The Application of Synchrotron Radiation to Semiconductor Materials Characterisation

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In recent years, many new synchrotron-based X-ray radiation sources have been built or are in the project or construction phase. This strong level of activity is an acknowledgement of the unique properties of synchrotron radiation, which present many advantages when compared to conventional X-ray sources. The high X-ray intensities can allow significant reductions in acquisition times and/or permit huge improvements in data quality/statistics. Furthermore the high degree of collimation of the X-ray beam can be particularly beneficial for the study of small sample volumes. Energy tunability permits ready optimisation of the operating conditions for measurements and is particularly powerful when used in spectroscopic analysis around X-ray absorption edges. Synchrotron X-ray beams are typically highly polarised, a property that can be usefully exploited in both scattering and spectrometry measurements. Finally the well-defined time structure of the X-ray photons can be used for the stroboscopic measurement of cyclic phenomena.

Continual improvements in both the synchrotron sources themselves and the associated beamline instrumentation (notably the X-ray optics) have extended the capabilities of established X-ray analysis techniques and allowed the development of many new techniques which are currently impossible or impractical using even the most intense laboratory-based sources.

The diverse range of techniques which are routinely applied at synchrotrons means that there are many potential or current applications related to various fields of semiconductor technology. Apart from a number of advanced lithography programmes which are underway in facilities around the world which tend to exploit the low energy (EUV/soft X-ray) emission of the sources there are many analytical techniques which benefit from the full spectral range of available X-rays. Localised measurements of band structure using photoelectron spectroscopy may contribute to the understanding of the basic physics underlying device operation. Measurements of surface contamination levels can reach unprecedented sensitivities using total-reflection X-ray fluorescence and can in certain instances give information regarding the chemical state of the contaminants (1). X-ray microscopy methods can allow direct imaging of sub-surface manufacturing defects in multilayer device structures (e.g. Figure 1). Both X-ray topography and diffraction methods can be used to assess both crystalline defects and lattice strains in both homo- and hetero-structures (2). The intense photon fluxes which are available mean that often such phenomena can be measured in real-time. An example of this is the observation of electromigration phenomena using full-field X-ray microscopy (3).

In this presentation, an overview of the possibilities of synchrotron techniques applied to semiconductor devices and materials will be given, illustrated by examples from past and on-going studies both from the ESRF and other sources around the world.

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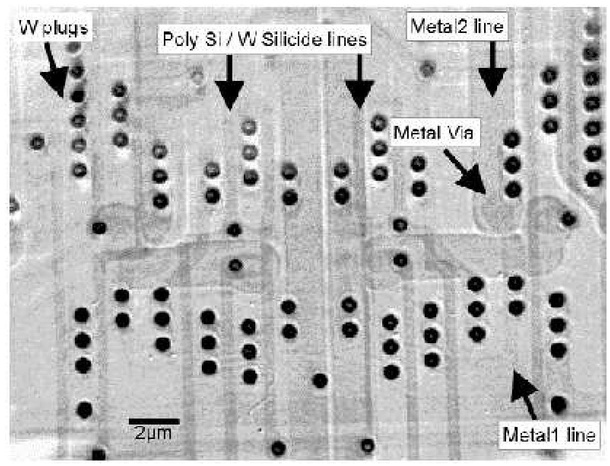

Figure 1: X-ray micrograph of an intact integrated circuit with two AlCu metallisation layers and tungsten plugs connecting the levels (courtesy G.Schneider).