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# Admittance Spectroscopy and Deep-Level Transient Spectroscopy in Multijunction: a Tutorial to Characterize the Entire Cell

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## A Tutorial to Characterize the Entire Cell

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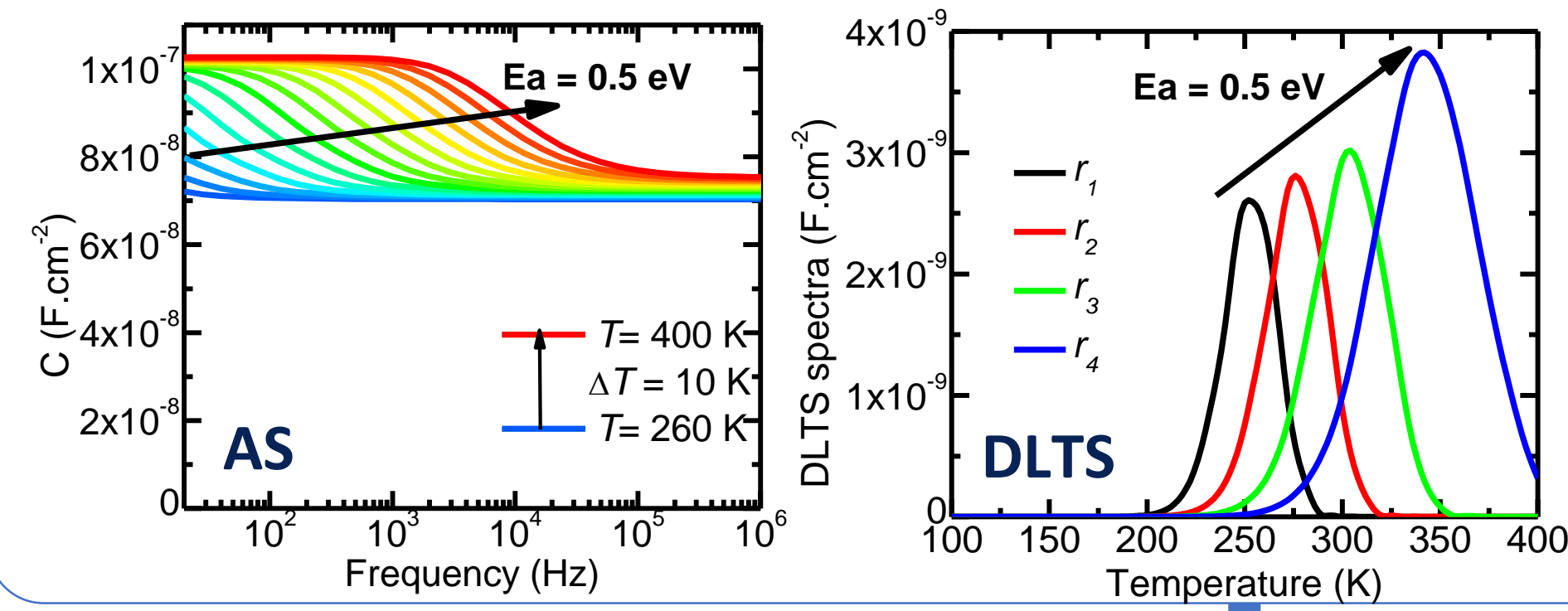
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AlGaAs cell (Eg = 1.7 eV)  
Si cell (Eg = 1.12 eV)

### Objectives

- John wants to get the defect properties of the AlGaAs subcell within his 2T tandem cell using Admittance Spectroscopy (AS) and Deep-Level Transient Spectroscopy (DLTS).
- He doesn't know yet that within the AlGaAs subcell, a 0.5 eV deep defect is present. If he could characterize this subcell alone, he would get:

