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# WAFER PREPARATION AND IODINE-ETHANOL PASSIVATION PROCEDURE FOR REPRODUCIBLE MINORITY-CARRIER LIFETIME MEASUREMENT

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## INTRODUCTION

- Measurement of the bulk minority-carrier lifetime ($\tau_b$) by optical methods, such as photocurrent decay or quasi-steady-state photoconductance (QSSPC), is strongly influenced by surface recombination.
- Several techniques are known to lower the effective surface recombination velocity, including the following: use of oxidation, floating N/P junction, SiN:H layer, HF immersion, and use of iodine in ethanol or methanol (I-E solution).
- Using I-E appears to be very simple and does not require any high-temperature treatment such as oxidation, diffusion, or nitridation processes, which can change $\tau_b$.
- However, this is not a preferred procedure within the photovoltaic community because it is difficult to obtain same $\tau_b$ values reproducibly, particularly when the wafer lifetime is long.

## OBJECTIVES FOR STUDYING LIFETIME MEASUREMENTS AND I-E PASSIVATION

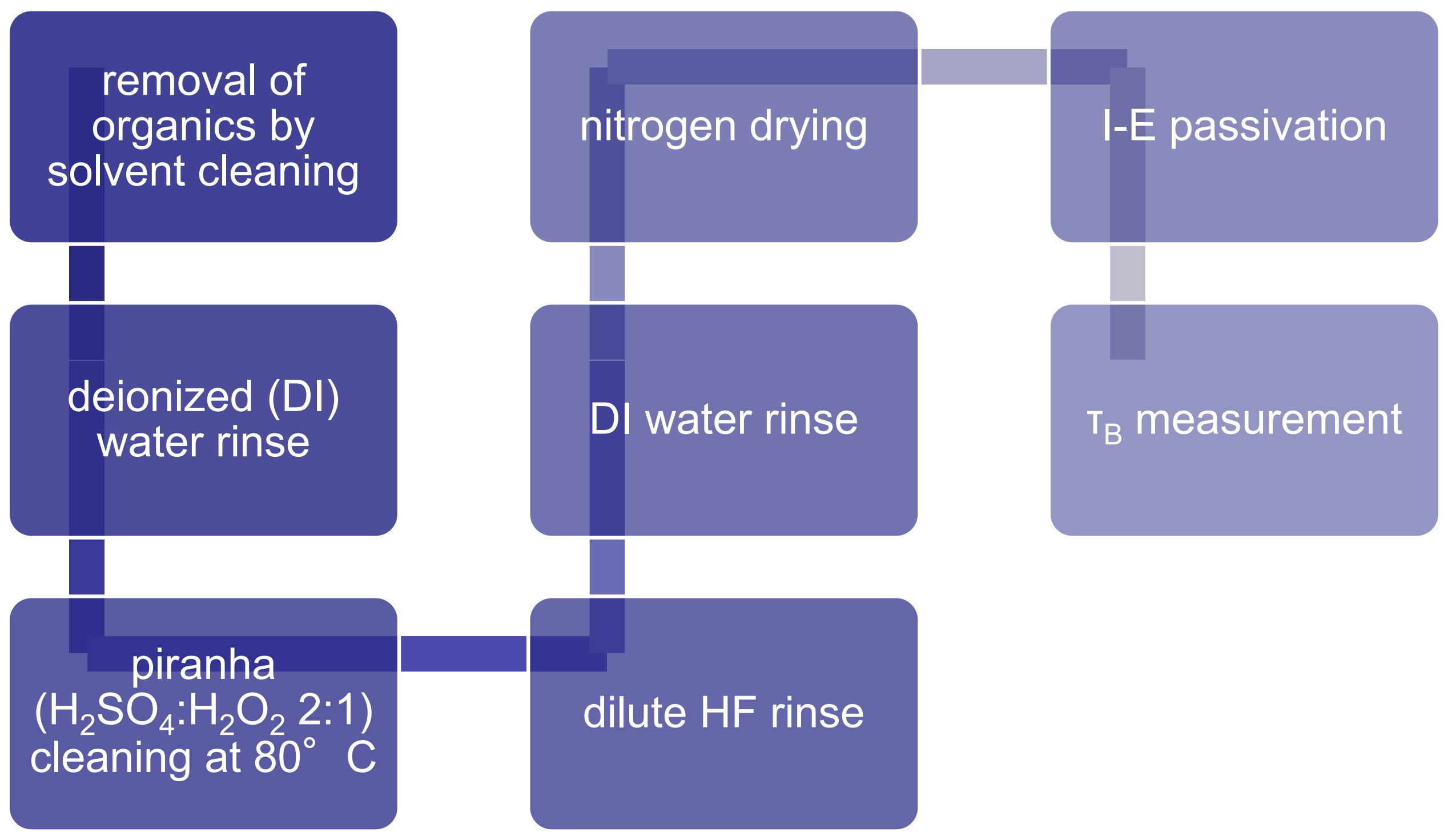
(i) Investigate various reasons why lifetime measurements may be irreproducible using I-E solution passivation.

