TiN_x thin films

Since the titanium nitride (TiN_x) has a high thermodynamic stability, a low resistivity and can be deposited with a good step coverage, it is commonly used as *diffusion barrier in contact structures* of silicon integrated circuits. It can also be used as *Anti-Reflective Coating* (ARC) (*).

The structure described in figure 1 is an example of TiN_x application for metal interconnects. TiN_x films are used to improve the barrier integrity of the full metal stack TiN/AlCu/TiN/Ti in preventing junction leakage. The bottom TiN is used as barrier and the top TiN as ARC.
In both applications, it is important to characterise the thickness and the optical parameters of these films, because TiN_x films with different properties (optical and electrical) can be distinguished by their optical constants n (refractive index) and k (extinction coefficient).

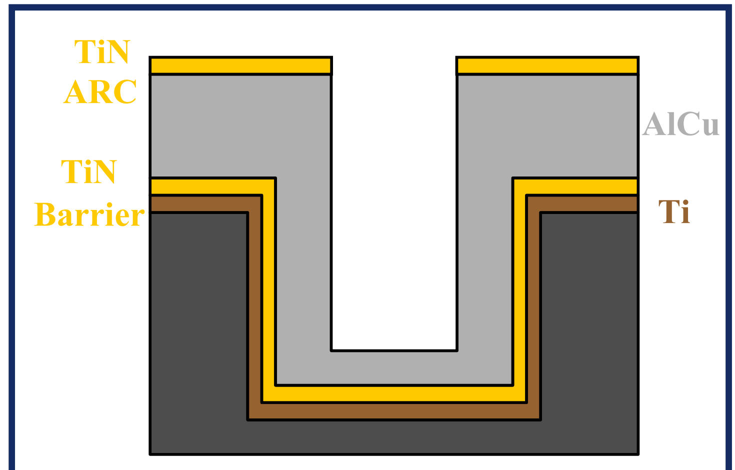


Figure 1

Such a characterisation can be made in a simple and straightforward manner. **Spectroscopic Ellipsometry (SE)**, which is rapid, contactless, non-destructive and allows on-line control, is an excellent technique to perform reliable and accurate characterisation of TiN_x films.

From the measurement of two parameters tan Ψ (amplitude) and cos Δ (phase), **thickness and optical parameters (n, k) can be extracted** (**). Figure 2 shows the optical constants of two different TiN_x layers on silicon substrate (respectively 355 and 365 Å thick) in the UV-visible-NIR (210-830 μm) spectral range.

The observation of the k parameter shows an absorption growth in the infrared part of the spectrum. This phenomena is related to electrical conductivity of the material. Therefore, in addition to optical properties and thickness, **SE provides a qualitative information on the electrical conductivity of the material through the extraction of the extinction coefficient k**: the highest this growth in the infrared, the more conducting the material is (TiN-2 is more conductive than the TiN-1).