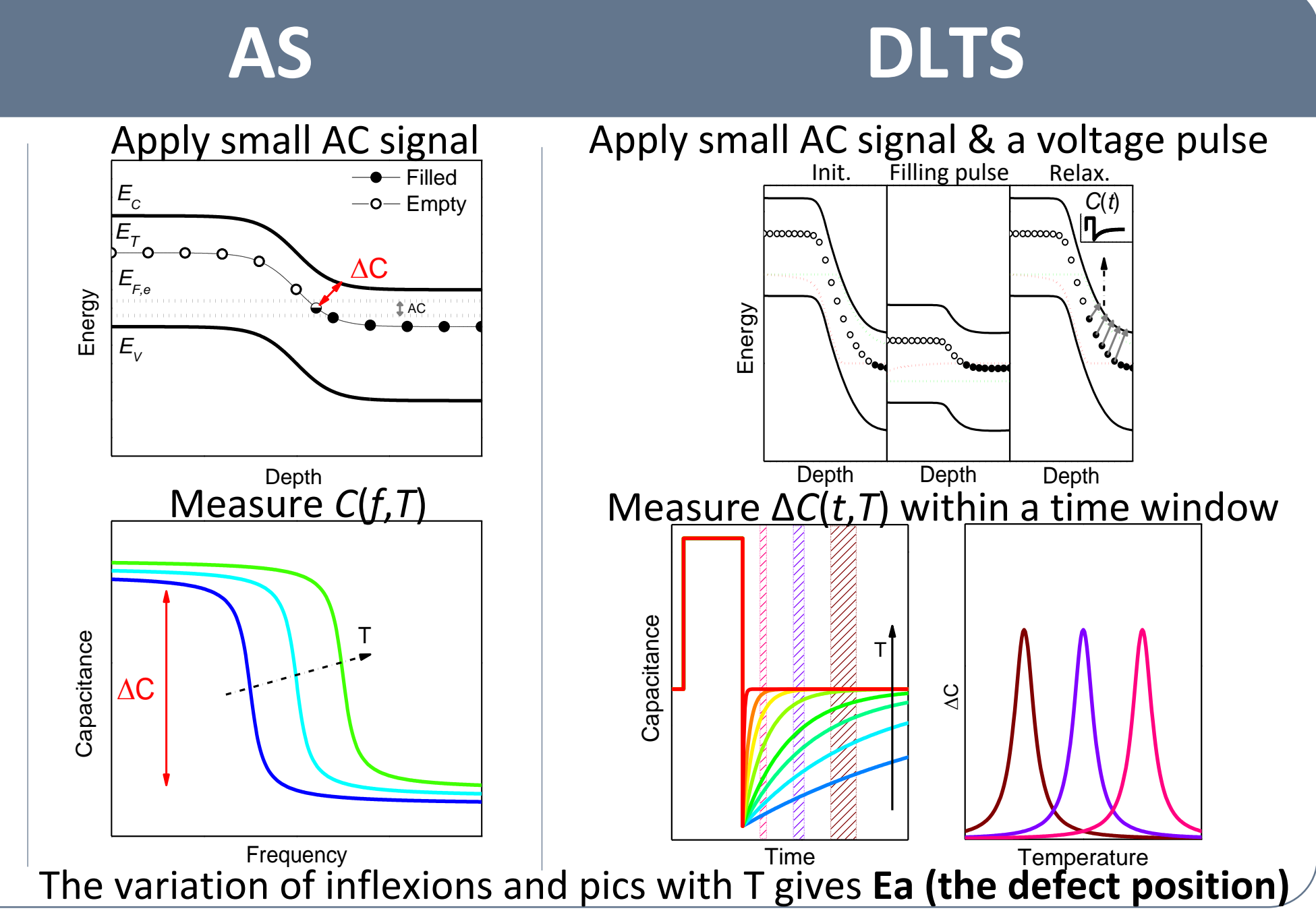


Thanks to TCAD modeling, we will assist John in his mission to get the same results while working on the whole tandem cell.

### Context & principles

- AS and DLTS are two characterization techniques to extract information on the defects electrically active in a semiconductor.

- Although these techniques are widely used to characterize simple devices, they have never been used to characterize multijunctions.

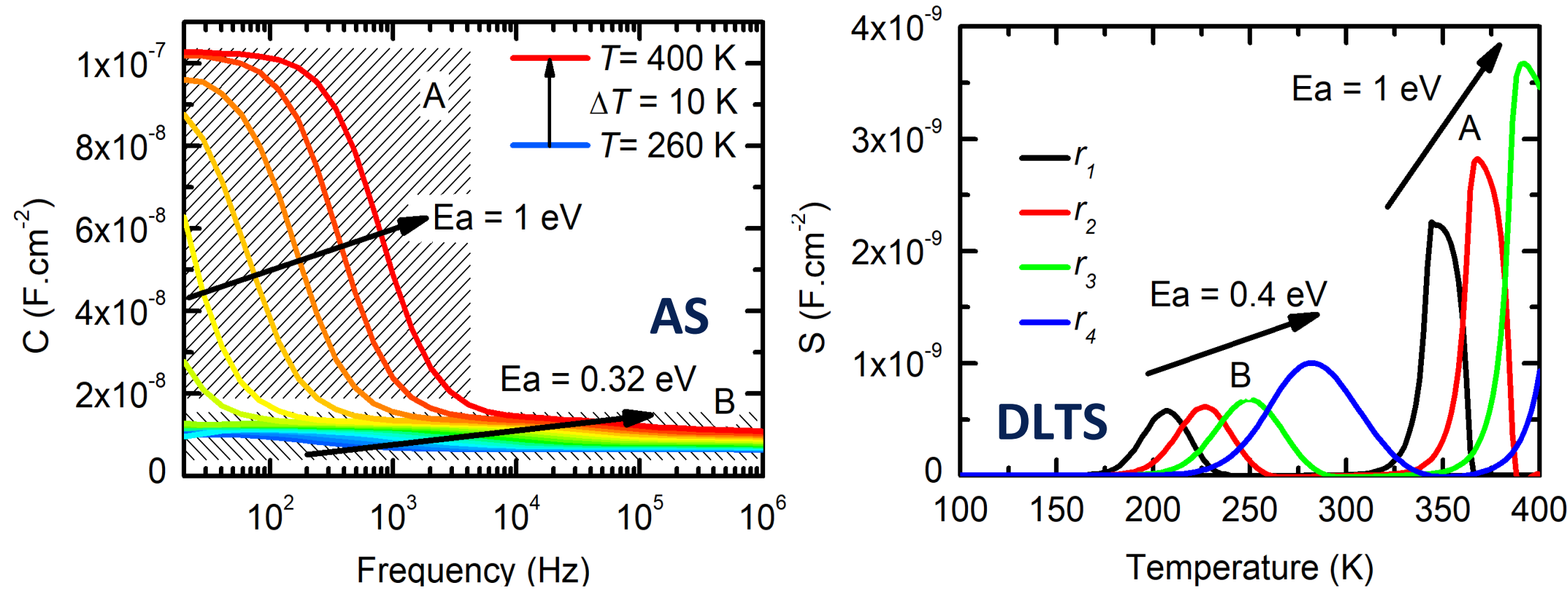


### First approach

#### Measuring a tandem cell like a single junction

John simply places his tandem cell in his AS and DLTS setup and performs the measurements. He obtains:

- John notices a 1 eV defect signature. (Larger than half of the bandgap ??)
- He also guesses a ≈ 0.35 eV defect signature (AS and DLTS gives different results ??)
- However, he has no idea in which subcell those defects are located.



Poor John! He did not get the expected results. Also, he is damn wrong with his conclusions.

### Step by step tutorial

#### Step 1: Read

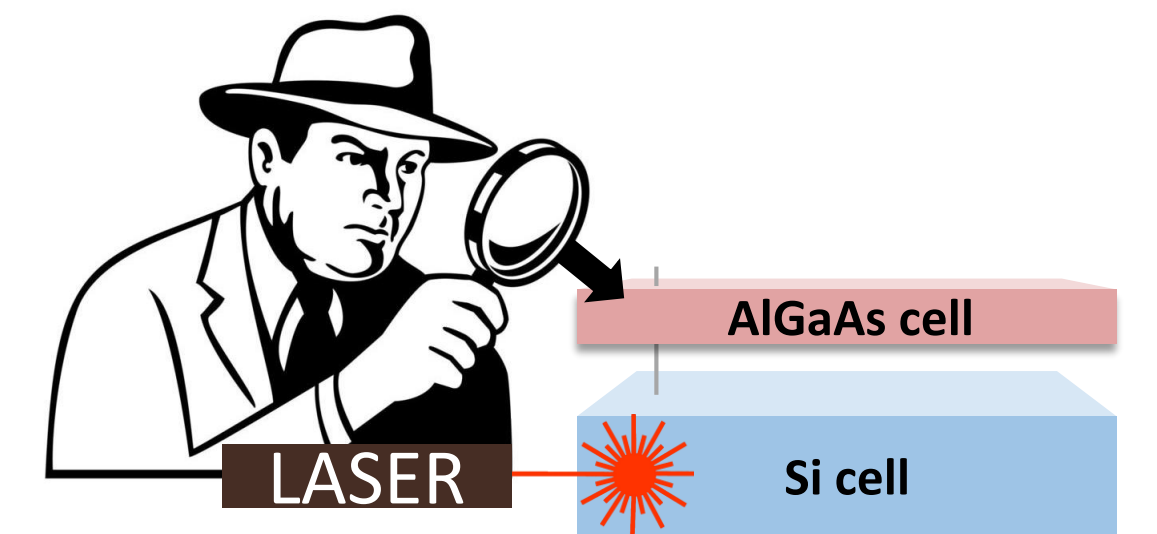
We suggested John to read this article:  
C. Leon et al. SolMat 240, 11699 (2022)



#### Step 2: Let there be light!

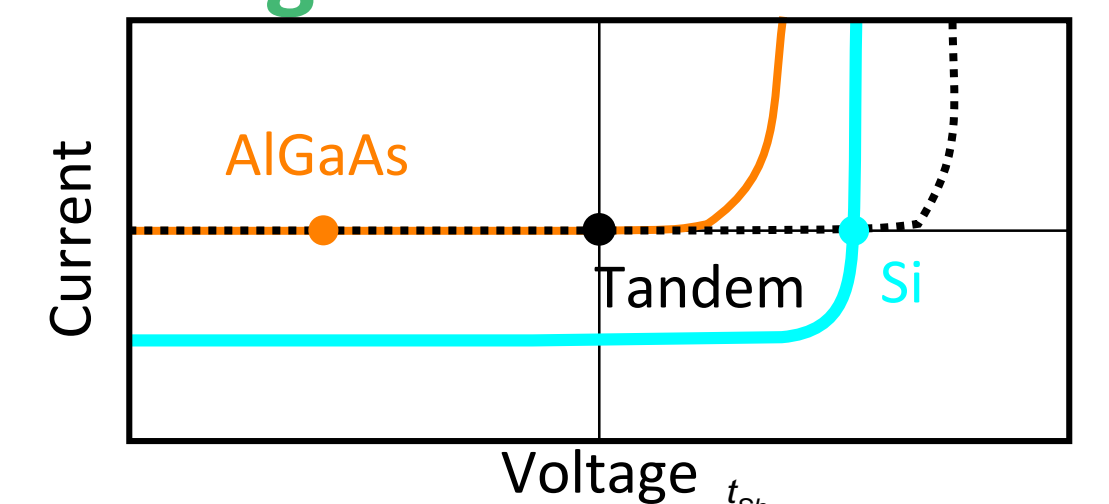
Now, he knows that he needs to light bias the subcell that he does not want to probe.

Example: He uses an IR laser to light bias the bottom Si cell and probe the top AlGaAs cell.