(ii) Study the influence of the strength of iodine in the ethanol solution, wafer-cleaning procedures, influence of the wafer container during lifetime measurements, and the stability of I-E.

(iii) Compare lifetimes of wafers (having different $\tau_b$) by various techniques such as QSSPC and transient photoconductive decay using short laser pulses of different light intensity;

(iv) Make minority-carrier diffusion length (L) measurements by a surface photovoltage technique, and to use $\tau_b$ and L data to determine diffusivity (D) values for various impurity and defect concentrations, using the relationship $L^2 = D^* \tau_b$.

## INITIAL CLEANING PROCEDURE (ICP)



removal of organics by solvent cleaning

deionized (DI) water rinse

piranha ($H_2SO_4$:$H_2O_2$ 2:1) cleaning at 80° C

dilute HF rinse

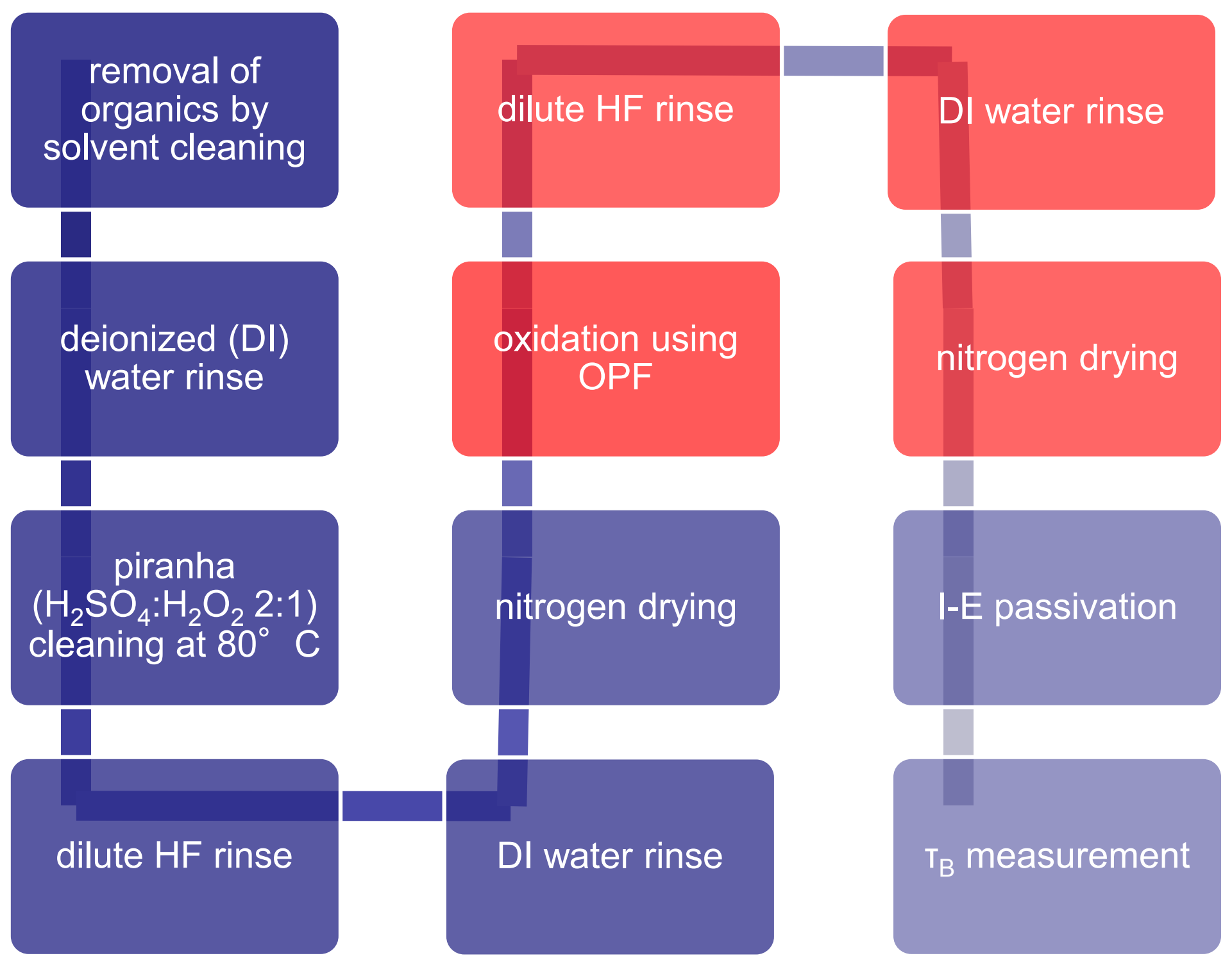
DI water rinse

nitrogen drying

I-E passivation

$\tau_B$ measurement

## IMPROVED CLEANING PROCEDURE



removal of organics by solvent cleaning

deionized (DI) water rinse

piranha ($H_2SO_4$:$H_2O_2$ 2:1) cleaning at 80° C

dilute HF rinse

DI water rinse

