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Effect of mechanical backside damage upon minority carrier recombination lifetime measurement by laser/microwave photoconductance technique

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기계적 후면 손상이 레이저/극초단파 광전도 기법에 의한 소수 반송자 재결합 수명 측정에 미치는 영향

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Abstract We investigated the effect of mechanical backside damage upon minority carrier recombination lifetime measurement in Czochralski silicon substrate by laser excitation/microwave reflection photoconductance decay method. The intensity of mechanical damage was evaluated by X-ray double crystal rocking curve, X-ray section topography and wet oxidation/preferential etch methods. The data indicate that the higher the mechanical damage intensity, the lower the minority carrier lifetime, and the threshold full width at half maximum value which affect minority carrier lifetime measurement is about 13 secs.

요 약 초크랄스키 실리콘 기판의 뒷면에 형성된 기계적 손상이 레이저 여기/극초단파 반사 광전도 감쇠법에 의한 소수반송자 재결합 수명 측정에 미치는 영향을 고찰하였다. 기계적 손상의 정도는 X-선 이중결정 회절법과 X-선 단면 측정법 및 습식산화/선택적 식각 방법으로 평가하였다. 그 결과, 웨이퍼 뒷면에 가해지는 기계적 손상의 세기가 강할수록 소수반송자 재결합 수명은 짧아지고, 소수반송자 재결합 수명 측정에 영향을 미치는 반치전폭의 임계값은 약 13초임을 알 수 있다.

1. Introduction

It has been reported [1,2] that laser excitation/microwave reflection photoconductance decay (μ-PCD) method is a noncontact, nondestructive and high throughput technique with higher sensitivity than secondary ion mass spectroscopy and total reflection X-ray fluorescence spectrometry in metal contamination monitoring point of view. Also it is commonly recognized that minority carrier lifetime measured by μ-PCD method is very sensitive to crystallographic defects which can act as trap centers [3].

In silicon wafer industry, mechanical damage method, which provides dislocation and/or stacking fault nuclei [4,5] on wafer backside, is one of the extensively used extrinsic gettering techniques [6] since it is simple and less costly.

In this work, a systematic experimental investigation on the effect of mechanical backside damage upon minority carrier recombination lifetime measurement by μ-PCD method in Czochralski (CZ) silicon wafers has been performed using X-ray double crystal rocking curve, X-ray section topography and wet oxidation/preferential etch methods.

2. Experimental

The starting materials in this study were p-type (boron-doped, 9 ~ 20 Ω·cm) CZ silicon wafers, with 200 mm diameter (100), single-side polished and 725 μm thick. The oxygen concentration measured with Bio-RAD QS-100 FTIR according to the new ASTM procedure (ASTM F121-81 [7]) was 13.3 ~ 16.6 ppma, whereas the carbon level was less than 0.05 ppma which is below the detection limit of FTIR.

The wafers were heat treated at 700℃ for 10 min in N_2 ambient for oxygen donor annihilation [8] and each cleaved into quarter pieces. One piece from each wafer was not mechanically damaged. This piece is designated as reference to distinguish it from the second, the third and the fourth pieces, designated grade 1, grade 2 and grade 3, whose backsides were mechanically damaged with three kinds of grades as shown in Table 1, respectively, using liquid honing method (in Fig. 1).

After liquid honing process, the samples were cleaned by RCA cleaning method and then subjected to surface passivation treatments, such as HF dipping for 10 min using high purity 49 % HF chemical of semiconductor grade and dry oxidation at 1000℃ for 40 min (growth of about 400 Å thick

Table 1
Liquid honing process parameters

Grade	Air pressure* (kgf/cm^2)	Conveyer speed* (mm/sec)	No. of nozzle*
1	1	12.3	1
2	4.3	12.3	1
3	5.7	10	2

* : normalized value.

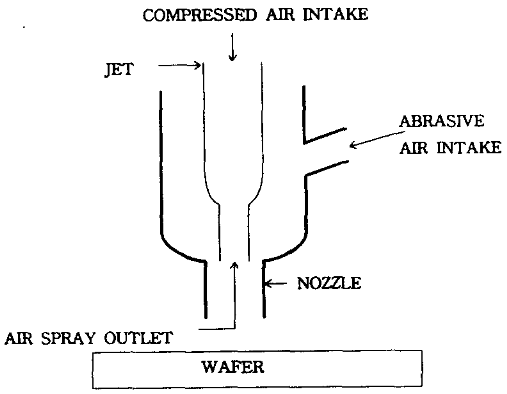


Fig. 1. Schematic of liquid honing method.

oxide layer), to minimize the surface recombination velocity for lifetime measurements [9].