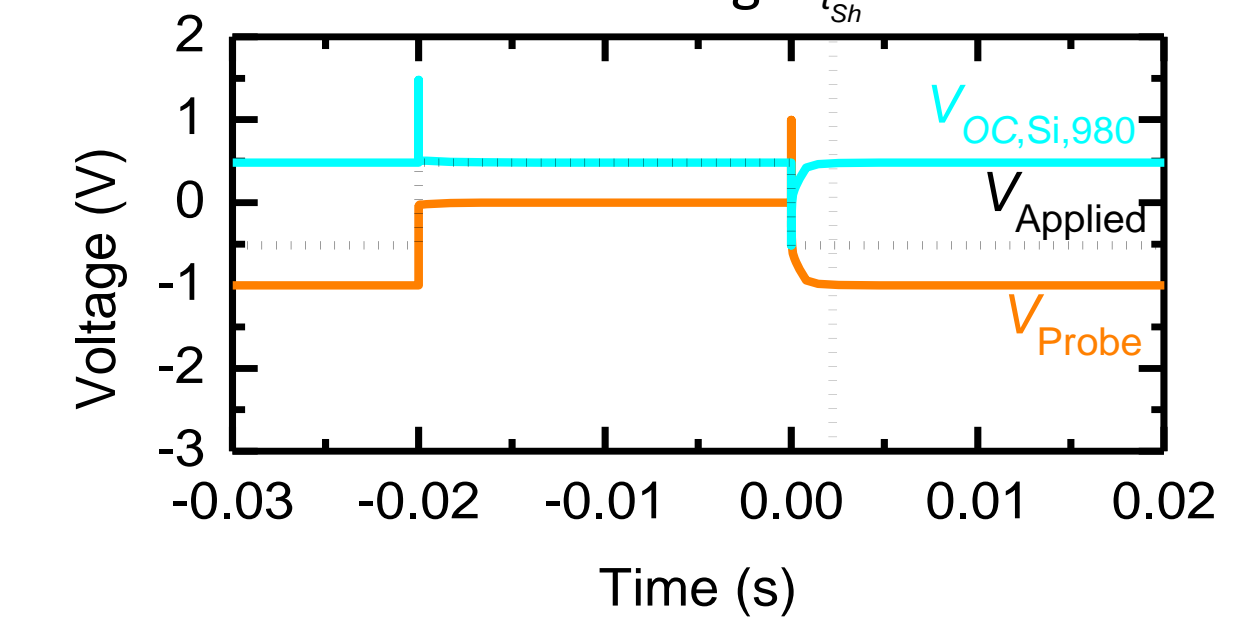


#### Step 3: Measure & correct the voltage shift

The subcell in the dark limits the current, forcing the absorbing subcell to be polarized at its  $V_{OC}$ . The voltage in the probed cell is:  
 $V_{probe} = V_{applied} - V_{OC, Biased}$



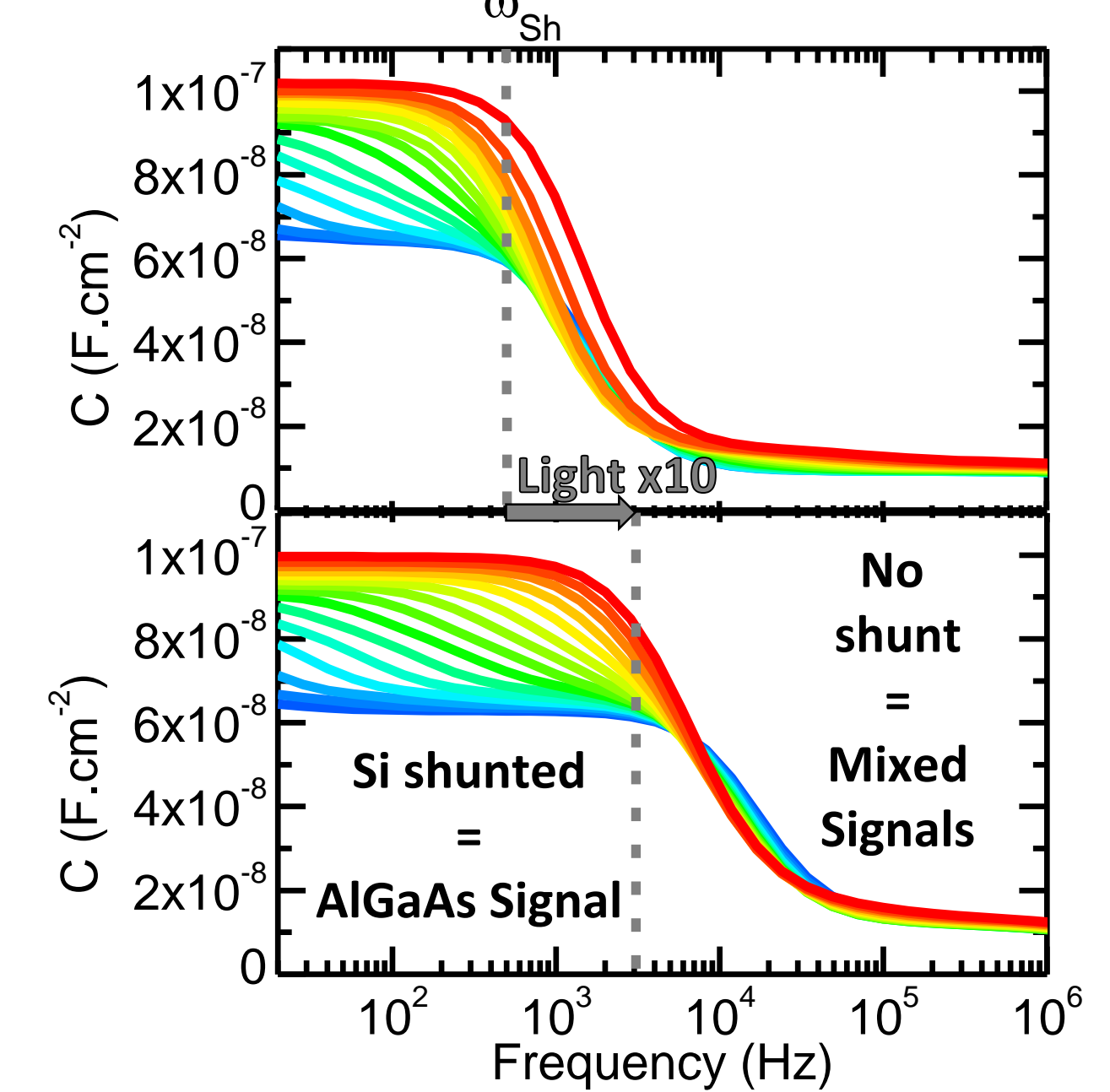
Under the IR laser, John measures  $V_{OC, Si} = 0.5$  V. He knows that in DLTS, to apply a filling pulse between -1 V and 0 V on the AlGaAs cell he has to apply on the whole tandem a filling pulse between -0.5V and 0.5V.