oxidation using OPF

dilute HF rinse

DI water rinse

nitrogen drying

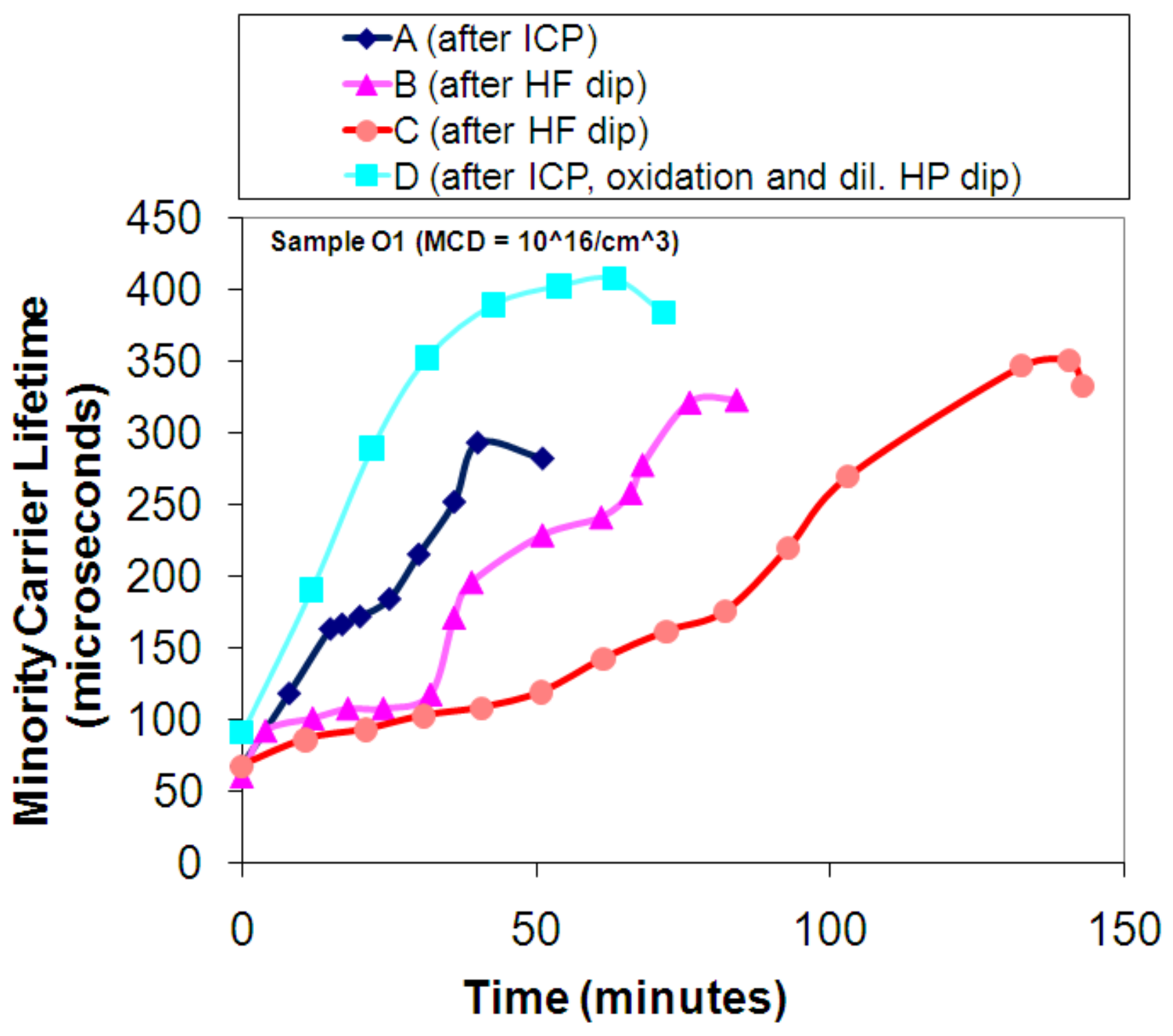
nitrogen drying

I-E passivation

$\tau_B$ measurement

red - new process steps

## COMPARISION OF CLEANING PROCEDURES

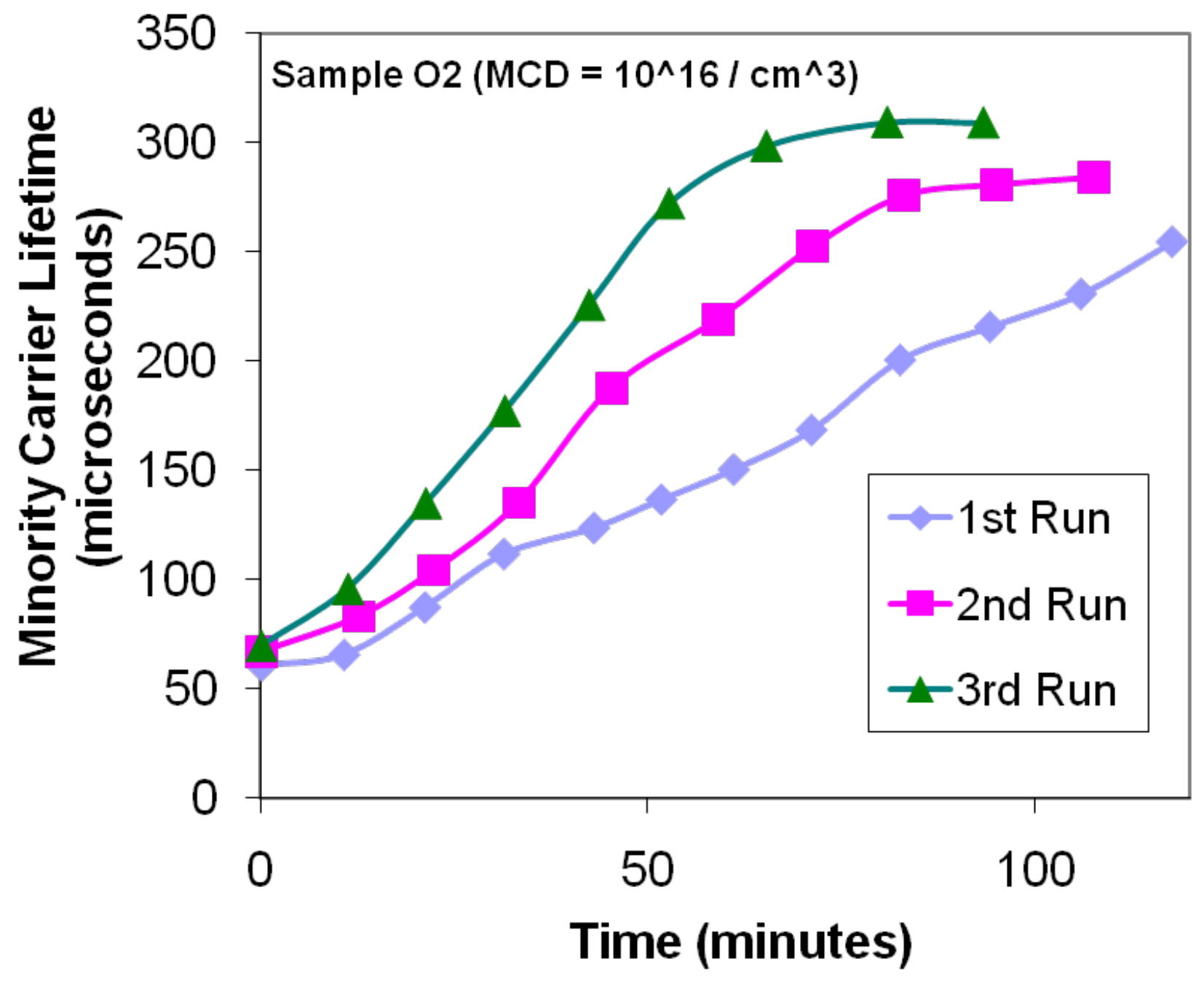


During run A, B and C sample surface became **progressively less clean**, resulting in a longer time to reach final lifetime.

Curve D shows that the **improved cleaning procedure** caused lifetime maximum to be reached much faster and the maximum was higher than previous values.