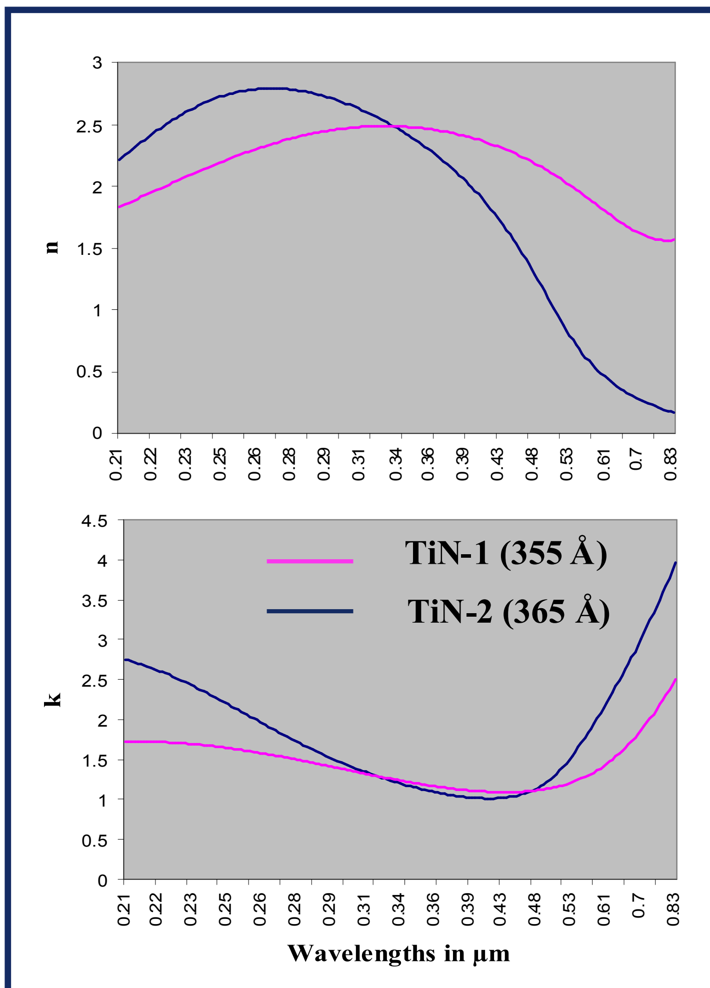


Figure 2

(*)Refer to application note number 4.
(**)Refer to SOPRA web page (www. SOPRA-SA.com) for tutorial on ellipsometry principles, and terminology.

SE can measure TiN_x films as a single layer as well as a sub-layer in multilayer stacks and deposited on any kind of substrate. The example hereafter, shows the characterisation of a metal multilayer stack.

The structure is described Figure 3. The AlCu layer is thick enough to be opaque to light and the films underneath do not need to be taken into account for the analysis.

In this structure, **the thicknesses of the top layers** (TiN, PTEOS and flowing oxide) **can be simultaneously and independently determined**.

The measurement has been performed with the **scanning mode of SOPRA's SE300 system** which allows fast, precise and accurate measurement.

