NANOELEC.
PLATFORM FOR ADVANCED CHARACTERISATION
GRENOBLE

Origin of delamination
in microelectronics interfaces

NEUTRONS FOR SOCIETY

Neutron reflectivity provides insight on the origin of delamination in interfaces used in microelectronics and more particularly if hydrogen is involved in the fabrication process

Context

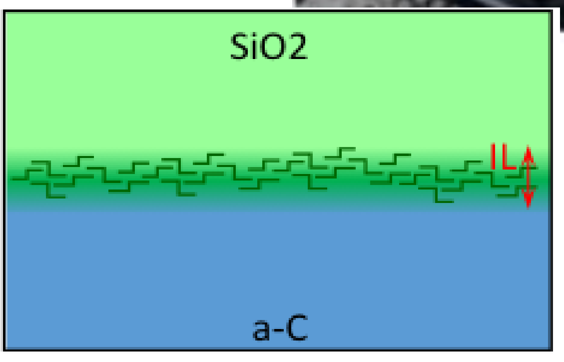
The fabrication of integrated circuits (ICs) in the microelectronics industry frequently involves multilayer structures with stacked materials (metals and dielectrics) on a silicon substrate. Delamination at a particular interface is obviously a serious problem in manufacture not only due to the loss of the wafer itself but mainly from the equipment downtime due to contamination. This is the main reason why the semiconductor industry seeks solutions to minimise delamination risks well in advance of full-scale IC manufacture.

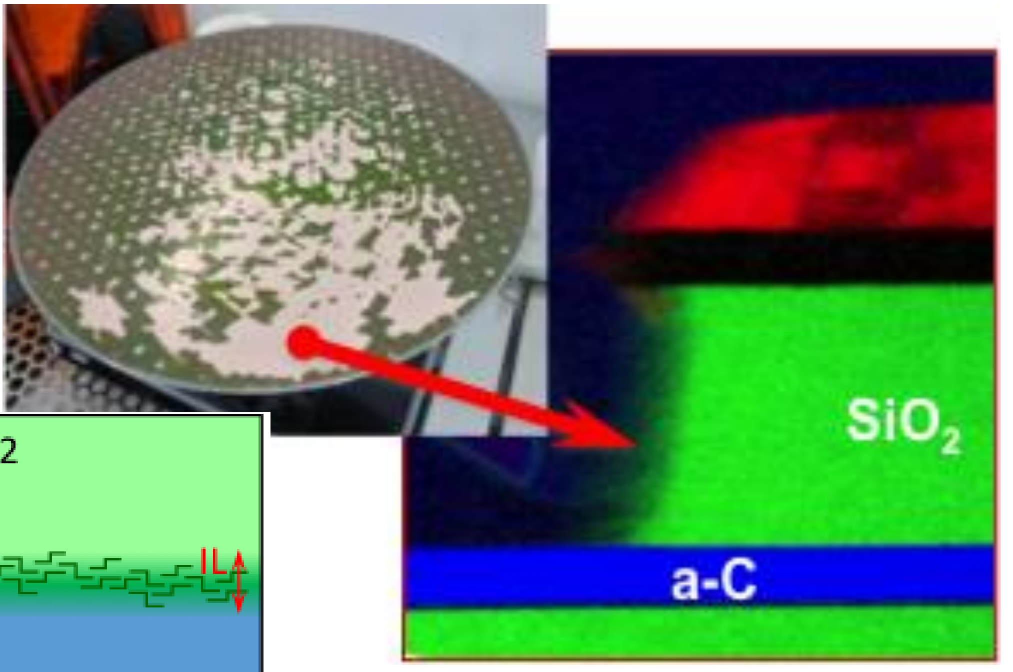
The challenge

The main objective of this study is to develop a method to anticipate the risk of delamination of a given interface well before the IC manufacture. It would be desirable to predict the risk of delamination not only qualitatively, but also quantitatively. To do this, the mechanism behind the delamination should be identified and fully characterised, in order to relate one or several of its characteristics to the risk of delamination. This will allow the implementation of a procedure for a prediction of the delamination risk before of full-scale IC manufacture, allowing it to be mitigated.

The results

At the Institut Laue-Langevin (ILL) neutron reflectivity was used to characterise the interface between amorphous carbon (a-C) and SiO2 widely employed in microelectronics industry. Two different deposition conditions used to grow the SiO2 layer on top of a-C were tested. One particular condition showed a qualitative difference in terms of adhesion when attempting to detach layers using adhesive tape. The NR measurements were complemented with XRR in order to unambiguously determine the chemical composition of the structure as a function of depth. Samples measuring 50x50x0.75 mm3 were cut from two different 300 mm silicon wafers. The NR measurements were performed on the D17 reflectometer at ILL and XRR measurements at the nanocharacterisation platform (PFNC) at the Minatec Campus in Grenoble, using a commercial X-ray bench. XRR showed the same results for both samples. This means that the XRR, was unable to detect any difference between the characterised samples apart from slight differences in roughness and density of the SiO2 layer. On the other hand, NR results showed the presence of an extra layer between the a-C and the SiO2. This intermediate layer (IL) has a lower neutron Nb than the a-C and SiO2 layers due to the presence of hydrogen. Furthermore, the IL main characteristics differ for the two samples (different thickness and H-concentration). The appearance of non-specular signal in the NR data of the sample with the weakest interface indicates the existence of a microstructure associated with cracking at the interface.





a: schematic of defects at the interface
b: delamination on processed wafer
c: structure of the multilayer

Conclusion

Combined NR and XRR characterisation of the a-C/SiO_2 interface showed that the weakness of this interface is related to the accumulation of hydrogen at the interface. The weakness is more important for a thinner IL with a higher H-concentration. H-concentration and thickness of the IL seem to be correlated with a greater susceptibility of cracking in the vicinity of this interface, consistent with the appearance of off-specular scattering. This discovery should allow the risk of delamination to be anticipated and quantified. The H-accumulation could take place in other interfaces of interest for microelectronics, broadening the application of this technique.

The technique

Reflectivity techniques are powerful tools for the characterisation of multi-layers, surfaces and interfaces. Reflectivity involves reflecting a well-collimated beam from a surface and measuring its fraction as a function of wave vector transfer. From X-ray reflectivity (XRR) characterisation, the thickness, roughness and density of material as a function of depth can then be accurately modelled. For these reasons, XRR is widely used in microelectronics industry for quality assurance on the production line. However, this technique has proven unable to detect differences in layers having different risks of delamination. Its neutron counterpart, neutron reflectivity (NR), is complementary. Neutrons are highly penetrative, but most importantly are very sensitive to the presence of hydrogen. X-rays only measure the electron density regardless of the elemental composition, so light elements such as hydrogen are particularly challenging to detect. Therefore, NR could be suitable if hydrogen, widely used in deposition techniques used in microelectronics industry, is involved in the delamination mechanisms.

Get in touch today for further details:

Rafael Varela Della Giustina, Business Developer
of The Platform for Advanced Characterisation - Grenoble (PAC-G)

support@pac-grenoble.eu | +33 (0)4 57 42 80 77

www.pac-grenoble.eu