$\tau_B$ is also a function of number of measurements made in a given time

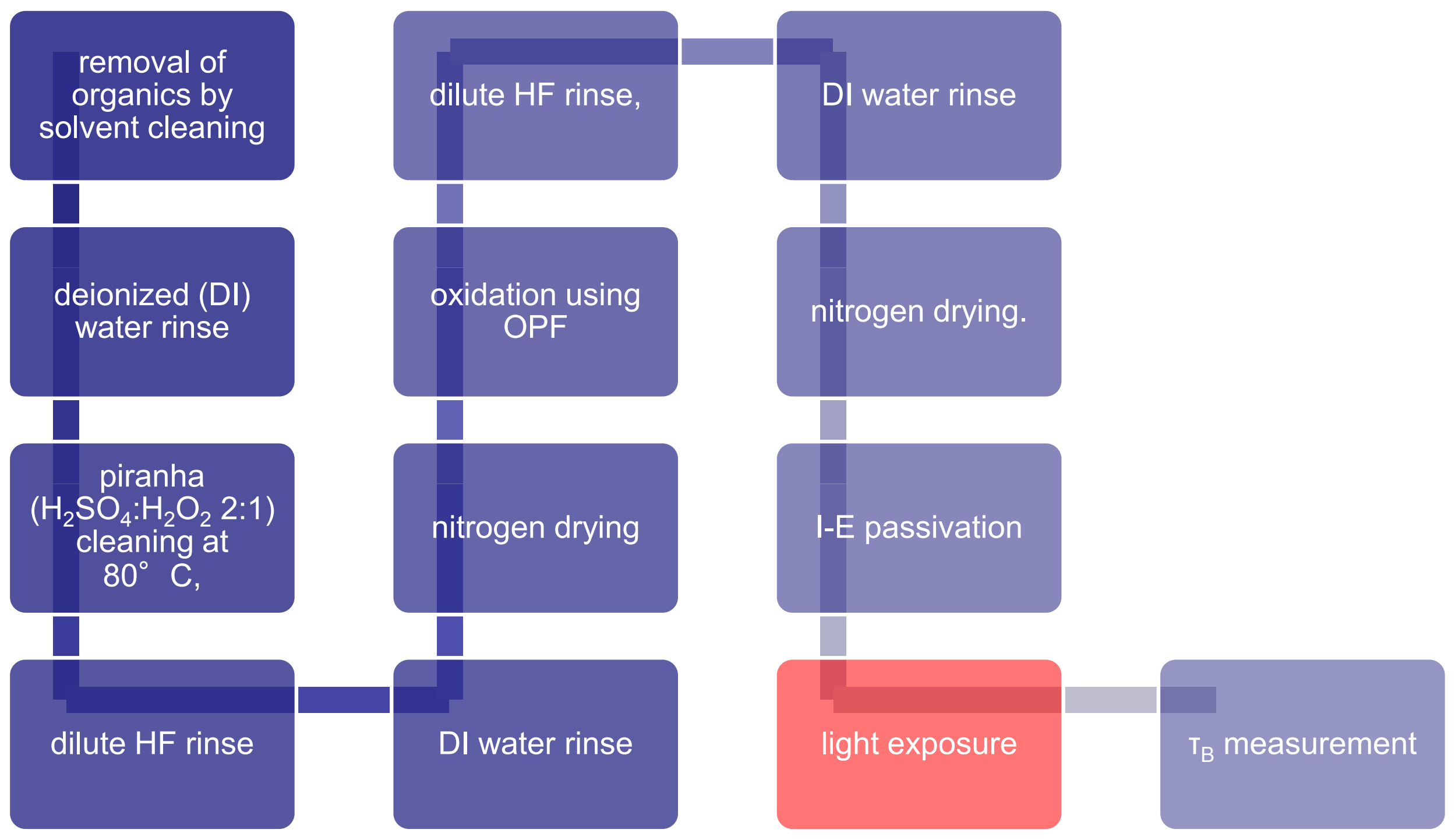
## RESULTS FOR SEQUENTIAL CLEANING



To establish how deep the surface must be removed, we performed oxidation in steps. The sample was cleaned and oxidized after each set of measurements.

Further oxidations only increased the slope of the curves, whereas the $\tau_{max}$ remained the same.

## LIGHT EXPOSURE EFFECT



removal of organics by solvent cleaning

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piranha ($H_2SO_4$:$H_2O_2$ 2:1) cleaning at 80° C,

