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B-3-4 Improvement in CZ Wafers by Reducing Oxygen Impurity

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Oxygen impurity, heavily contained in CZ silicon crystal, has become the most important factor to determine the quality of integrated circuit substrate. In this work, relation between impurity, such as oxygen, and thermally induced defects and MOS device performances was studied.

Several silicon ingots, whose oxygen concentration were controlled to the values between 2×10^{17} and 12×10^{17} atoms/cm^3, were grown for the investigation. Oxygen concentration was controlled by using the CZ growth furnace heated with a graphite heater connected to a three phase AC source and by controlling the seed and the crucible rotation in conjunction with the fluid rotation[1]. Oxygen and carbon concentrations versus a fraction of the melt solidified are shown for five typical ingots in Figs. 1 and 2. It is useful that several portions are available which contain the same oxygen content but have different carbon content and/or different thermal annealing history during crystal growth.

Thermally induced defects were investigated for specimens obtained from these ingots by examining etch hillocks[2] through Wright etching after various heat treatments. The relations between defects and oxygen concentration are shown in Fig. 3. Variation in defect densities induced by the simulated annealings to conventional MOS device fabrication process is shown by curve (a) in Fig. 3. Results for several specimens received 2-step annealing are shown by curves (b) and (c) in Fig. 3. The defect densities strongly depend on oxygen concentration in all annealings. The differences in defect formation were examined between specimens which had the same oxygen concentration and different carbon concentration, but no close correlation was found between carbon and defect density values. The top portion of ingots suffered from annealing with about 100°C/hour in cooling rate from 1000°C to 600°C during crystal growth. No annealing effect during growth process on the defect formation[3] was found in low oxygen content specimens (below 7×10^{17} atoms/cm^3) obtained from the top portion of the ingot. Therefore, it was clarified that oxygen reduction is important to reduce thermally induced defects.

Three kinds of wafers with different oxygen concentrations obtained from 10 % and 60 % solidified in ingot NO. 1 and 20 % solidified in ingot NO. 5 were mirror-polished and MOS devices were fabricated on them. Junction leak current I_J and current gain α for lateral transistors are shown in Fig. 4. It was found that oxygen reduction in a CZ wafer is very preferable to improve device characteristics. Though wafer warpage was found to be increased from 10∼30 μm to 20∼50 μm during the MOS processing, no correlation between warpage and oxygen concentration of the wafers has been observed in the present study.

References:

1) K.Hoshikawa, H.Kohda, H.Hirata and H.Nakanishi; Jpn.J.Appl.Phys. 19 (1980) pL33
2) H.Takaoka, J.Osaka and N.Inoue; Jpn.J.Appl.Phys. 18 (1979) Suppl. 18-1, p179
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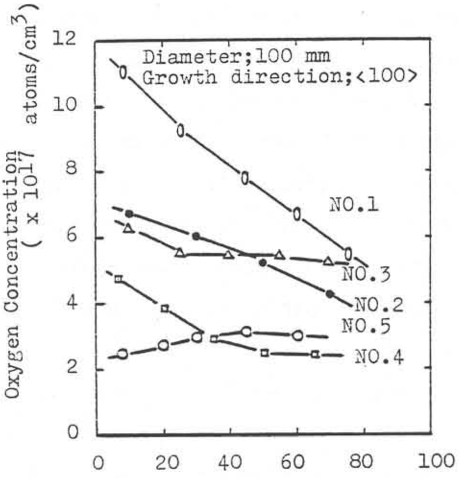

Fig.1 Oxygen concentration variation vs. fraction of melt solidified.

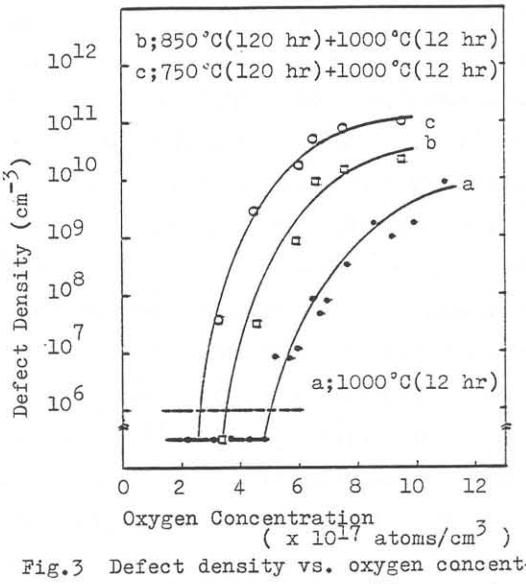

Fig.3 Defect density vs. oxygen concentration under various annealings. a;1-step annealing and b,c;2-step annealing. Broken line indicates detectable level of defect density.

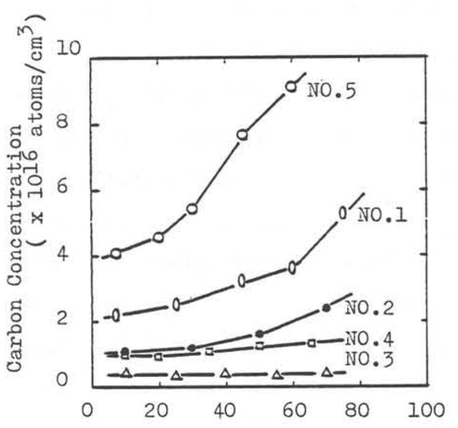

Fig.2 Carbon concentration variation vs. fraction of melt solidified.

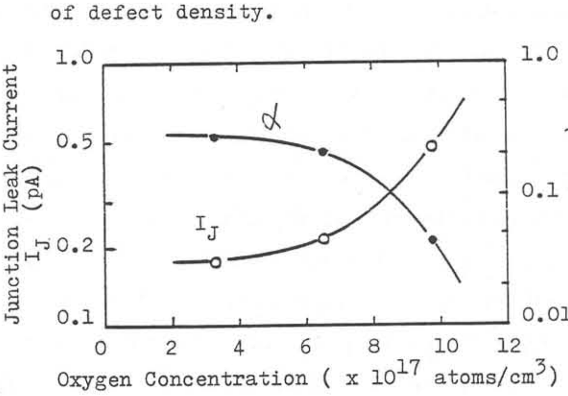

Fig.4 Junction leak current and current gain for lateral transistor vs. oxygen concentration.