SOPRA
APPLICATIONS
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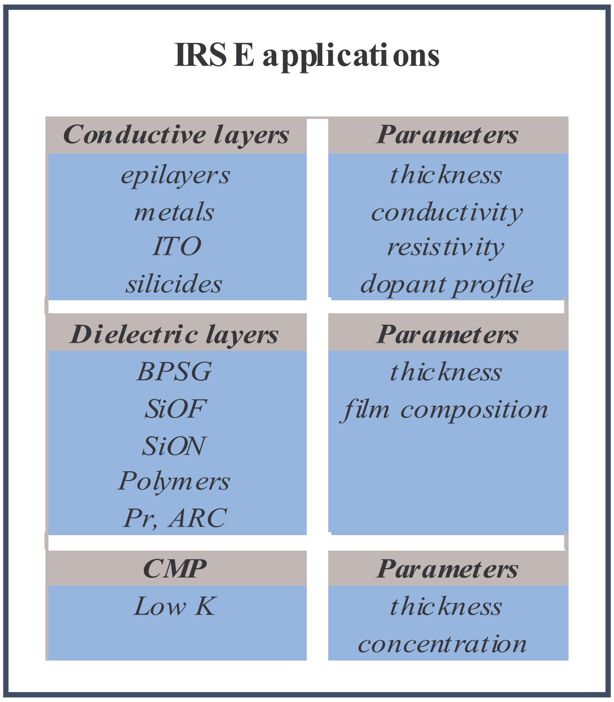
IRSE for Semiconductor Industry

IR spectral range is of great interest since materials exhibit behaviours which are very different from those observed in the visible spectral range: dielectrics have characteristic absorbing bonds, semiconductors are transparent and metals or doped semiconductors exhibit Drude tail. IR Ellipsometry allows consequently a structural and a chemical composition of these materials.

In Semiconductor Industry, Infrared Spectroscopic Ellipsometry has been arisen as a **non-destructive, non-invasive and a contacless technique** in the characterisation of ***conductive and dielectric layers.*** (cf. Figure 1.)

Infrared Spectroscopic Ellipsometer (IRSE) has been coupled to a Fourier Transform Spectrometer to provide a **short measurement time and a wide spectral range** (from 1.5 mm to 17 mm).

The optical properties of the sample are extracted by fitting an appropriate model to the measured spectrum. The fitted parameters are generally: the thickness and/or the dispersion model parameters (Lorentz oscillator or Drude law) of the films. These parameters are determined independently and at the same time by **WINELLI software developed by SOPRA.**



IRSE applications

Conductive layers	***Parameters***
epilayers	*thickness*
metals	*conductivity*
ITO	*resistivity*
silicides	*dopant profile*
Dielectric layers	***Parameters***
BPSG	*thickness*
SiOF	*film composition*
SiON	
Polymers	
Pr, ARC	
CMP	***Parameters***
Low K	*thickness*
	concentration

Figure 1. IRSE applications.

Figure 2 displays the indices of undoped silicon and the indices measured on a 10^{18} at./cm^3 phosphorus doped silicon substrate. This figure highlights the differences between the indices values. No absorption and a nearly constant value of refractive index for undoped silicon whereas doped silicon exhibits a rapid increase of the extinction coefficient with the wavelength.

This behaviour is related to the **doped silicon free carriers** and can be modelled by a **Drude dispersion law.**