The minority carrier recombination lifetime measurements for the samples were performed at room temperature with μ-PCD lifetime measurement system (SEMILAB WT-85X). The decay of excess minority carriers generated by irradiation with a pulsed laser beam (pulse width : 200 nsec, wavelength : 904 nm) impinged onto the polished surface is observed by monitoring the time decay of the microwave (10.3 GHz) reflection power since the conductivity decreases with the recombination of excited carriers and accordingly the microwave reflection power decays.

The stresses caused by mechanical damage were evaluated by employing X-ray double crystal diffractometer (Bede diffractometer 300) and X-ray topography system (Bede L6). In order to reveal the defects generated as a result of relieving the stresses caused by liquid honing method, the samples were oxidized at 1100℃ for 60 min in wet oxygen ambient and then inspected under the optical microscope after Wright etch [10] for 1 min.

3. Results and discussion

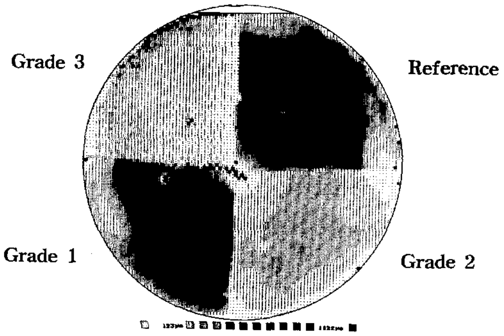
3.1. *Relationship between mechanical damage intensity and lifetime*

Figure 2 (a) and (b) shows minority carrier recombination lifetime data measured with μ-PCD technique in nondamaged ("Reference") and backside mechanically damaged silicon wafers. These data clearly show that the higher the mechanical damage intensity, the lower the minority carrier lifetime. It is well known that the actual penetration depth of laser beam (904 nm wavelength) into silicon crystal bulk is less than 30 μm [11].

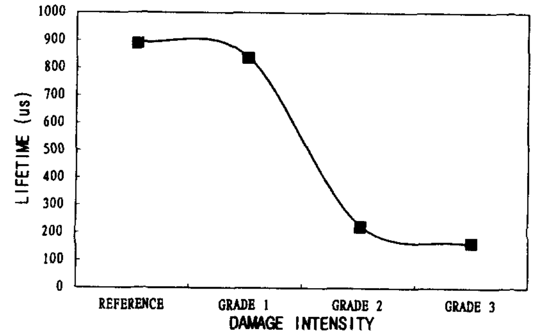
However, as shown in Fig. 2, it is obvious that electrons and holes excited by laser beam are propagated up to wafer backside, consequently affecting the minority carrier recombination lifetime value. Judging from this, it is suggested that nondamaged wafers be used to obtain correct data for contamination monitoring during device processing.

3.2. *Characterization of stresses*

To evaluate the stresses caused by liquid honing method we have performed X-ray double crystal rocking curve and X-ray section topography analyses. It is generally accepted that' the silicon crystal with the full



(a) Lifetime mapping data



(b) Trend of average lifetime value

Fig. 2. Relationship between mechanical damage intensity and minority carrier recombination lifetime meaured by μ-PCD technique. (a) Lifetime mapping data and (b) Trend of average lifetime value.

width at half maximum (FWHM) value lower than 10 sec does not contain crystallographic imperfections [12]. Figure 3 shows the rocking curves taken on "Reference" and backside damaged (Grade 1) samples with (115) reflection. In case of Grade 1 samples FWHM values range from 13 sec to 20 sec, whereas "Reference" samples have FWHM values lower than 9 sec very near the perfect crystal value. By combining Fig. 2 (b) with Fig. 3, it can be said that the threshold FWHM value which affect minority carrier recombination lifetime measurement by μ-PCD technique is about 13 sec.

Figure 4 displays the stresses revealed by X-ray section topography technique with (440) reflection and Mo $K_{\alpha 1}$. The Pendellösung fringes indicate high perfection of CZ silicon wafers used for this study. These data clearly indicate that the stresses due to even Grade 1 of liquid honing method are propagated from mechanically damaged points on backside toward front surface to the extent of almost whole wafer thickness.