dilute HF rinse

DI water rinse

oxidation using OPF

dilute HF rinse,

DI water rinse

nitrogen drying

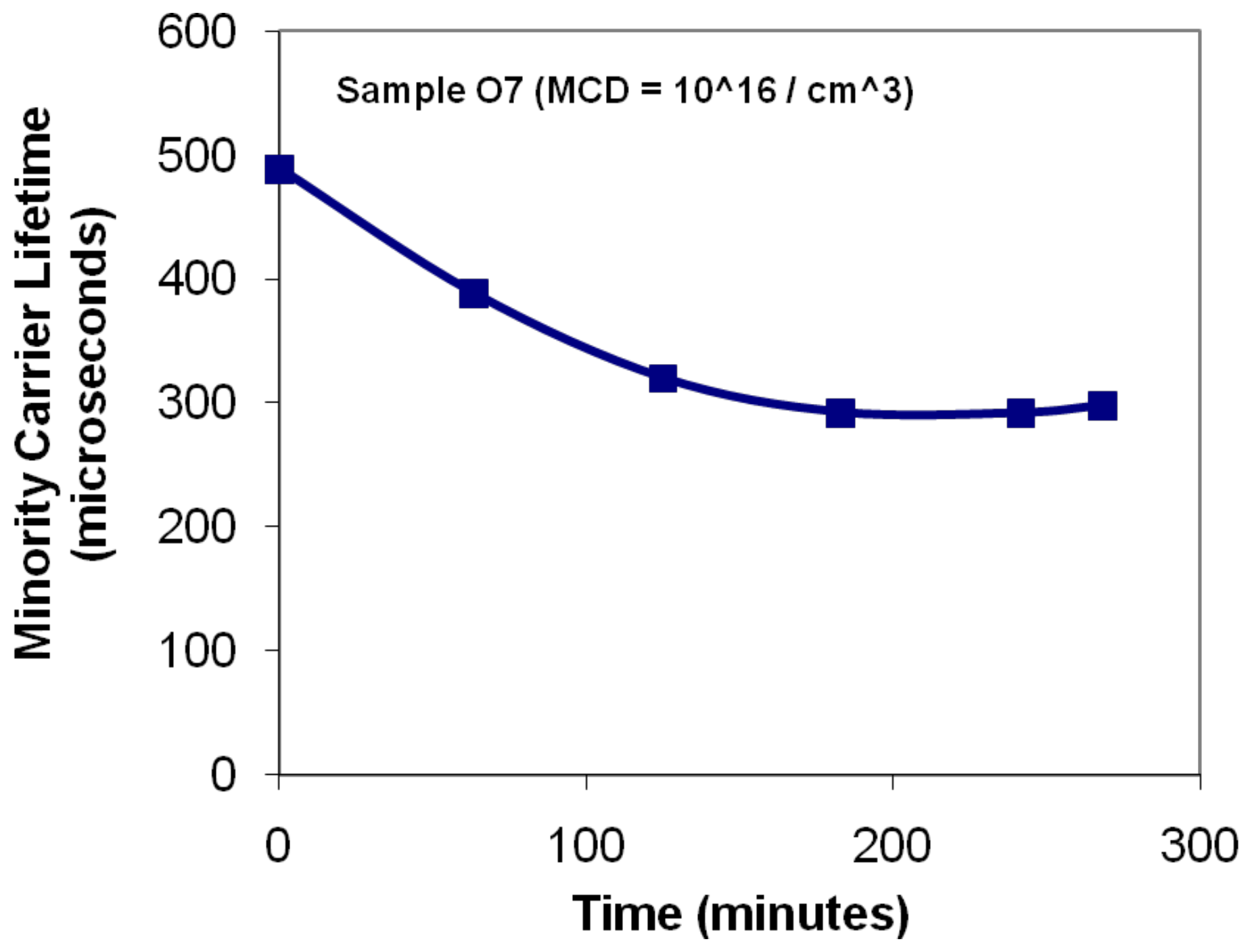
nitrogen drying.