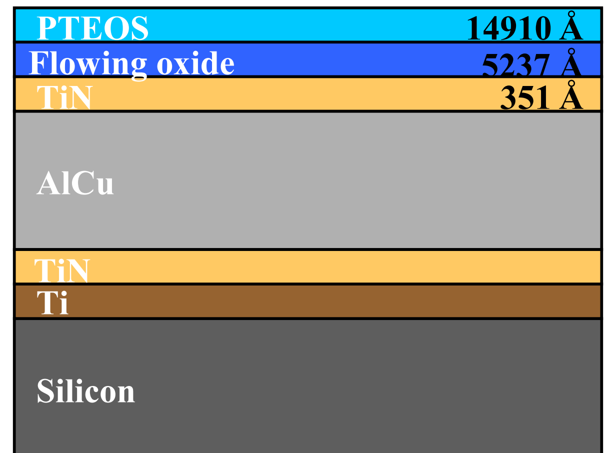


Figure 3

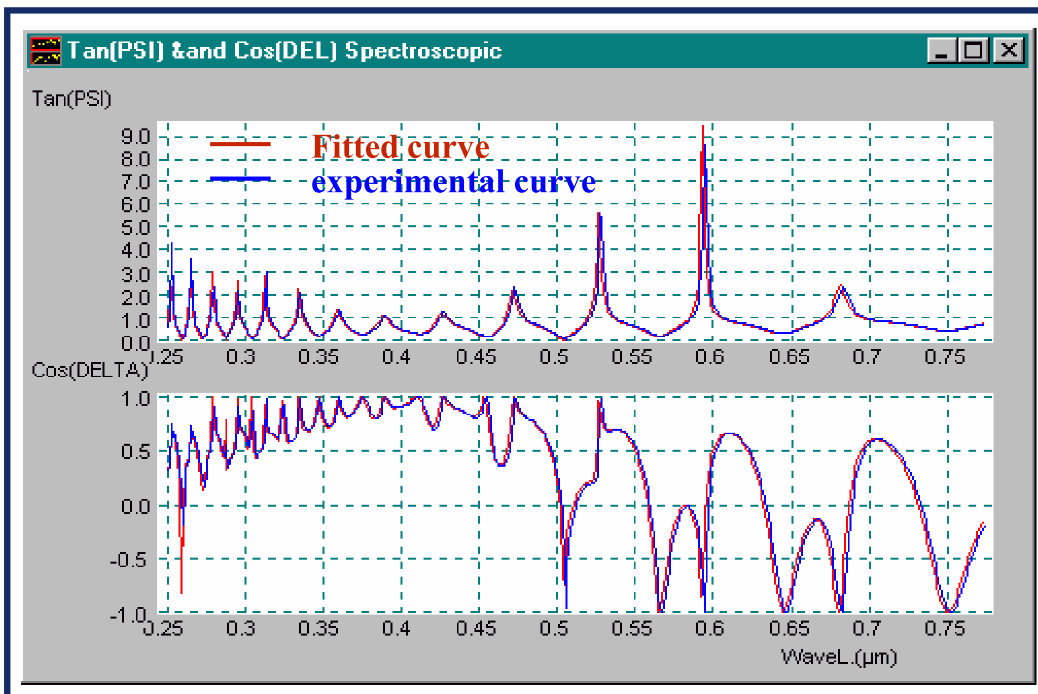


Figure 4

After running **SOPRA's regression analysis software**, the fitting and the experimental curves are presented on figure 4. The calculated spectra fit very well with the experimental ones. It confirms the determination of the thicknesses displayed figure 3.

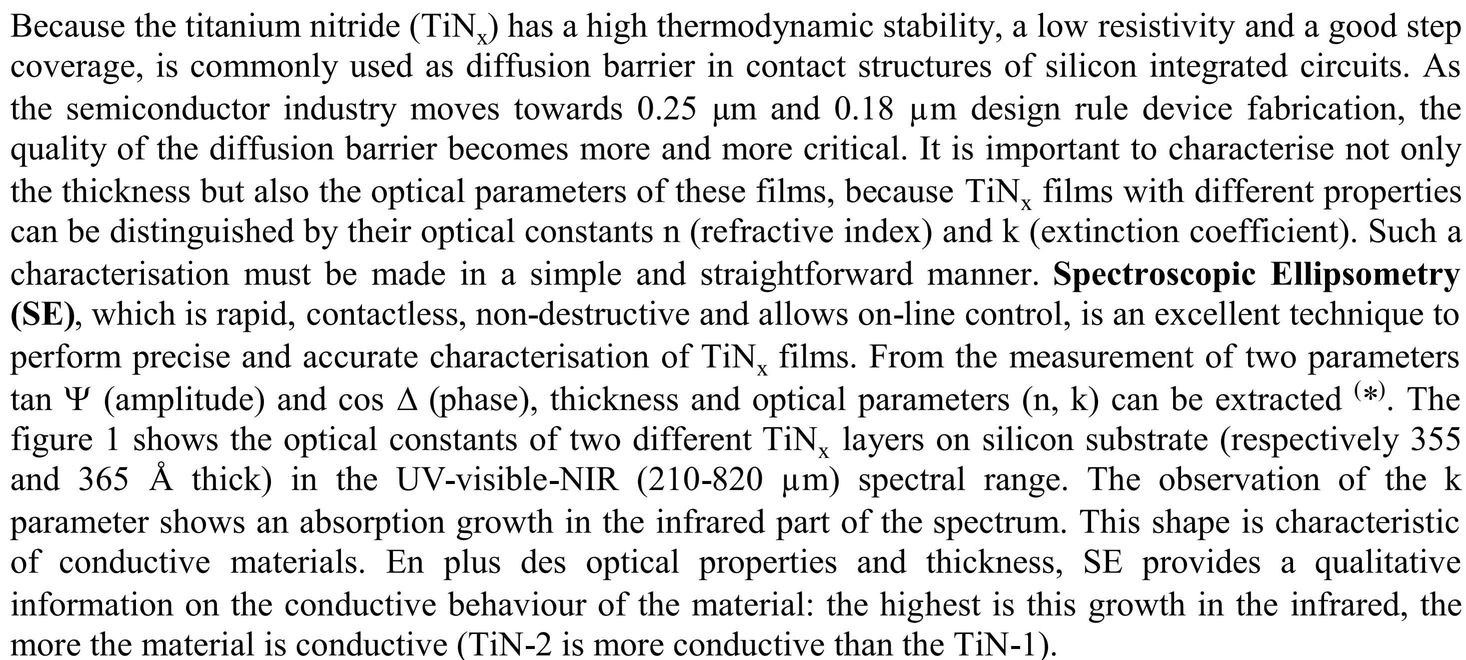
Using SOPRA's SE300 Spectroscopic Ellipsometer in the UV-visible-NIR range, the thickness and the optical properties of any TiN_x can be determined.

