Nondestructive Observation of the Depths and Dimensions of Subsurface Micro-defects in Silicon Wafers

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The quality of the subsurface region in silicon wafers is one of the dominant factors for successful ULSI fabrication. In this report, we apply a nondestructive short-wavelength laser scattering topography (S-LST) technique to determine the depth and dimensions of individual micro-defects in the subsurface region of silicon wafers. We call this the two-temperature S-LST method, to emphasise its capability for observing the depth and dimensions of micro-defects in the subsurface region of the wafers. Measurements were made at two different temperatures, i.e., 23ºC and 83°C, utilising the temperature dependence of the absorption coefficient of silicon at the wavelength (680nm) of the laser. The depth beneath the wafer surface, (d) and the quantity (A) that reflects the dimensions of the micro-defects are derived as follows

$$d = ln(I_{23}/I_{83})/2[\alpha_{83} - \alpha_{23}] \qquad (1)$$

$$A = I_{23}\, exp[2\alpha_{23} d] \qquad (2)$$

where α_{83} and α_{23} are the absorption coefficients of silicon at 83°C and 23°C, and I_{83} and I_{23} are the scattering intensity of the micro-defects at 83°C and 23°C respectively [1]. Theoretically, it was clear that d and A for the micro-defects could be determined from the scattering intensities and absorption coefficients using the two-temperature S-LST method. An experimental example of the two-temperature method is shown below. The sample we prepared was a boron-doped mirror polished (100) CZ-Si wafer, and we were able to observe grown-in defects in this sample wafer. Fig.1 shows the correlation between d and logA of the micro-defects detected in the subsurface region of the CZ wafer. From Fig.1, we can see that the detection region was expected to form a triangular shape, and the reason for this is as follows. In CZ wafers, the size distribution and the density of micro-defects at each depth should be similar over all of the subsurface. Thus, the upper limit of their detectable size is constant at all depths. On the basis of Fig.2, the factor A_{min}, corresponding to the minimum size of detectable defects at a given depth d, increases exponentially with d, as follows

$$A_{min}(d) = A_o \exp(2\alpha_{23} d) \qquad (3)$$

where A_0 is the dimension factor of A, which corresponds to the minimum size of detectable defects. From this equation, it is predicted that the detectable region will take the form of a triangular shape with a flat line denoting the maximum, as shown in Fig.2, and in Fig.1 we can indeed see a triangular region in the d-logA plot, just like that shown in Fig.2. From this result, we could conclude that the two-temperature S-LST method displayed a high degree of relativity for measuring micro-defects in the subsurface region. In summary, it was found that by using the two-temperature method, micro defects in a Si wafer could be measured with respect to their depth and size by a non-destructive technique, and the experimental results confirmed that this was the case.

[1] Hiroyuki Goto et al., *Electrochem. Solid-State Lett.* **4**, G107 (2001)

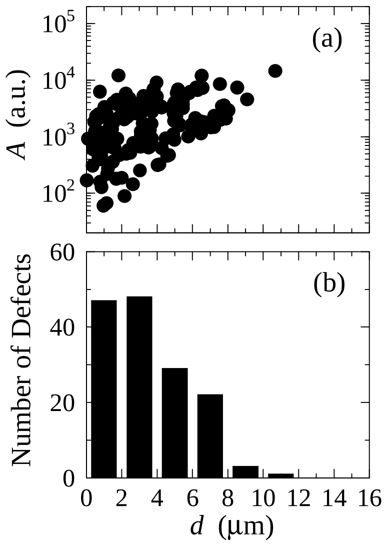

Fig.1. Observed depths and dimensions of the subsurface micro-defects detected in a CZ sample wafer by the two-temperature S-LST method.

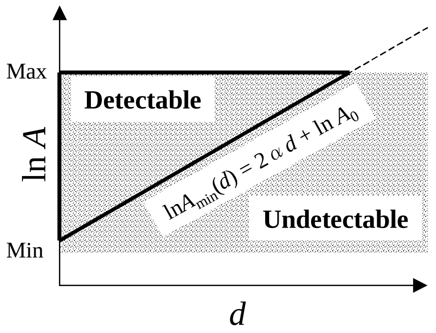

Fig.2. Predicted correlation (d-log$A$ plot) between the depth d and the dimension factor A of the subsurface micro-defects detected in a CZ wafer by the two-temperature S-LST method.