# DARTWARS meeting

Normal resistance measurements
Josephson Junction Reproducibility Test

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# Aim of the measurement campaign

Test which of two oxidation processes results in a lower statistical dispersion

- Substrate 02 - Dynamic oxidation
  - $O_2$ pressure = $4.30 \cdot 10^{-4}$ Torr
  - Oxidation time   = 660 s
- Substrate 05 - Static oxidation
  - $O_2$ pressure = $1.58 \cdot 10^{-3}$ Torr
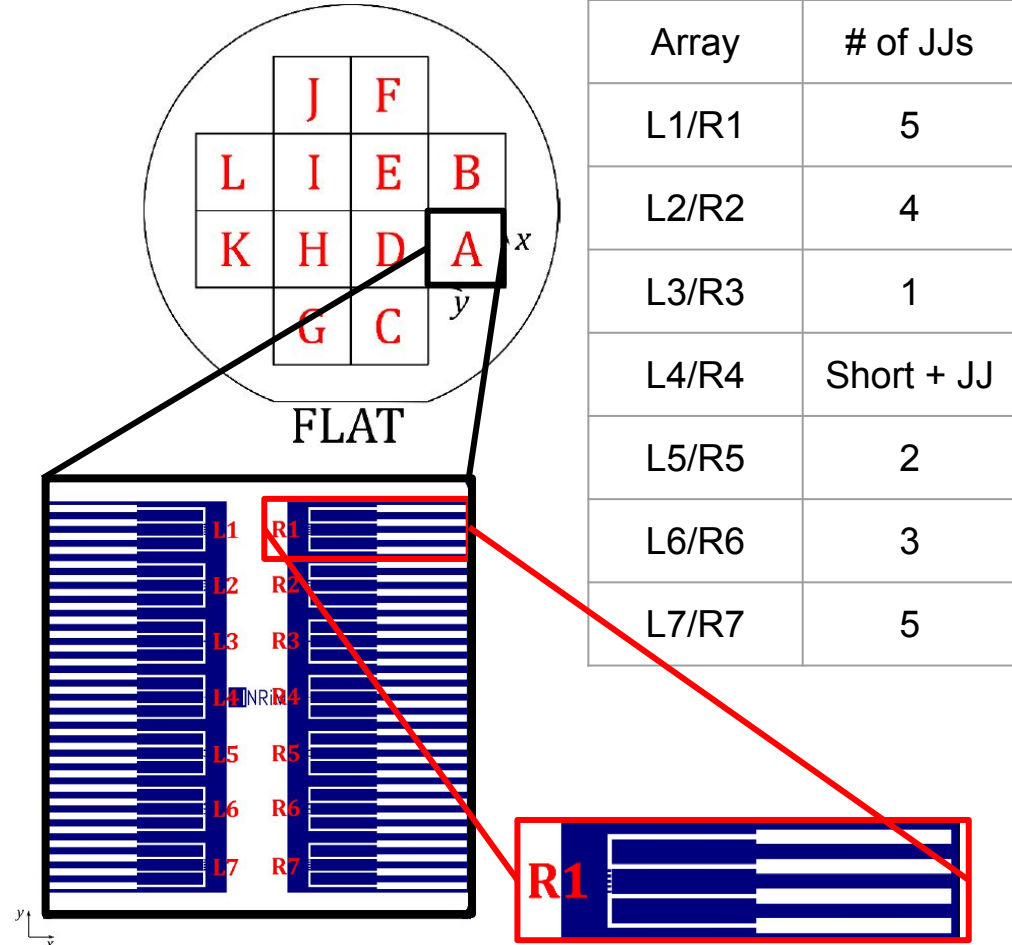  - Oxidation time   = 344 s

$$\left. \begin{array}{l} \\ \\ \\ \\ \\ \end{array} \right\} \text{Same } \sqrt{pressure} \times time \text{ product}$$

The thickness of the oxide barrier and the normal resistance ($R_n$) should be similar.

# Josephson Junctions

- Each substrate consists 12 devices, hosting 40 JJs each, organized in 14 arrays (total of 336 measurements)

- JJs were designed to have a critical current $I_C$= 4 µA and a self-capacitance C=225 fF

- The expected normal resistance (from Ambegaokar-Baratoff) is of about $R_n \approx 80$ Ω

| Array | # of JJs |
|-------|----------|
| L1/R1 | 5 |
| L2/R2 | 4 |
| L3/R3 | 1 |
| L4/R4 | Short + JJ |
| L5/R5 | 2 |
| L6/R6 | 3 |
| L7/R7 | 5 |



