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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, $L_D$, and recombination velocity, $V_r$, after different thermal treatments. The geometric orientations of bicrystals are $26^\circ 62^\prime <001>$ $\Sigma 13$ and $16^\circ 26^\prime <001>$ $\Sigma 25$. The grain boundary planes are $(510)$ and $(710)$ respectively. Small deviations of the order of $0.15^\circ$ to the exact coincidence orientation are observed. The thermal treatments were carried out in a high purity argon flow at $450^\circ$C, $750^\circ$C and $950^\circ$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 : $5.1 \times 10^{14}$ P at.cm$^{-3}$ ($\Sigma 13$) and $3.6 \times 10^{14}$ P at.cm$^{-3}$ ($\Sigma 25$). For the thermal treatments at $450^\circ$C and $750^\circ$C the concentration of free carriers in the bulk can vary because of the formation of thermal donors ($450^\circ$C) and new donors ($750^\circ$C). So their concentrations were deduced from $V = f(B)$ plots by determining the Hall constant $R_H$. The parameters $L_D$ 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 $\Sigma 13$ seems to be slightly higher than that of $\Sigma 25$. The recombination becomes real for the treatments $75h$ $450^\circ$C and $92h$ $450^\circ$C and a slight increase of the free carrier rate is observed for the $\Sigma 13$ orientation whereas this rate is nearly constant for the $\Sigma 25$ orientation. No significant variation of oxygen and carbon concentrations is detected.

The $750^\circ$C treatments are characterized by the formation of a EBIC dotted contrast for the $\Sigma 13$ orientation except for the shortest treatment which shows a homogeneous contrast. For the $\Sigma 25$ 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 ($\Sigma 13$). At $950^\circ$C, the EBIC contrast is always dotted for the $\Sigma 13$ orientation except for the shortest treatment ($2h$), in this case a homogeneous contrast is detected with a very weak dotted contrast. For the $\Sigma 25$ 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 ($\simeq 5$ 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.