

Imaging strain and defects in electronic materials and devices : State of the art and future trends

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Since the early 1960s microelectronics has made extraordinary progress that shows up in our daily lives. Ever decreasing transistor size, use of new materials or intentional strain have allowed this amazing evolution which has followed Gordon Moore's predictions [1] until very recently. Based on a complex assembly of materials with vastly different thermo-mechanical properties, microelectronic devices are a fantastic playground for investigating elastic strains and defects in a large range of scales (from millimetres to nanometres). Because of their high penetrating power X-rays are perfectly suited for investigating elastic strains in buried materials within electronic chips. X-ray diffraction is moreover extremely sensitive to lattice deformations. One should mention also the flexibility of bringing various environments and complementary measurements around the sample. On the other hand, X-ray beams are difficult to focus, which has limited the spatial resolution of X-ray strain imaging until recently.

Strain and defect imaging with X-rays have made very impressive progress lately. Progress in X-ray focusing optics allows nowadays scanning x-ray diffraction mapping to be performed with a resolution in the 50-100 nm range [2]. Full field X-ray microscopy is improving a lot too with resolutions in the 100 nm range [3]. Micro-Laue diffraction is very sensitive to lattice rotations and plasticity-induced defects [4]. By far the best spatial resolution is obtained with coherent diffraction imaging, which is a lensless imaging technique, with a typical resolution of 8-10 nm [5,6].

These recent progresses, which have been made possible thanks to the development of brighter and more coherent synchrotron sources, are revolutionizing the field of strain and defect imaging at small scales. I will show various examples in the field of electronic materials and devices, where X-ray diffraction and strain imaging can bring very detailed information, often critical for understanding and improving device properties: strain-engineered Si and Si_xGe_{1-x}, GaN nanowires, Cu-filled though Si vias (TSVs), phase change materials for memories, ...

Operando experiments and time resolution are critical for understanding reliability issues or, from a more fundamental viewpoint, to investigate the dynamics of defects. They maybe within reach with the new "4th generation" synchrotron sources that are becoming available.

References

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