#### Step 4: Optimization

- Diffusion phenomena in the absorbing subcell can shunt its capacitance.
- But also creates an inflexion in AS curves and a transient evolution in DLTS.
- These artefacts can be excluded from the measurement range by increasing the light intensity.

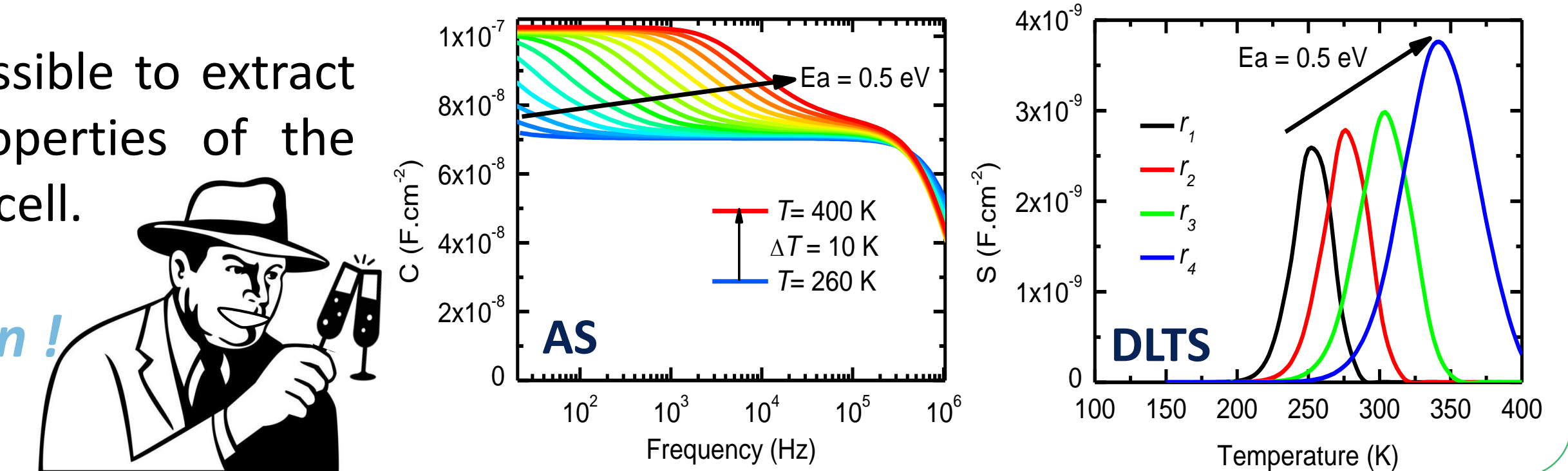
John measures  $C(f)$  and  $C(t)$  curves at room temperature. He notices some artefacts that shift when increasing the light intensity of the laser. He observes that at 100 mW, the artefacts are out of the frequency and time range of the measurement.



#### Step 5: Enjoy (AS & DLTS measurements)

Finally, it is possible to extract the defect properties of the top AlGaAs subcell.

Good job, John!



