RELIABILITY OF MICROWAVE PHOTOCONDUCTIVITY LIFETIME MEASUREMENTS

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ABSTRACT: The microwave reflection photoconductivity decay (MW-PCD) is a well known technique to measure lifetime in silicon wafers by the analysis of the decay of the reflected incident microwaves on the sample. However this decay can be affected by for instance surface properties, namely surface recombination. Besides HF, iodine in an ethanol solution has been used to achieve good passivation results. Here we show that iodine concentration and the time taken to measure the lifetime are aspects have to be considered to achieve reliable and reproductible results.

Keywords: Lifetime, microwave PCD, silicon

1 INTRODUCTION

The microwave reflection photoconductivity decay (MW-PCD) is a well known technique to measure lifetime in silicon wafers. One big advantage of this technique is that it is contactless. A pulsed light is used to generate free carriers that in turn change the reflectivity of the wafer to the incident microwaves. When the light pulse goes off, the measured decay profile of the reflectivity enables the extraction of the lifetime of these carriers. However this decay can be affected by for instance surface properties, namely surface recombination, which can significantly change the effective lifetime extracted from the decay. It is well known that HF can passivate monocrystalline silicon surfaces very effectively [1]. More recently it was shown that iodine in an ethanol solution can give similar passivation effects, with the advantage of being also suitable for multicrystalline wafers [2].

The effect of injection level has to be taken into account when measuring lifetime because, for some materials, recombination is dependent on the injection level [3]. Besides this effect we found that other aspects have to be considered to achieve reliable lifetime measurements.

2 EXPERIMENTAL WORK

The lifetime that is obtained by MW-PCD is an effective lifetime that incorporates the effect of both surfaces of the sample, which are assumed to have similar properties, according to the equation

$$\frac{1}{\tau_{eff}} = \frac{1}{\tau_B} + \frac{1}{\tau_s}$$

where τ_B is the bulk lifetime and τ_S the lifetime associated with the surface.

In this work we studied the effect of parameters such as the iodine concentration in ethanol and the time dependence of the passivation. This later effect can be important when a slow scanning lifetime measurement is performed, because the passivation effectiveness will change with time thus masking the results of the sample regions that are measured in last place.

Several silicon samples of Czochralski(CZ) and Float Zone (FZ) wafers were prepared. The samples were etched in a solution of HF:HNO3:CH3COOH (22:47:31) to remove the saw damage and rinsed in deionised water. Just before the lifetime measurement they were dipped in diluted HF and again rinsed in deionised water.

The lifetime was measured with a Semilab WT-1000, while keeping the samples immersed in iodine solution in ethanol with different concentrations.

3 RESULTS

3.1 Effect of iodine concentration

The results we obtained show that an optimized concentration of iodine in the ethanol solution can be found to maximize the passivation effect. This is shown in Fig.1

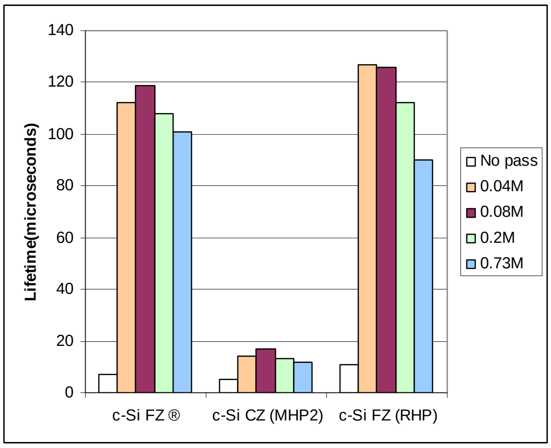

Figure 1: The figure shows the measured lifetime (microseconds) for different wafers (Czochralski –CZ; Float Zone-FZ) against the iodine concentration solution. The white bar refers to measured lifetime for the same samples without passivation.

3.2 Time dependence of the passivation

We observed that the measured lifetime is not constant over time, but decreases with time. This decrease depends on the iodine concentration and can be fitted to an exponential decay that characterizes each solution. In Fig. 2 we show the variation of the effective lifetime versus time for one of the samples, showing effects of different locations in the sample.

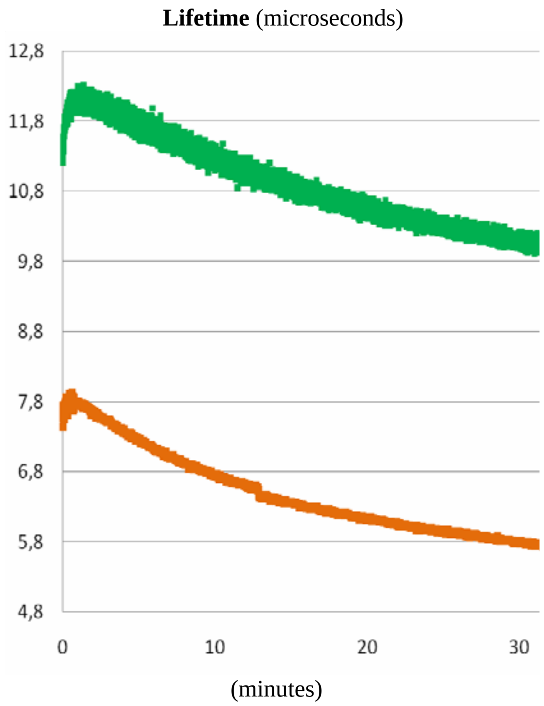

Figure 2: Decrease of the measured lifetime (microseconds) versus time (minutes) for the same sample in the same solution but different sample locations. The decrease can be fitted to an exponential with a time constant decay in both cases.

Calculating the time constant from each decay for all the samples and all the iodine solution concentrations studied we obtained the graph shown in Fig.3.

From these results we conclude that there is an optimum iodine solution concentration that not only provides the best surface passivation but also its effectiveness lasts longer.

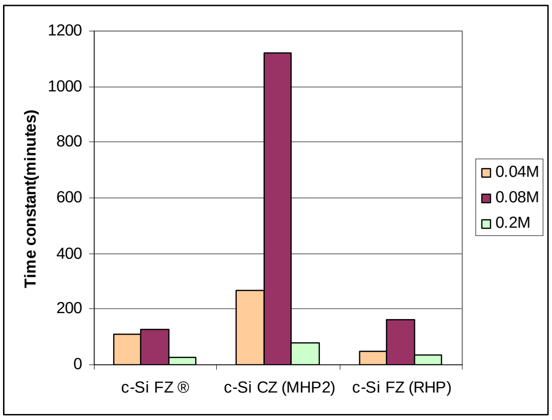

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Figure 3: Time constant decay (minutes) of the measured lifetime for the iodine concentration solutions that were studied.

4 CONCLUSIONS

The measured lifetime in MW-PCD using iodine solution in ethanol shows a time dependence indicating a variation of the surface passivation in time. There is an iodine concentration that maximizes the passivation effect.

MW-PCD is an attractive technique for lifetime measurements in semiconductor materials characterization but requires some precautions in order to achieve reliable and reproducible results.

5 ACKNOWLEDGMENTS

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