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EBIC MEASUREMENTS OF ANNEALED SILICON BICRYSTALS

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Two silicon bicrystals have been analyzed by EBIC to determine the evolution of minority carrier properties such as diffusion length, $L_n$, and recombination velocity, $V_r$, after different thermal treatments. The geometric orientations of bicrystals are 26°62 <001> Σ13 and 16°26 <001> Σ25. The grain boundary planes are (510) and (710) respectively. Small deviations of the order of 0,15° to the exact coincidence orientation are observed. The thermal treatments were carried out in a high purity argon flow at 450°C, 750°C and 950°C for 2, 24, 48, 75 and 92h.

The concentrations of interstitial oxygen and substitutional carbon were determined from infra-red spectra by measuring the absorbance of 1107 cm$^{-1}$ (oxygen) and 604 cm$^{-1}$ (carbon) bands. The doping rate of the as-grown bicrystals was deduced from $C=f(V)$ plots: 5.1 x 10$^{-14}$ P at.cm$^{-3}$ (Σ13) and 3.6 x 10$^{-14}$ P at.cm$^{-3}$ (Σ25). For the thermal treatments at 450°C and 750°C the concentration of free carriers in the bulk can vary because of the formation of thermal donors (450°C) and new donors (750°C). So their concentrations were deduced from $V=f(B)$ plots by determining the Hall constant $R_H$. The parameters $L_n$ and $V_r$ were measured using Donolato’s model.

For the as-grown condition, a very slight EBIC contrast is observed for both bicrystals, the recombination of Σ13 seems to be slightly higher than that of Σ25.

The recombination becomes real for the treatments 75h 450°C and 92h 450°C and a slight increase of the free carrier rate is observed for the Σ13 orientation whereas this rate is nearly constant for the Σ25 orientation. No significant variation of oxygen and carbon concentrations is detected.

The 750°C treatments are characterized by the formation of an EBIC dotted contrast for the Σ13 orientation except for the shortest treatment which shows a homogeneous contrast. For the Σ25 orientation, the contrast varies from homogeneous (2h), homogeneous plus dotted contrast (24h, 48h), homogeneous (75h) and finally dotted (92h). This dotted contrast has been attributed to precipitates but no clear evidence of a decrease of the oxygen concentration has been measured. Conversely, the behaviour of free carriers is more complex and the formation of acceptors can be assumed (Σ13).

At 950°C, the EBIC contrast is always dotted for the Σ13 orientation except for the shortest treatment (2h), in this case a homogeneous contrast is detected with a very weak dotted contrast. For the Σ25 orientation the EBIC contrast is always homogeneous, very strong, whatever the temperature. It is worth noticing that a supplementary band (1225 cm$^{-1}$) attributed to SiO, precipitated is detected for the 75h treatment. A decrease of the interstitial oxygen is also measured for the 92h treatment but the supplementary band has not been seen.

Two types of precipitates have been observed by TEM: a homogeneous distribution of small precipitates ($\approx$ 5 nm) and larger aggregates (100 nm). The distance between the largest precipitates corresponds approximately to the distance between the darkest spots observed in EBIC mode.

From these observations, it is clear that, at least, two types of EBIC contrast, homogeneous or dotted, are detected. If the dotted contrast can be due to the largest precipitates, the homogeneous contrast could be attributed to the smallest precipitates.