

Characterization of iron-contaminations on silicon wafer surface

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Metallic contaminations on wafer surface are known to be a serious limiting factor to yield and reliability of CMOS based integrated circuits. Total Reflection X-Ray Fluorescence (TXRF) is a wide spread analytical technique for the monitoring of surface contamination on non patterned wafers in the semiconductor industry. In laboratory based instruments it offers detection limits down to the $1\text{E}10$ at/cm². When higher sensitivity is requested monitoring is typically carried out by vapour phase decomposition (VPD) of the native oxide layer and analysis by means of laboratory based TXRF and/or ICP-MS on the expense of the loss of the information relative to the location and distribution of the contamination on the wafer. For tracing the source of the contamination not only the distribution of the contamination is very valuable but also additional information on the chemical state of the element can be necessary.

Synchrotron radiation induced TXRF (SR-TXRF) is a microanalytical technique which offers sensitivities as high as 8000 cps/ng and detection limits in the fg range for transition metals with a multilayer monochromator and a bending magnet beamline. With a crystal monochromator the technique can be coupled to X-ray Absorption Spectroscopy (XAS) to gain information on the chemical environment of the specific elements of interest. With this modified set-up there is a flux reduction of about two orders of magnitude, but it is still sufficient for the analysis at ppb level [1-3].

Wafer samples from IBM laboratories, showing surface contaminations in the $1\text{E}12$ at/cm² range for Fe have been investigated. SR-TXRF XANES measurements were accomplished at the bending magnet beamline L of HASYLAB modifying the micro-XRF setup to allow TXRF measurements with scanning capability. The Si(111) double crystal monochromator was used and a Silicon Drift Detector (SDD) for the detection of the fluorescence radiation.

Figure 1a shows the iron contamination map on a 200mm Si wafer obtained with a laboratory TXRF instrument; three areas are marked and labeled (A5, A7, A21). Figure 1b shows Fe maps of the marked areas carried out with SR-TXRF. The lateral resolution was determined by the collimator of the detector (8mm diameter) and the vertical beam dimension (1.5mm). The marked positions (P5, P7, P21) have been chosen for further investigations.

Angular scans have shown that in all the positions the contamination is present in form of residue as is indicated by the angular intensity curve of the Fe K fluorescence reported in Figure 2a.

Fe K-edge XANES measurements have been carried out in the positions indicated. Fe standards of possible iron species have been measured for comparison. Figure 2b shows the XANES spectra for position P5 along with the spectra of standards of the most probable species. Notwithstanding the poor counting statistic, linear fits were carried out to have an estimation of the composition of the Fe contamination. The results are reported in Table1.

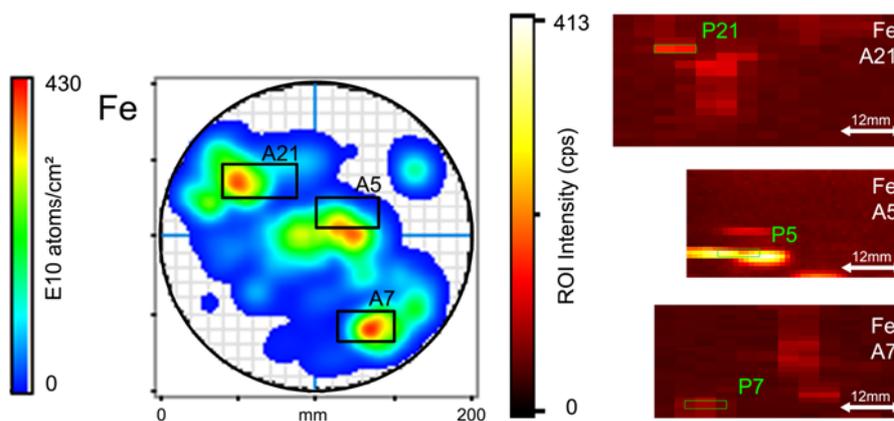


Figure 1: Lateral distribution of Fe contamination on wafer surface a) measured with a laboratory TXRF instrument and b) by means of SR-TXRF.

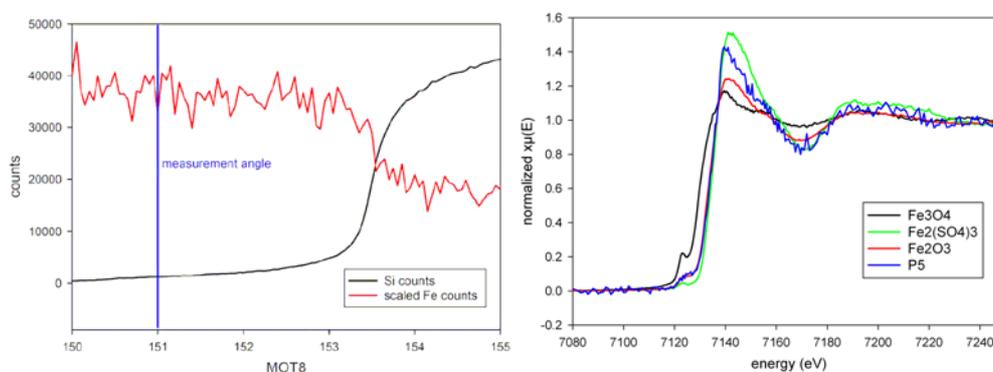


Figure 2: a) Measured angle dependent fluorescence intensity of Fe-K α and Si-K α at P5 and b) TXRF-XANES spectrum at P5 in comparison with spectra of standard samples.

	Fe ₂ O ₃	Fe ₃ O ₄	Fe ₂ (SO ₄) ₃
P21	72 ± 6 %	25 ± 4 %	3 ± 4 %
P5	44 ± 4 %	6 ± 3 %	50 ± 3 %
P7	42 ± 5 %	58 ± 5 %	

Table 1: Results of best linear combination fits

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