### What is wrong with the first approach ?

#### Too many unknown & unmonitored parameters

**Voltage distribution:**  
Depends on the unknown  $J(V)$  of each subcell.

**Filling pulse distribution:**  
Depends on the unknown capacitance values of each subcell.

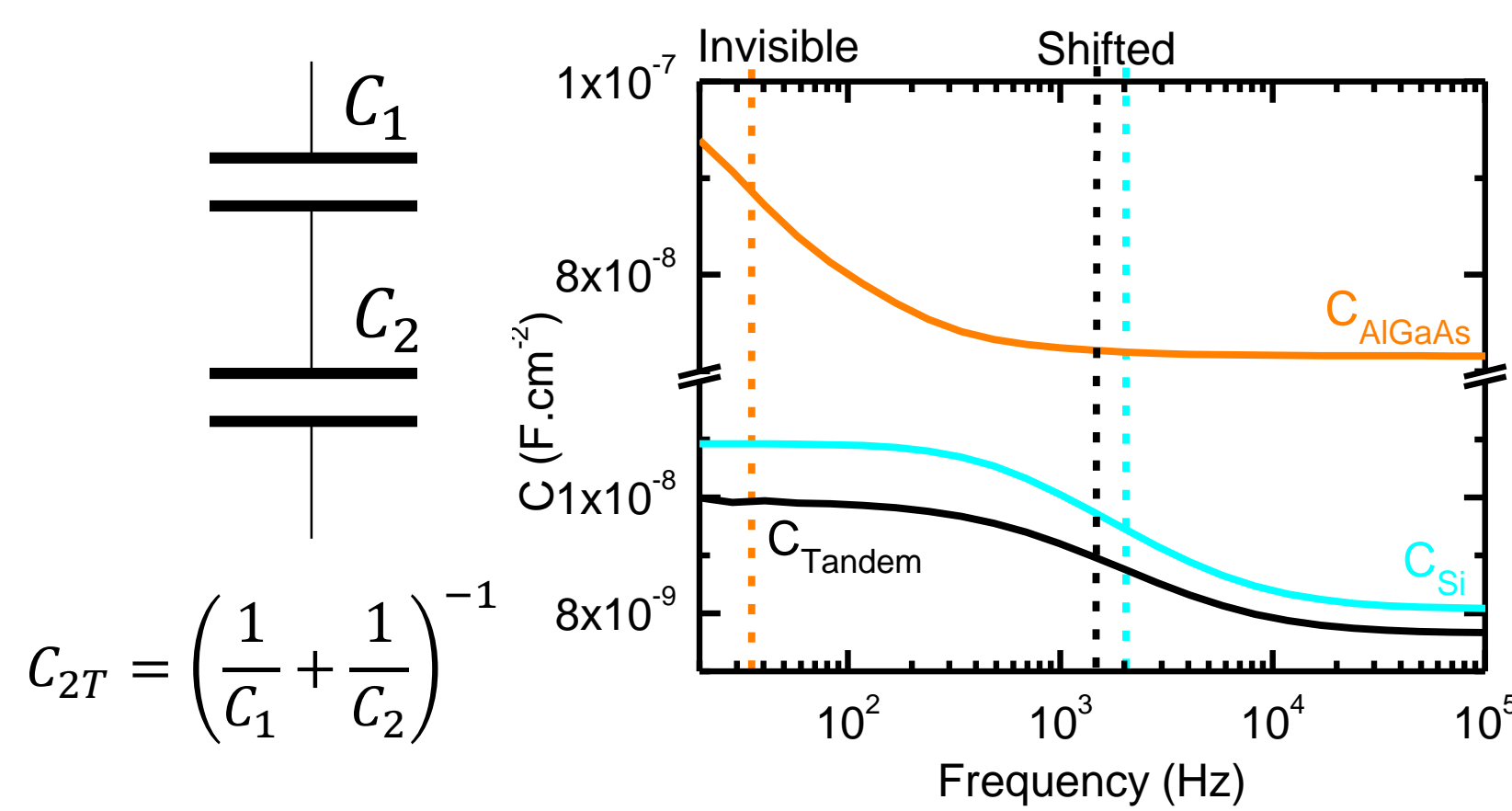
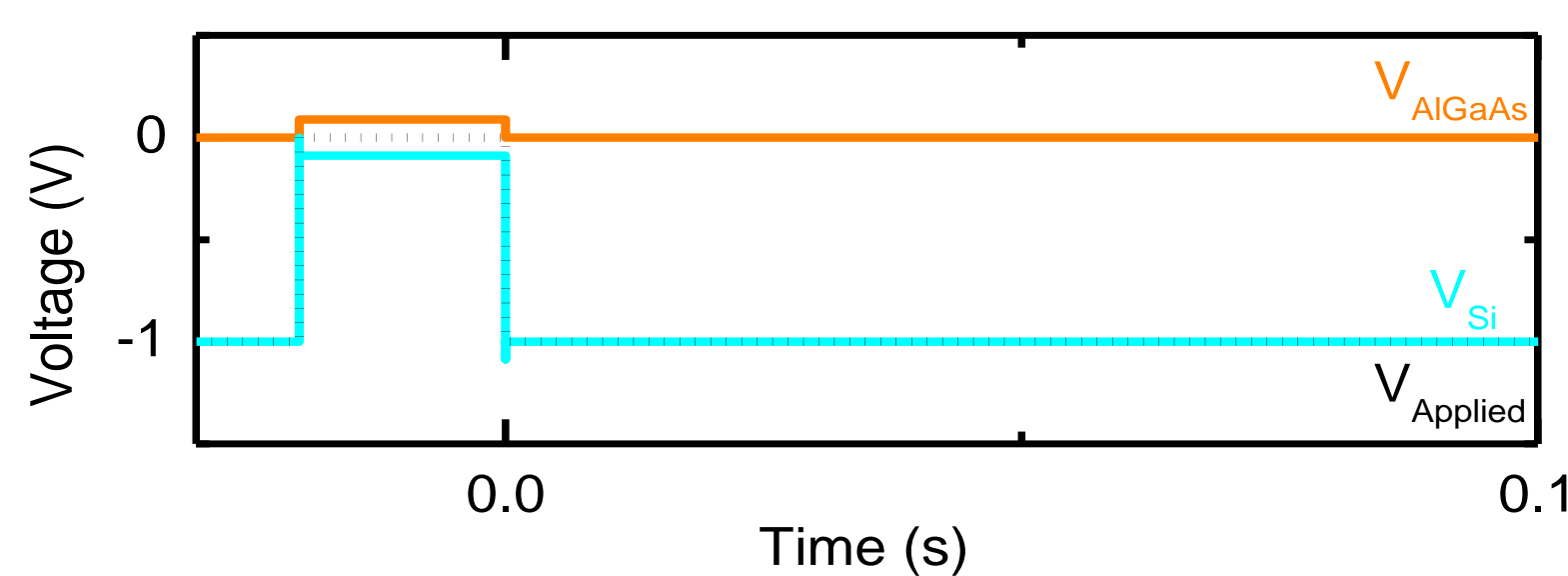
**Capacitance coupling:**  
The measured capacitance results in a coupling of both unknown subcells capacitance. Leading to mixed, shifted or invisible defect signatures.

