Nitrogen in Thin Silicon Wafers Determined by Infrared Spectroscopy

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Introduction

Adding nitrogen to silicon leads to drastic changes of some properties of Si materials as well as of the atomic processes under heat treatment.

Two methods are commonly used for the detection of nitrogen: secondary ion mass spectrometry (SIMS) and Fourier transform infrared spectroscopy (FTIR). The latter seems to be of particular interest, because it is non-destructive, faster, relatively low-cost and able to provide additional information about the atomic state of a given impurity. However, the relatively weak intensity of the nitrogen related absorption bands did not allow to perform measurements on standard silicon wafers so far. Special samples with a thickness of approximately 10mm are usually used for nitrogen determination by infrared spectroscopy [1]. This approach is not suitable for monitoring the concentration of nitrogen and its state in the silicon lattice for wafers before and during semiconductor processing. Consequently, the development of analytical methods for the determination of nitrogen in silicon wafers is very important.

The aim of this work was to develop a method for the determination of nitrogen in 200- and 300mm silicon wafers by means of infrared spectroscopy.

Results

After analyzing the infrared spectra of thick samples and relatively thin wafers we have concluded that two factors limit the sensitivity of infrared measurements of nitrogen in silicon wafers:

1) strong interference effects in the wafer
2) noise and instabilities of the signal in the spectroscopic equipment (FTIR spectrometer BOMEM DA8 in our case).

The interference has been drastically suppressed by using Brewster's angle of incidence, approx. 73°, and p-polarised light instead of conventionally used normal incidence and unpolarised light. Moreover, the Brewster angle geometry allows one to perform spectroscopic measurements not only on a single thin sample, but on a stack of samples, too. This enhances the intensity of the bands in a transmission spectrum and, thus, the sensitivity of the measurements.

The photometric quality of the signal has been improved by increasing the number of scans as well as by a modification of the equipment.

The obtained differential spectra of a single thin sample as well as of a stack of 3 samples cut from the same wafer are shown in Fig. 1. A sample cut from a nitrogen undoped wafer has been used as a reference sample. No precise adjustment of the thickness of the pair of samples was necessary because of the small thickness tolerance of the standard wafers. Two well known nitrogen related bands of N-N pairs and NNO complexes are seen in each curve. The estimated concentration of nitrogen is equal to $1.2 \times 10^{15} cm^{-3}$.

The improvement of the photometric quality of the recorded spectra after the modification of the equipment is demonstrated in Fig. 2. The 100% line has been obtained by dividing two subsequent transmission spectra recorded on the same sample. One can clearly see the improvement of the 100% line after the modification.

The detection limit for nitrogen in the standard wafers is equal to 3×10^{14} cm^{-3}, according to the achieved quality of the 100% line.

1. K. Tanahashi, H. Yamada-Kaneta, N. Inoue. Jap. J. Appl. Phys., **43**, L436(2004)

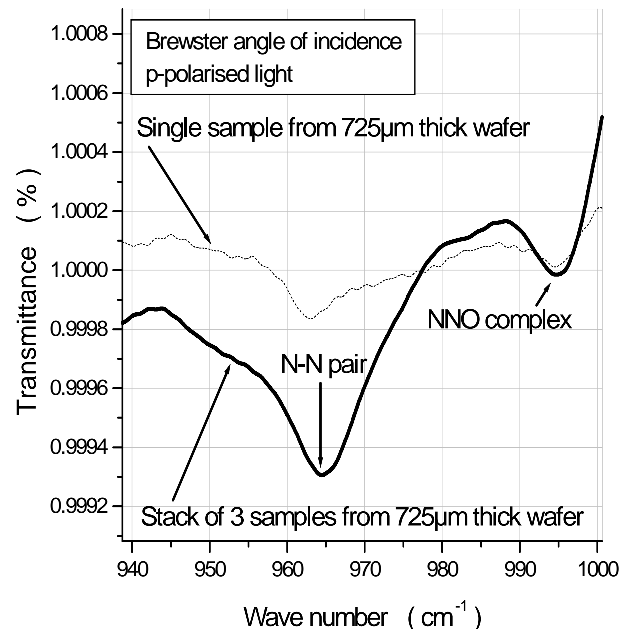

Fig.1. Infrared spectra of N-doped Si wafers

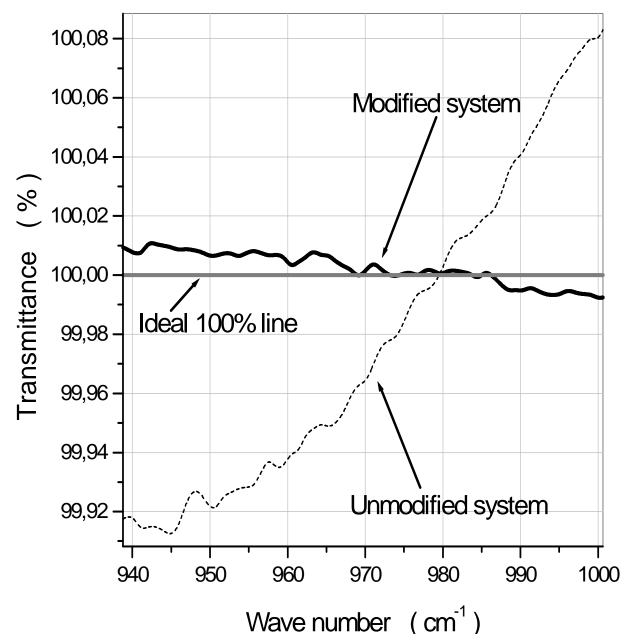

Fig.2. Quality of the 100% line of the spectrometer