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3D-RSM Phase and texture characterisation of **polycrystalline thin films**

ESRF The European Synchrotron

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Ultrathin polycrystalline films are usually formed during contact deposition in semiconductor devices. Important electronic and mechanical properties depend on their microstructure, internal phases and texture (preferred crystallographic orientation of grains). Knowledge and control of these parameters is crucial in the development of new products and processes for microelectronic, MEMS and photovoltaic applications.

Context

Source-Drain contact deposition in FDSOI components is particularly challenging for sub-10 nm technology nodes. In these devices, contact materials form a very thin epilayer, usually composed of alloys of metal and semiconductors. Thermal annealing of these thin-films leads to the creation of new phases and grain boundaries of polycrystals. As a consequence, different preferred crystallographic orientation of grains appear. All of these phenomena have a great impact on the functionality of the future component. Measuring and controlling these features is critical in order to improve yield and device performance.

The challenge

Polycrystalline films in microelectronic applications are usually in the range of several Angstroms to few nanometres, making them very difficult to characterise using lab-based equipment. A synchrotron source is an ideal tool to get a full image of these films by looking at its reciprocal space, which is a natural magnified photograph given by X-ray.

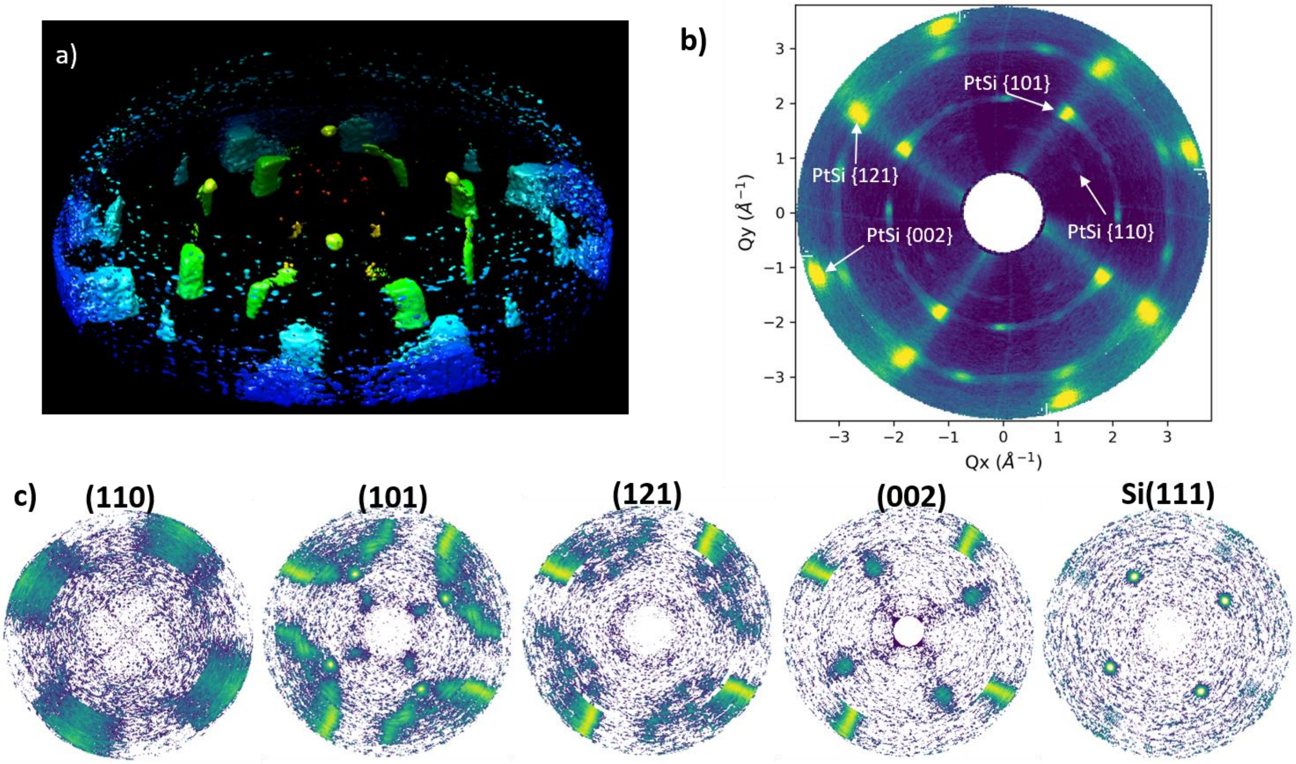
A reciprocal space map (RSM) needs a strong and microfocused X-ray beam because the patterns in these applications are usually in the order of 100 µm. In addition, the low diffraction volume requires a high brilliance source as the one provided by the ESRF.

The results

The exceptional properties of the X-ray beams provided by the ESRF allow to map the reciprocal space of nanolayers in 3D and reconstruct it in a volume. The reciprocal space map (RSM) provides several valuable information about the microstructure of thin polycrystalline films with only one measure.

The results allow the analysis of epitaxial relation, strain states of epilayers with the extraction of (hkl) planes in any direction. 3D RSM technique also makes possible the analysis of texture and the extraction of pole figures. The whole volume of the sample is integrated giving q-intensity relation and therefore the identification of phases

These results help unveil key physical properties of ultrathin nanolayers and understand different phenomena leading to better performance in semiconductor devices.



Reciprocal space map of a PtSi thin film sample used in microelectronic devices.

Conclusion

With only one measurement of 3D-RSM, all information about your materials is accessed even in a very thin film. Analysis of these features requires good crystallographic knowledge but it is relatively simple to do.
From the 3D volume, Fig. (a), we can slice the in-plane map, Fig. (b), which in this example shows two grains of PtSi lying in 90° cross-over, with the b axis pointing out-of-plane. Extraction of pole figures, Fig. (c), helps scientists figure out the preferred crystallographic orientation of the grains, which are responsible for important electrical and mechanical properties. This information can help enhance the performance of semiconductor devices.

The technique

- 3D Reciprocal Space Mapping (RSM) gives a complete overview of the reciprocal space in a large range of Bragg angles to characterise the nature and texture of all phases present in a polycrystalline film. Diffraction images of polycrystalline samples are collected with a 2D detector while rotating the sample in 360°.
- Samples can be in a full wafer (fullsheet) or patterned in dies of hundreds of micrometres. In this case, individual samples can be measured thanks to a microfocused X-ray beam.
- Both in-plane and out-of-plane information are accessed thanks to a 5-circle diffractometer available.

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