For John, only the defect in the Si cell can be seen but with errors in AS.

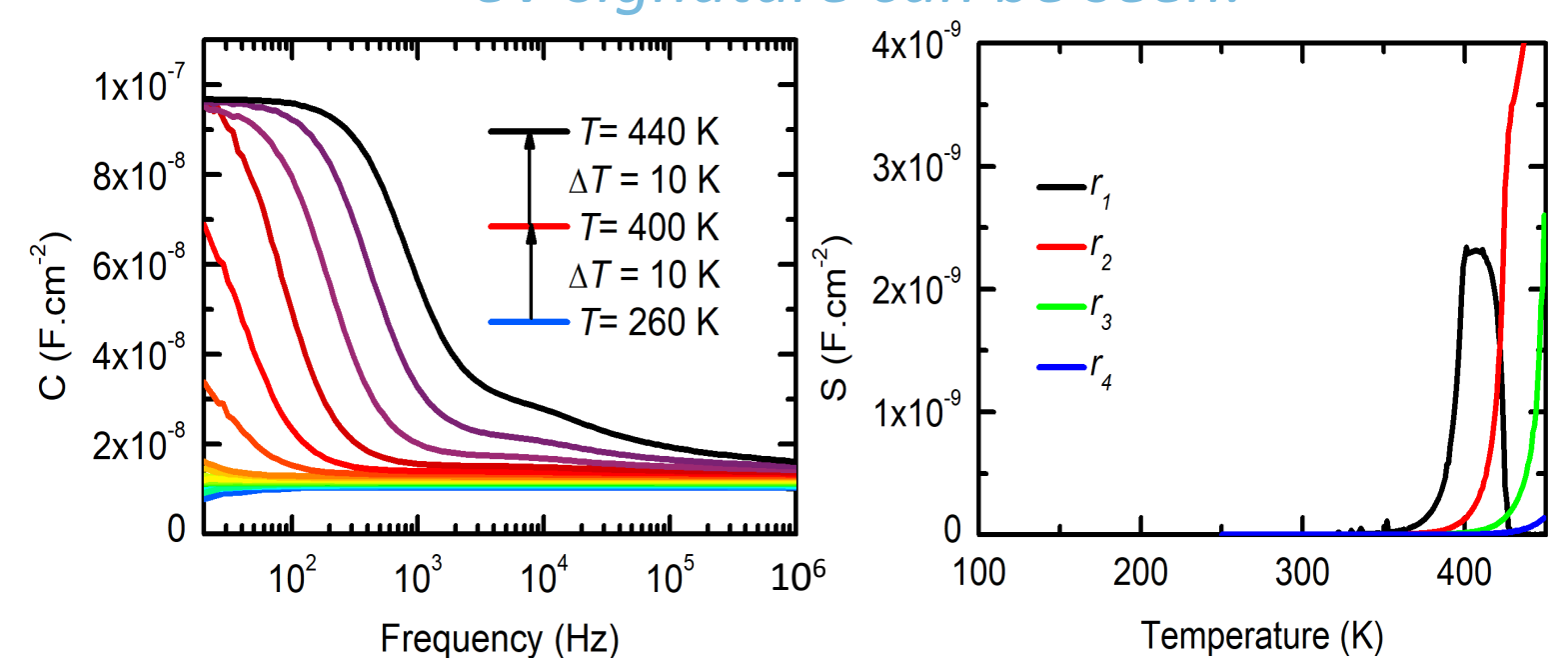
**Impact of the temperature:**  
The temperature can increase the diffusion phenomena leading to an artefact in the measurement that can be mistaken as the signature of a defect.

Poor John, by mistake, he probed the wrong subcell with errors and artefacts!

In John's case, 90 % of the filling pulse only apply on the Si cell and not on the AlGaAs cell.



