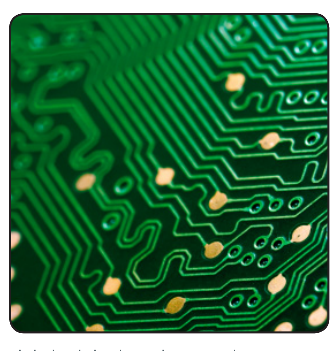


Typical applications where step height measurement is required

Mems devices

Solar PV


Semiconductors


Hybrid circuits and electrical contacts

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3 Case study

The graph below shows results of a synthesised standard step height measurement of SiO2 on Si (without PCOR correction). This is based on the material's properties (n and k values). The nonlinearity of the step height variations can be clearly seen. This is due to the distortion of the fringe series caused by phase change on reflection.

Figure 3(a) Synthesised step-height measurement: SiO2 on Si (SiO2 thickness 0 to 5 um; x10 lens, Daylight)

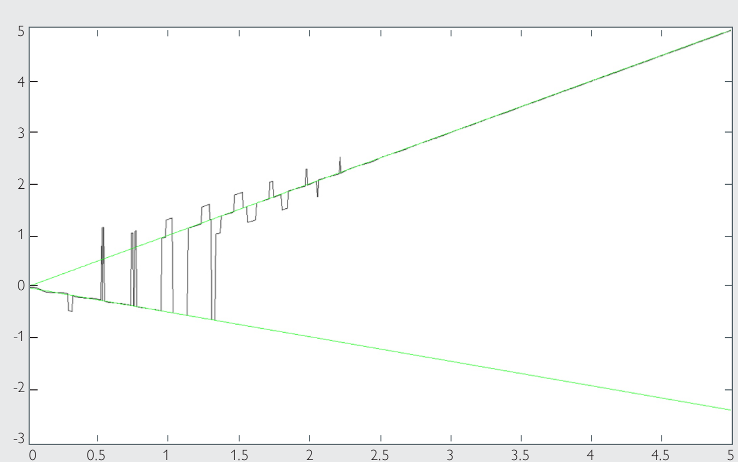
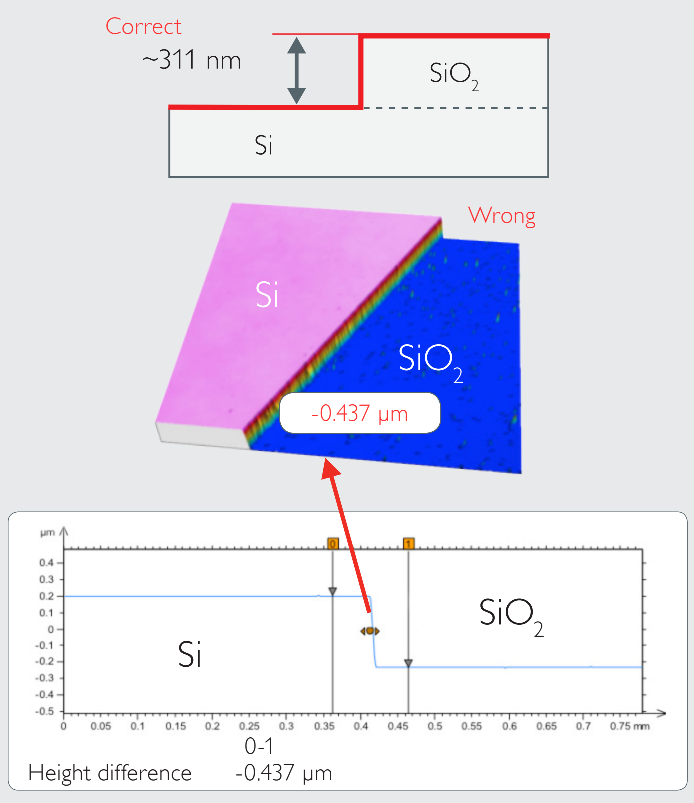


Figure 3(b) Example of actual measurement of a step height standard: ~311nm thickness of SiO2 on Si using a 10x lens and a white light source (top surface mode)



Errors in different material step heights when using standard measurement techniques

The presence of thin film SiO2 on the top of the step - in addition to the bottom surface being a semiconductor (Si) - results in a considerable distortion of the interference fringe series. This leads to a significant step height measurement error. The step, as indicated, is reversed and shows a negative step height value of ~437 nm.

4 Summary

Both thin film steps and dissimilar material steps give rise to a phase-change on reflection which inevitably distorts the interference series, resulting in the presence of a DC-shift in the measured topographical surface. This leads to step height measurement errors.

Technical Note T154 shows how Taylor Hobson's CCI system overcomes these issues and can successfully measure such 'different material step heights'.

References

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3 D. Mansfield, 'CCI simulation', (internal Taylor Hobson MATLAB program), 2013

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