I-E passivation

light exposure

$\tau_B$ measurement

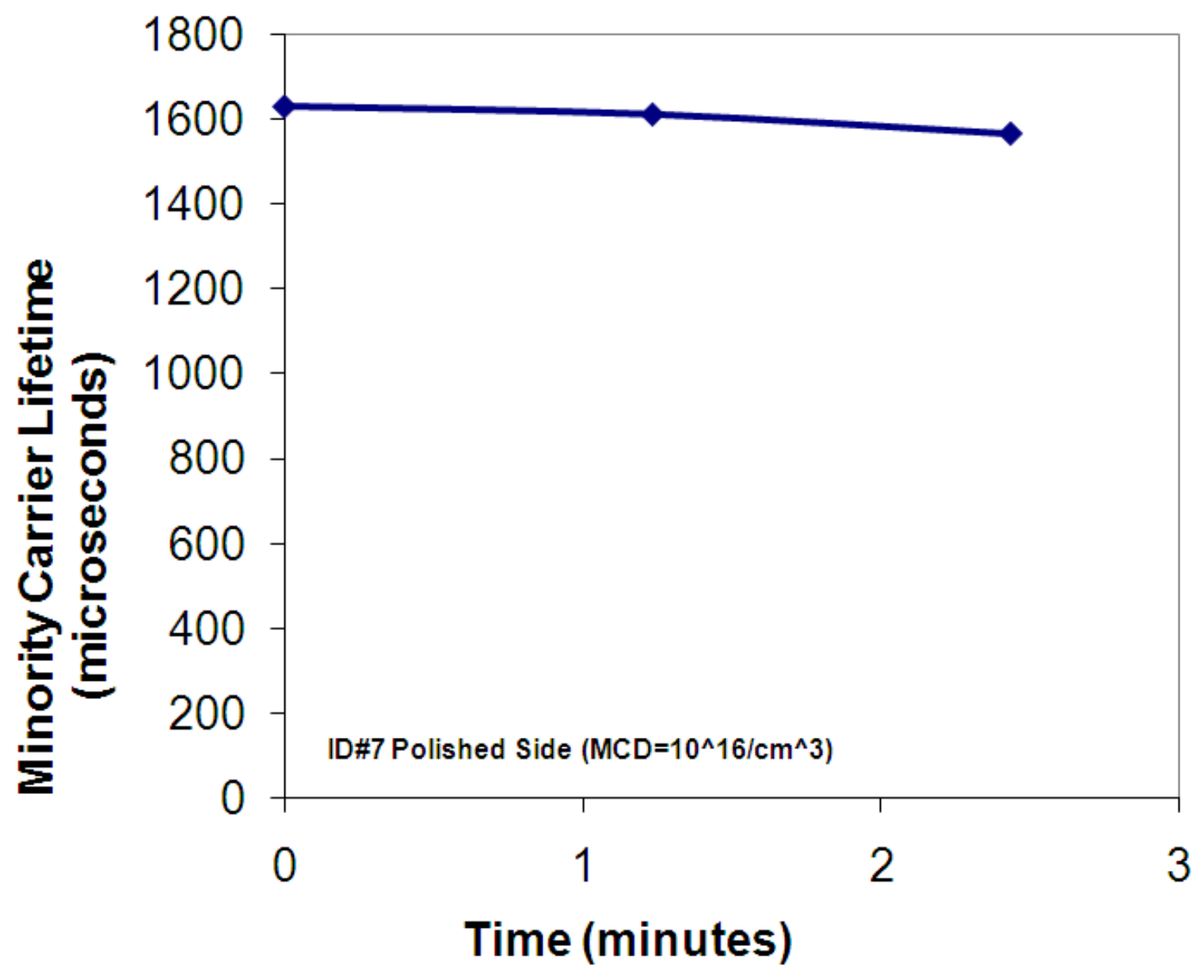
## $T_B$ DECAY AFTER LIGHT EXPOSURE



We found that the lifetime after the light exposure (~1 sun for 5-15 minutes) gave the $\tau_{max}$ immediately after the exposure.

Furthermore, there was a slow decrease.

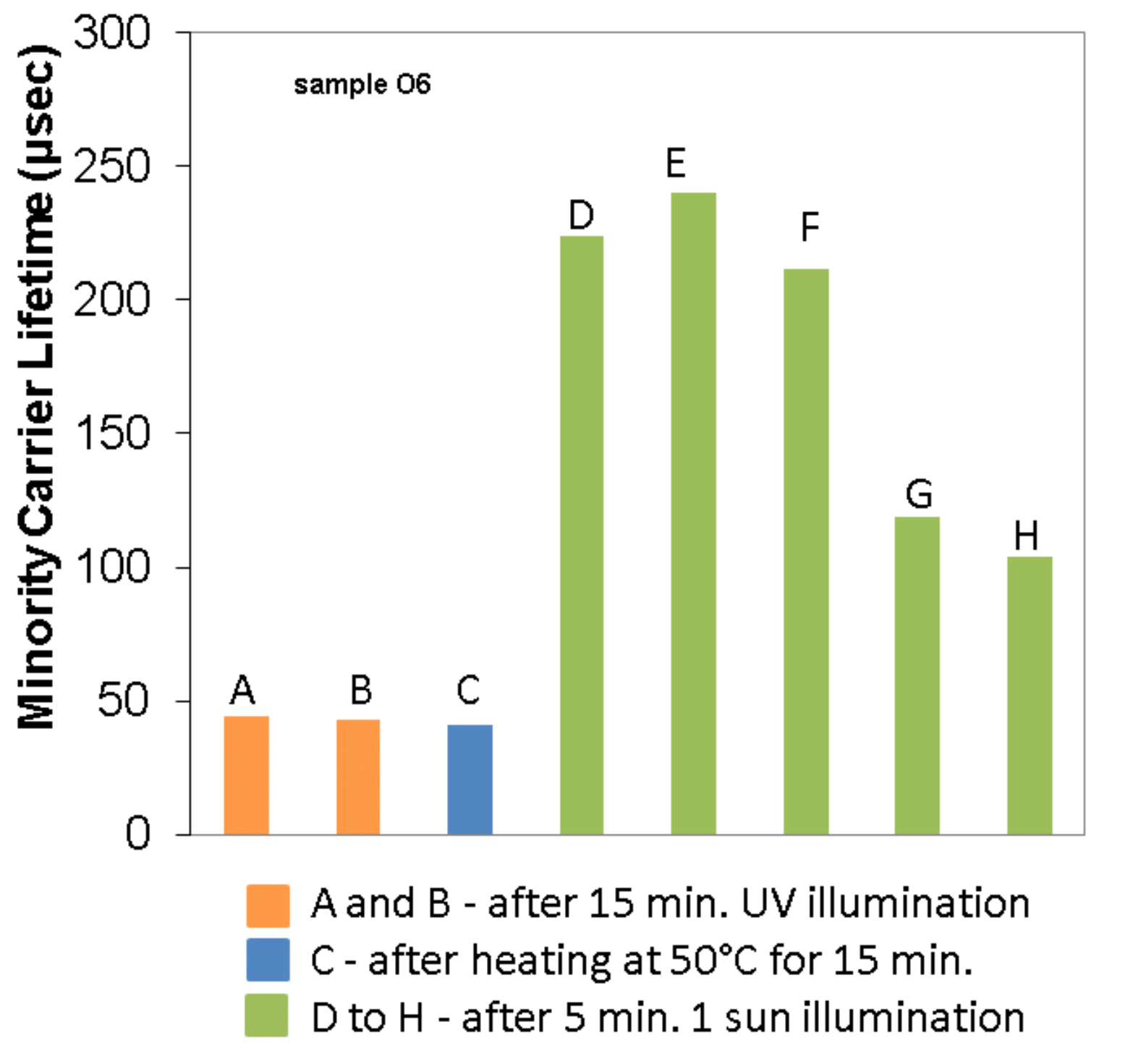
## VARIATION OF $T_B$ FOR A LONG LIFETIME WAFER