The same kind of measurement and results can be obtained on other materials like WSi_x or TaN_x which is the best candidates as diffusion barrier for copper interconnects in semiconductor manufacturing.

SOPRA USA
Tel.: +1 650 566 1270
Fax: +1 650 566 1267
sales@soprainc.com

SOPRA France
Tel.: +33 1 46 49 67 00
Fax: +33 1 42 42 29 34
sales@sopra-sa.com

SEIKA Corp. Japan
Tel.: +81 3 52 21 71 18
Fax: +81 3 52 21 71 35
moss@jp.seika.com



Because the titanium nitride (TiN_x) has a high thermodynamic stability, a low resistivity and a good step coverage, is commonly used as diffusion barrier in contact structures of silicon integrated circuits. As the semiconductor industry moves towards 0.25 µm and 0.18 µm design rule device fabrication, the quality of the diffusion barrier becomes more and more critical. It is important to characterise not only the thickness but also the optical parameters of these films, because TiN_x films with different properties can be distinguished by their optical constants n (refractive index) and k (extinction coefficient). Such a characterisation must be made in a simple and straightforward manner. **Spectroscopic Ellipsometry (SE)**, which is rapid, contactless, non-destructive and allows on-line control, is an excellent technique to perform precise and accurate characterisation of TiN_x films. From the measurement of two parameters tan Ψ (amplitude) and cos Δ (phase), thickness and optical parameters (n, k) can be extracted [(*)]. The figure 1 shows the optical constants of two different TiN_x layers on silicon substrate (respectively 355 and 365 Å thick) in the UV-visible-NIR (210-820 µm) spectral range. The observation of the k parameter shows an absorption growth in the infrared part of the spectrum. This shape is characteristic of conductive materials. En plus des optical properties and thickness, SE provides a qualitative information on the conductive behaviour of the material: the highest is this growth in the infrared, the more the material is conductive (TiN-2 is more conductive than the TiN-1).

SE can measured TiN_x films in single layer as well as in multilayer stack.

When a TiN_x layer is deposited on a dielectric films, the thickness of all layers can be simultaneously determined. Figure 2 shows the measurement implemented with the scanning mode of SOPRA's SE300 system which allows fast, precise and accurate measurement. After running SOPRA's regression analysis software, the fitting and the experimental curves are displayed figure 2. The calculated spectra agree very well with the experimental ones. It confirms the determination of the thicknesses displayed figure 3.

TiN_x films can also be measured within a film stack and on any kind of substrate. The example hereafter, shows the characterisation of a metal multilayer stack. The structure is described Figure 4. The AlCu layer is thick enough to be opaque to light. Therefore, the films under the AlCu layer do not need to be taken account in the analysis. Figure 5 shows the good agreement between the fitted and the measured curves. The thicknesses determined are reported Figure 4.

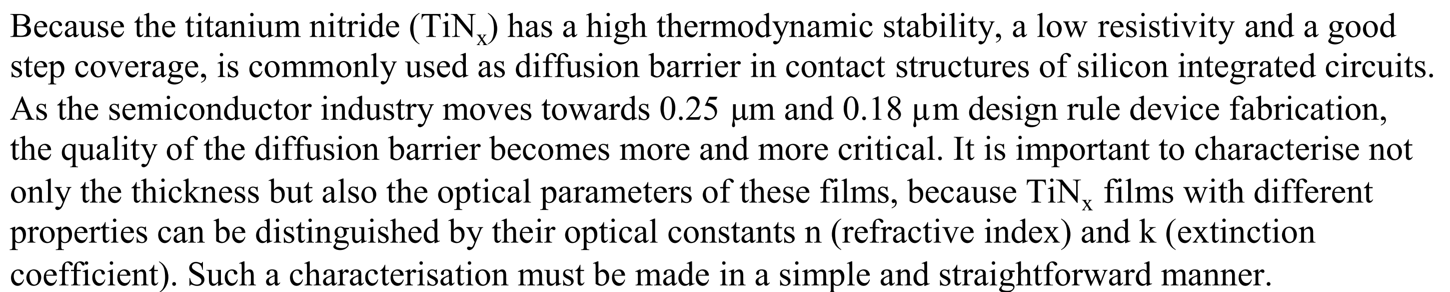
Using SOPRA's SE300 Spectroscopic Ellipsometer in the UV-visible-NIR range, the thickness and the optical properties of any TiN_x can be determined.

