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Excess carrier lifetime and surface recomination velocity in dielectrically isolated Si-tubs

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INTRODUCTION

We have compared the performance of dielectrically isolated photodiodes fabricated with wafer bonding and with a competing technology. We measured the effective excess carrier lifetime in the isolated tubs and derived the bulk lifetime in the tub and the surface recombinaton velocity at the buried oxide interface. We conclude that wafer bonding improves the short circuit current per unit area (J_{sc}) and the open circuit output voltage (V_{oc}) significantly compared to dielectrical isolation. This result is supported by device measurements and simulations.

PHOTOVOLTAIC CELL

The photovoltaic cell consists of a chain of photodiodes, all placed in silicon tubs, isolated from each other. These devices can be fabricated with two different technologies. With wafer bonding, the device wafer, which contains isolated trenches, is bonded to the handle wafer. The dielectric isolation is obtained by the vertical trenches and the oxide at the bonded interface. The competing technology is based upon etching of moats at the backside of a single wafer, followed by an oxidation and a poly-Si deposition at the backside as the handle material. In both cases, the bulk tub material is p-type, and there is a n^+ emitter at the top surface. At the sidewalls and at the backside, there is also a n-type diffusion, but this emitter is electrically fully transparant : the diffusion lenght in this emitter is still more than 10 microns. In practice, this means that the cell is very sensitive to surface recombination at the backside and sidewalls of the cell. Together with the bulk excess carrier lifetime (τ_b), the backside surface recombination velocity (S_{back}) is therefore a determing internal parameter for the performance of the cell. We determined both parameters for the Si-tubs. Correctness of these parameters is also important to build an accurate model for simulations of the device.

DETERMINATION OF BULK LIFETIME AND SURFACE RECOMBINATION VELOCITY

We measured the effective lifetime by the microwave-detected photoconductance decay technique (PCD). The microwave reflectance is a function of the carrier density in the wafer. The change of the reflectance can be used as a probing tool for the carrier decay within the wafer after a laser pulse. In the IMEC setup, the excess carriers are generated by a laser pulse and the microwave frequency is 22 GHz. Since we are only interested in the lifetime in the tub, the excess carriers are generated by a green laser (523 nm) to insure that full absorption of the laser light takes place in the Si-tub. By proper passivation of the top surface by a cleaning treatment, applying a varnish layer (1) and the fact that the lateral dimensions of the structure are a factor of 10 larger than the depth, one can relate the effective lifetime τ_{eff} to τ_b and S_{back} through the following equation, with W being the depth of the Si-tub.

$$\frac{1}{\tau_{eff}} = \frac{1}{\tau_b} + \frac{S_{back}}{W} \quad (1)$$

To determine the (S_{back}, τ_b) pair, a second relation is needed. This relation comes from dark I-V measurements. We simulated I-V curves for several (S_{back}, τ_b) pairs which all correspond to eq. 1. The pair which gives the best fit is choosen.

RESULTS

For the single wafer substrates, we measured an effective lifetime of 0.25 μs. Fitting the dark I-V curves to the I-V simulations gave us a bulk lifetime τ_b of 2 μs and a theoretical surface recombination velocity at the backside (S_{back}) of 10000 cm/s. On the devices fabricated with wafer bonding, the oxide at the backside of the tub was grown on the handle wafer before bonding. We measured an effective lifetime of 4 μs resulting in a S_{back} of 1000 cm/s and τ_b of 20 μs. This improvement increases the short-circuit current I_{sc} and the open-circuit voltage V_{oc}. On the conference, we will also present lifetime measurements on a new generation of bonded wafers with optimized backside surface passivation. On this wafers, the thermal oxide is grown on the device wafer instead of on the handle wafer, and a lower τ_b and S_{back} are expected.

CONCLUSIONS

We determined the two most important internal parameters for a photodiode in an isolated tub, namely the bulk lifetime and the back surface recombination velocity. With this result, we proved that wafer bonding significantly improves the performance of the diode.

REFERENCES

1. J. Poortmans, T. Vermeulen, J. Nijs, R. Mertens, *Development of easy-to-use surface passivation schemes for lifetime measurements on monocrystalline Si with (100)-orientation*, Proceedings 25th IEEE Photovoltaic Specialists Conference, p. 721-724, Washington D.C. (1996)