The wafer was cleaned with the new procedure.

As shown in the figure for a long lifetime wafer $\tau_B$ starts decreasing in just few minutes .

## WHAT IS BEHIND THE LIGHT EFFECT?



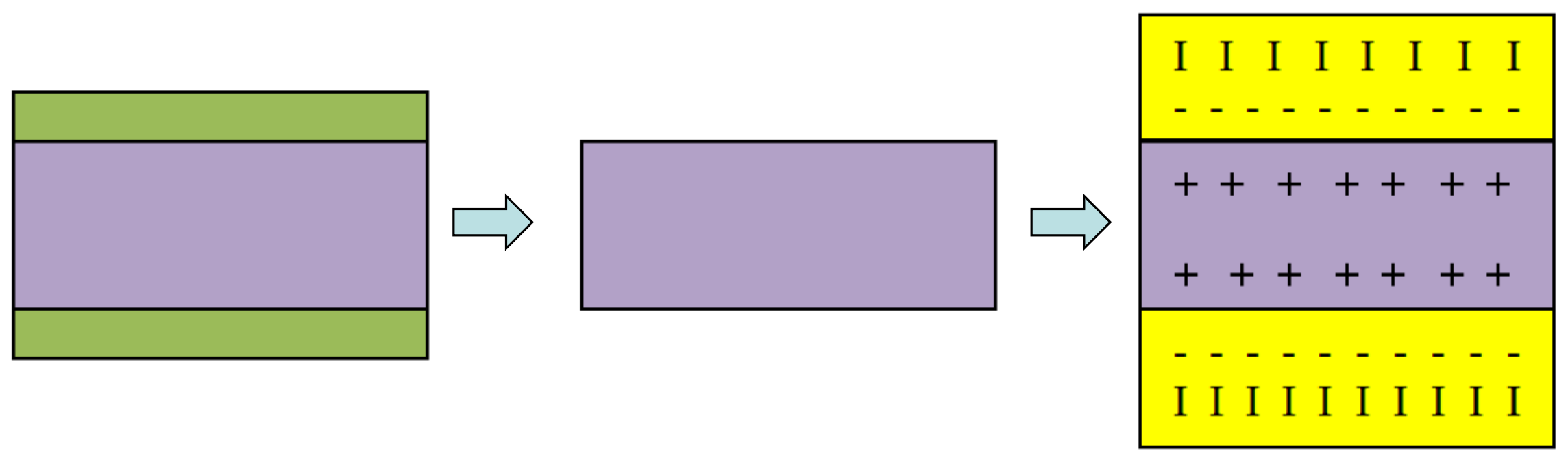
🟧 A and B - after 15 min. UV illumination
🟦 C - after heating at 50°C for 15 min.
🟩 D to H - after 5 min. 1 sun illumination

When the wafer in the I-E bag was exposed to UV light, the lifetime did not reach $\tau_{max}$.

Heating also did not produce any change in the lifetime.

Visible and IR-reach light source needs to be used to observe the light effect.

## SIMPLE MODEL FOR WAFER PREPARATION



a) wafer has contamination/surface damage, which must be removed to get high degree of passivation

b) contaminated surface removed

c) I-E passivation has a time constant (charge accumulation filling surface traps), which is activated by light (depends on bulk properties)

## CONCLUSIONS

- Wafer cleaning procedure should include removal of about 200–300 Å of Si from each surface.
- We have outlined a procedure that yields a very clean surface.
- IE passivation may be sensitivity to light
- Unfortunately, our data on a variety of wafers are not consistent. For example, wafers from the same lot do not have the same dependence of lifetime on light exposure.

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