The same kind of measurement and results can be obtained on other materials like Wsi_x or TaN_x which will be the likely diffusion barrier for copper interconnects in semiconductor manufacturing, on 0.13 µm device.

SOPRA USA
Tel.: +1 650 566 1270
Fax: +1 650 566 1267
sales@soprainc.com

SOPRA France
Tel.: +33 1 46 49 67 00
Fax: +33 1 42 42 29 34
sales@sopra-sa.com

SEIKA Corp. Japan
Tel.: +81 3 52 21 71 18
Fax: +81 3 52 21 71 35
moss@jp.seika.com



Because the titanium nitride (TiN_x) has a high thermodynamic stability, a low resistivity and a good step coverage, is commonly used as diffusion barrier in contact structures of silicon integrated circuits. As the semiconductor industry moves towards 0.25 µm and 0.18 µm design rule device fabrication, the quality of the diffusion barrier becomes more and more critical. It is important to characterise not only the thickness but also the optical parameters of these films, because TiN_x films with different properties can be distinguished by their optical constants n (refractive index) and k (extinction coefficient). Such a characterisation must be made in a simple and straightforward manner. **Spectroscopic Ellipsometry (SE)**, which is rapid, contactless, non-destructive and allows on-line control, is an excellent technique to perform precise and accurate characterisation of TiN_x films. From the measurement of two parameters tan Ψ (amplitude) and cos Δ (phase), thickness and optical parameters (n, k) can be extracted [(*)]. The figure 1 shows the optical constants of two different TiN_x layers on silicon substrate (respectively 355 and 365 Å thick) in the UV-visible-NIR (210-820 µm) spectral range. The observation of the k parameter shows an absorption growth in the infrared part of the spectrum. This shape is characteristic of conductive materials. En plus des optical properties and thickness, SE provides a qualitative information on the conductive behaviour of the material: the highest is this growth in the infrared, the more the material is conductive (TiN-2 is more conductive than the TiN-1).

SE can measure TiN_x films in single layer as well as within films stack and on any kind of substrate. The example hereafter, shows the characterisation of a metal multilayer stack using to improve its barrier integrity in preventing junction leakage. The structure is described Figure 2. The AlCu layer is thick enough to be opaque to light and the films under do not need to be taken account in the analysis. In this structure, the thickness of the layers (TiN, PTEOS and flowing oxide) can be simultaneously determined. Figure 2 shows the measurement implemented with the scanning mode of SOPRA's SE300 system which allows fast, precise and accurate measurement. After running SOPRA's regression analysis software, the fitting and the experimental curves are displayed figure 2. The calculated spectra agree very well with the experimental ones. It confirms the determination of the thicknesses displayed figure 3.
Figure 5 shows the good agreement between the fitted and the measured curves. The thicknesses determined are reported Figure 4.

Using SOPRA's SE300 Spectroscopic Ellipsometer in the UV-visible-NIR range, the thickness and the optical properties of any TiN_x can be determined.

The same kind of measurement and results can be obtained on other materials like Wsi_x or TaN_x which will be the likely diffusion barrier for copper interconnects in semiconductor manufacturing, on 0.13 µm device.

SOPRA USA
Tel.: +1 650 566 1270
Fax: +1 650 566 1267
sales@soprainc.com

SOPRA France
Tel.: +33 1 46 49 67 00
Fax: +33 1 42 42 29 34
sales@sopra-sa.com

SEIKA Corp. Japan
Tel.: +81 3 52 21 71 18
Fax: +81 3 52 21 71 35
moss@jp.seika.com