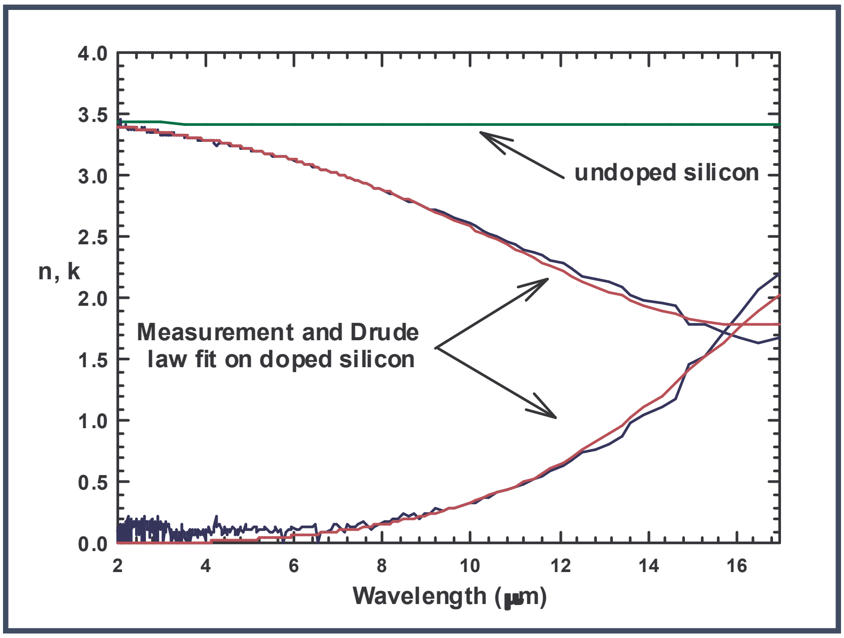


Figure 2. Undoped and Doped Silicon optical indices. Drude model.

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Silicon epitaxy is one of the most commonly practised process technologies used in semiconductors industries. Epi wafers are used instead of prime, polished wafers because of improved gate oxide integrity and latch-up suppression. **Accurate determination of the film thickness is critical since it affects, subsequent process steps in IC fabrication** such as the depths of the ion implantation retrograde well and the shadow trend isolation of crucial importance for controlling the final device operation. Visible ellipsometry is unable to determine the thickness of epi-layers since silicon is highly absorbing in the visible. On the contrary, silicon is transparent in the infrared and thickness measurement is then possible.

Figure 3 shows the measured spectra and the **doping profile of a P/P+ epilayer.** The model parameters, including thickness and doping concentration of the four layers used to describe the transition layer, are adjusted automatically to fit the measured spectrum. An excellent agreement between simulation and experiment is obtained after fitting. This proves the validity of the model and the sensitivity of the measurement to the transition layer.

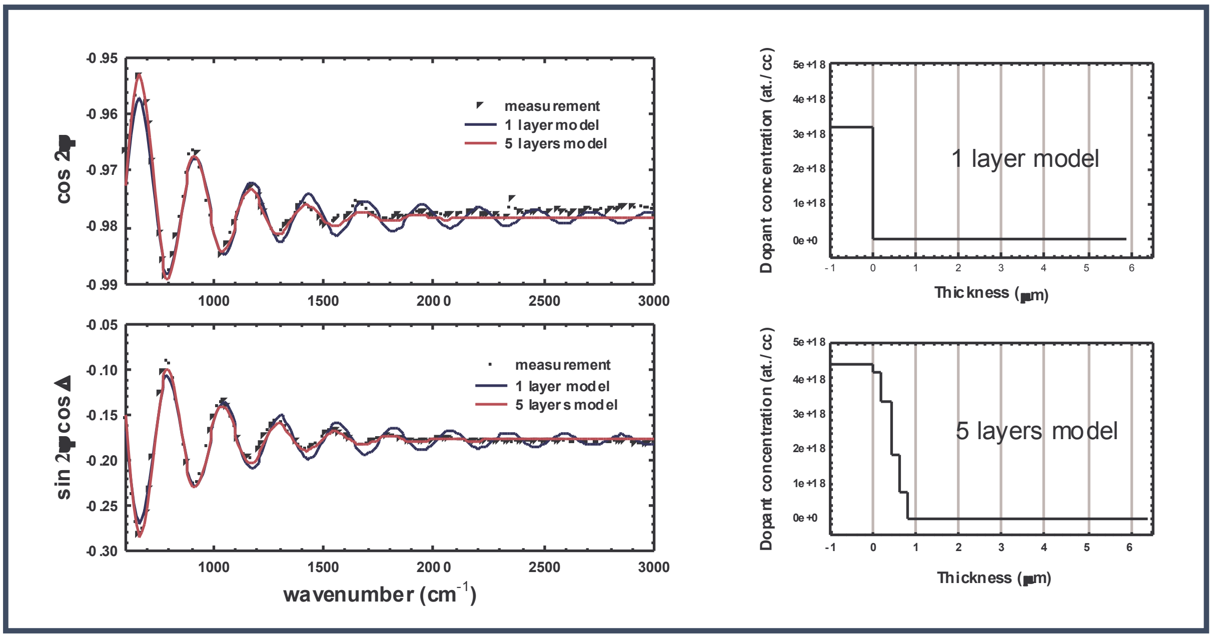

Figure 3. **P/P+ epilayer. Doping profile and ellipsometric spectra.**

In Semiconductor Industry, FT-IRSE is as a powerful technique that:

- **does not require *any reference spectrum or sample***
- **allows the *determination of material composition* of thin film in multi-layer stack**
- **provides *better sensitivity* that classical FT-IR due to larger optical path inside thin film**

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