The defects generated during wet oxidation at 1100℃ for 60 min as a result of relieving the stresses caused by liquid honing

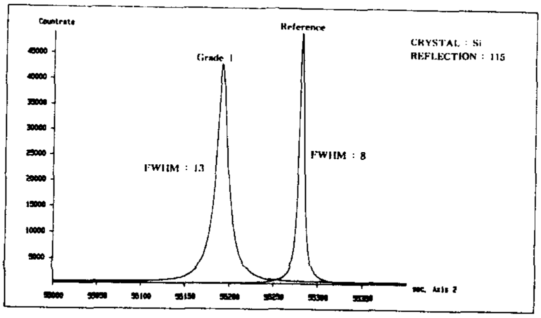


Fig. 3. X-ray rocking curves for "Reference" and backside damaged samples.

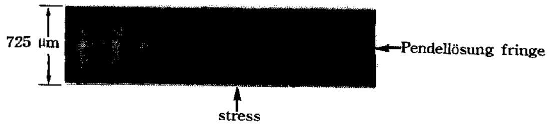
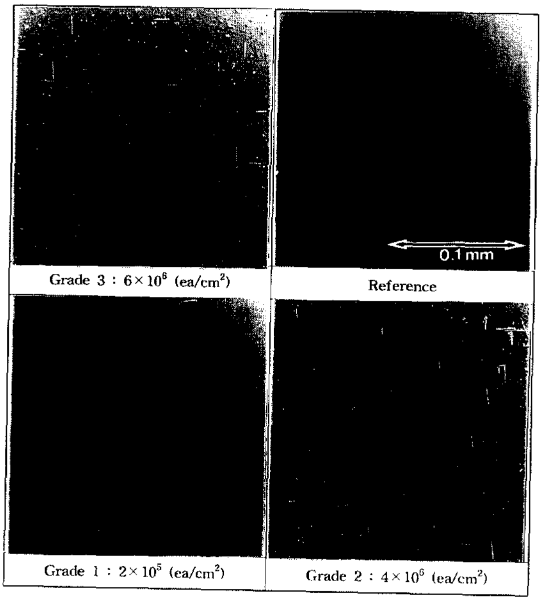


Fig. 4. The stress revealed by X-ray section topograph. [(440) reflection, Mo $K_{\alpha 1}$].



Grade 3 : 6×10^6 (ea/cm^2)

Reference

Grade 1 : 2×10^5 (ea/cm^2)

Grade 2 : 4×10^6 (ea/cm^2)

Fig. 5. Oxidation induced stacking faults generated during wet oxidation at 1100℃ for 60 min.

method are shown in Fig. 5. Note that the harder the mechanical damage intensity, the higher the oxidation induced stacking fault (OISF) density. It can be deduced that OISF test method may be a useful way to distinguish mechanical damage grades.

4. Conclusion

The stresses caused by mechanical damage method and their effects upon minority carrier recombination lifetime measurement by laser excitation/microwave reflection photoconductance decay method were investigated using X-ray double crystal rocking curve, X-ray section topography and wet oxidation/preferential etch methods. The results indicate that :

(1) The higher the mechanical damage intensity, the lower the minority carrier recombination lifetime, and

(2) The threshold full width at half maximum value which affect minority carrier recombination lifetime measurement is about 13 sec.

Acknowledgments

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References

[1] A. Usami, Proc. IEEE 1991 Int. Conference on Microelectronic Test Structures 4 (1991) 25.

[2] A. Buczkowski, Z.J. Radzimski, G.A. Rozgonyi and F. Shimura, J. Appl. Phys. 72 (1992) 2873.

[3] K. Katayama, Y. Kirino, K. Iba and F. Shimura, Jpn. J. Appl. Phys. 30 (1991) L1907.

[4] M.L. Polignano, G.F. Cerofolini, H. Bender and C. Claeys, J. Appl. Phys. 64 (1988) 869.

[5] F. Shimura, Semiconductor Silicon Crystal Technology, (Academic Press, Inc., San Diego, 1989) p. 350.

[6] S. Hahn, 1989 International Conference on VLSI and CAD (KITE/IEEE Korea section) 238.

[7] Annual Book of ASTM Standards,

F121-81, (American Society for Testing and Materials, Philadelphia, 1987).

[8] V. Cazcarra and P. Zunino, J. Appl. Phys. 4 (1980) 4206.

[9] D.K. Schroder, Semiconductor Material and Device Characterization, (John Wiley & Sons, Inc., New York, 1990) p. 359.

[10] M.W. Jenkins, J. Electrochem. Soc., 124 (1977) 757.

[11] 宇佐美晶，徳田豊，半導體デバイス工程評價技術，(REALIZE INC., 1990) p. 162.

[12] B.D. Cullity, Elements of X-ray Diffraction, 2nd ed., M. Cohen, Ed., (Addison-Wesley Publishing Company, Inc., Massachusetts, 1978) p. 277.