phys. stat. sol. (a) **163**, R5 (1997)
Subject classification: 73.25.+i; 68.35.Bs; S5.11

Detection of Silicon Wafer Contamination by Lifetime Measurement Using Infrared Photothermal Radiometry

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(Submitted August 26, 1997; accepted September 1, 1997)

Introduction. Laser infrared photothermal radiometry (PTR) [1 to 3] is rapidly evolving into a sensitive remote non-contacting measurement methodology for the inspection of industrial-level semiconductor materials and devices. Demonstrated applications of the PTR technique include monitoring of ion-implantation in Si with carrier plasma wave technology [4], characterization of semiconductor devices, such as photoconductive layers [5] and MOS capacitor structures [6]. The potential advantages of this new technique over conventional semiconductor characterization techniques such as photomodulated thermoreflectance [7], surface photovoltage [8] and microwave reflectance [9] have been found to include its exclusive sensitivity to the near-surface electronic properties [10], high spatial resolution, remote measurement capability and extremely high plasma-to-thermal contrast [6].

The objective of this work was the industrial-level application of the PTR technique as a process control tool: monitoring the contamination of Si wafers after the oxide layer growth by O_2/HCl oxidation in a furnace at high temperatures by carrier lifetime (τ) measurements.

Experimental results and discussion. The experimental setup used to measure the frequency dependencies of the PTR amplitude and phase has been described in details earlier [3, 4]. The investigated set of p-type FZ Si samples included six identical wafers, which passed a different number of consecutive oxidation cycles: from 1 to 6. After each thermal oxidation an additional oxide layer has been HF-etched, thus the oxide thickness remained the same for all samples: 33 nm. The PTR frequency scans were performed at the central point of each wafer with an expanded excitation beam spot size of 3 mm to satisfy the requirements of the one-dimensional geometry.

Fig. 1 shows the experimental PTR-amplitude frequency responses obtained from six Si wafers in the frequency range 100 Hz to 100 kHz. As it can be seen from Fig. 1, the PTR signal shows a very high sensitivity to changes in electronic properties associated with wafer contamination by heavy metals and other impurities from the metal-containing parts of the furnace. As the number of oxidation steps increases, the PTR amplitude at low frequencies, which is proportional to τ under certain experimental conditions [3, 7], decreases significantly.

However, the high-frequency slopes of the PTR amplitude dependencies in Fig. 1 do not change with the increasing number of oxidations and remain close to -1, indicating a very low surface recombination velocity in all Si wafers [3, 4, 6] which is characteristic for oxidized Si [3]. The τ values evaluated by the simultaneous fitting of the PTR amplitude and phase frequency responses to the corresponding finite-thickness one-dimensional theoretical model [3] are presented in Fig. 2. As it has been expected, the carrier lifetime, being an extremely sensitive parameter, drops from 550 μs in single-oxidized wafer down to 60 μs in the wafer which underwent six thermal oxidation

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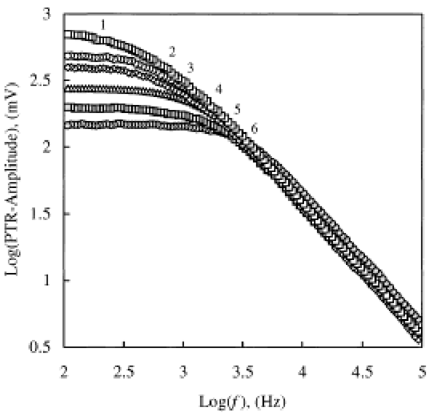

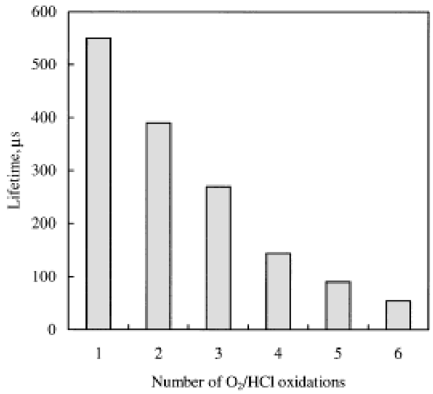

Fig. 1. (left) Experimental PTR-amplitude frequency responses from Si wafers after a different number of thermal oxidations (from 1 to 6)

Fig. 2. (right) Values of the carrier lifetime evaluated from the PTR frequency responses of Fig. 1 as a function of the number of O_2/HCl oxidations

cycles. The two-parameter fitting of the experimental data yielded the surface recombination velocity values within the range of 200 to 300 cm/s for all Si wafers.

An observed decrease in s with the growing number of thermal oxidations is associated with wafer contamination and can be monitored using the sensitive PTR technology immediately after the technological process without any sample preparation.

References

[1] S. Sheard, M. Somekh, and T. Hiller, Mater. Sci. Eng. **B5**, 101 (1990).
[2] A. Mandelis, R. Bleiss, and F. Shimura, J. Appl. Phys. **74**, 3431 (1993).
[3] A. Salnick, A. Mandelis, and C. Jean, Appl. Phys. Lett. **69**, 2522 (1996).
[4] A. Othonos, C. Christofides, and A. Mandelis, Appl. Phys. Lett. **69**, 821 (1996).
[5] A. Mandelis, A. Othonos, C. Christofides, and J. Boussey-Said, J. Appl. Phys. **80**, 5332 (1996).
[6] A. Salnick, C. Jean, and A. Mandelis, Solid State Electron. **41**, 591 (1997).
[7] J. Opsal and A. Rosencwaig, Appl. Phys. Lett. **47**, 498 (1985).
[8] J. Lagowski, P. Edelman, and A. Morawski, Semicond. Sci. Technol. **7**, A211 (1992).
[9] F. Shimura, T. Okui, and T. Kusama, J. Appl. Phys. **67**, 7168 (1990).
[10] S. J. Sheard, and M.G. Somekh, Infrared Phys. **28**, 287 (1988).