Even without defect in the modelling, the 1 eV signature can be seen:

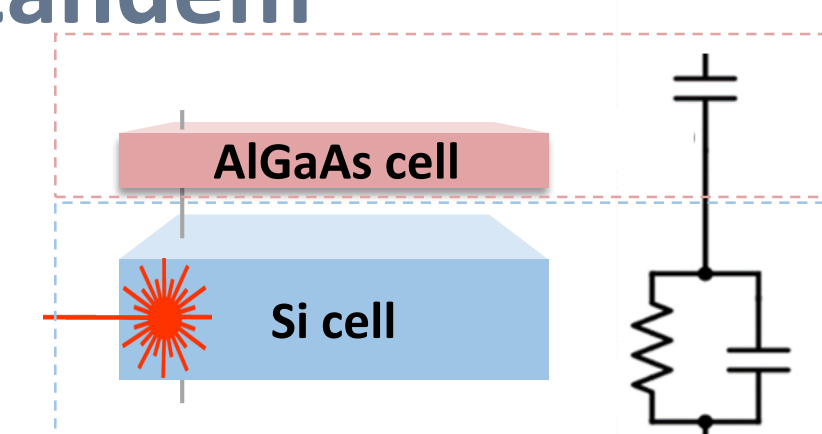


### Using light biases

#### Changes the electrical behavior of the tandem

Diffusion phenomena in a subcell:

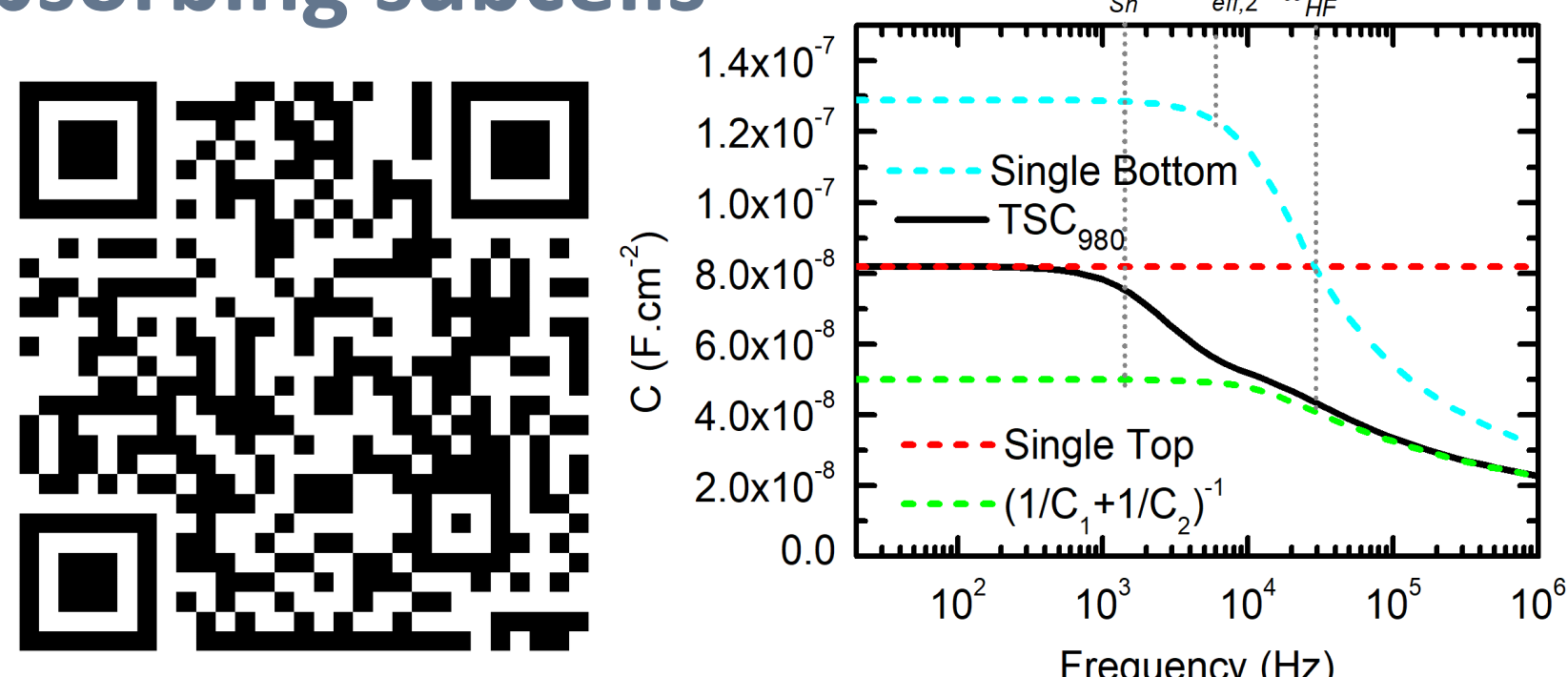
- Caused by the temperature in the dark (uncontrolled).
- Caused by a forward polarization (controlled using light bias).



#### Shunts the absorbing subcells

This has been experimentally validated by extracting the doping densities in an AlGaAs/Si tandem cells using  $C(V)$ . Here we extend the method to AS and DLTS.

C. Leon et al. Prog Photovolt Res Appl (28) 2020



### Conclusions

In the dark, signals of each subcell are mixed leading to wrong defect signatures.

Under well chosen light biases, the absorbing subcells can be shunted and only the one that remains in the dark is probed.

My mission is now complete and I am looking for a new one! (Available from September)



Curriculum Vitae