3

# Measurement setup

- Probe station FormFactor → 4-terminals measurements

- Keithley 4200A Parameter Analyzer

- Current ramp 0.1 µA - 10 µA



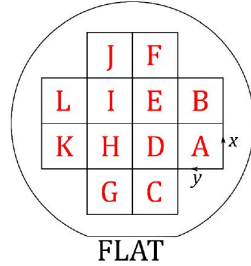$$V = R \times I + O$$
$$R = 39.03 \pm 0.06$$
$$O = -0.00 \pm 0.00$$
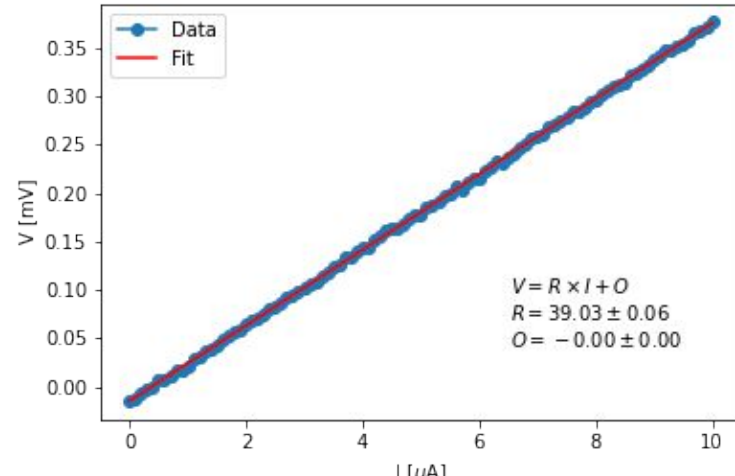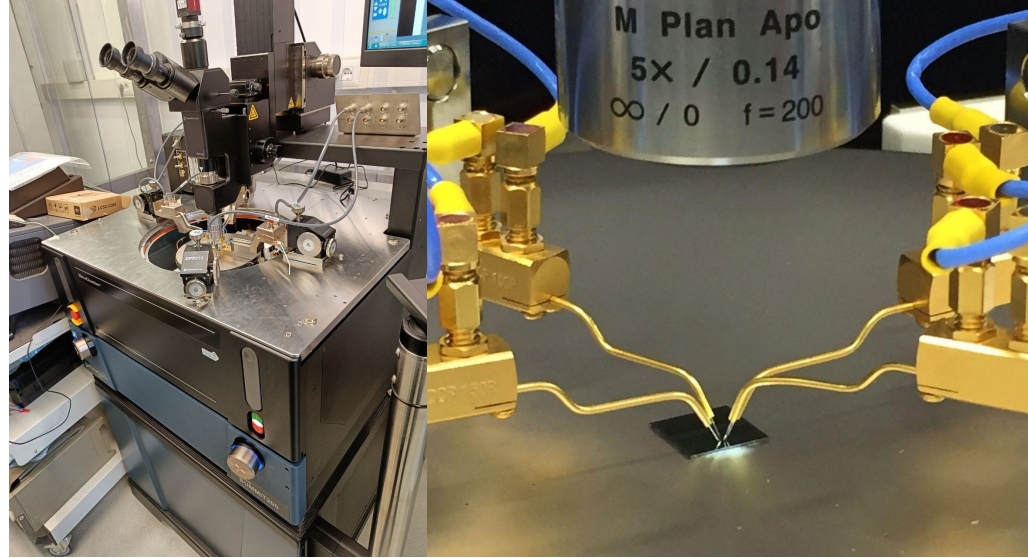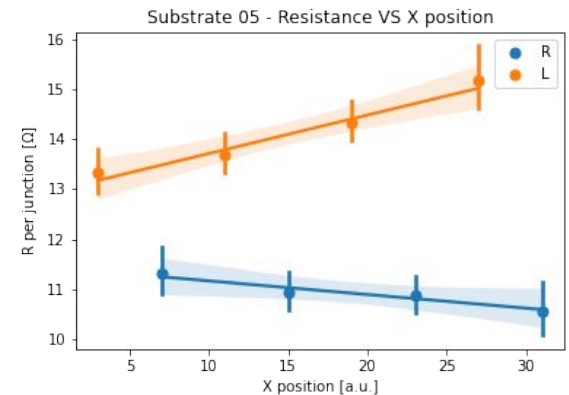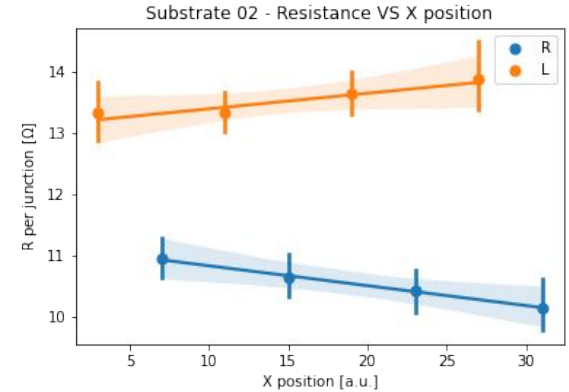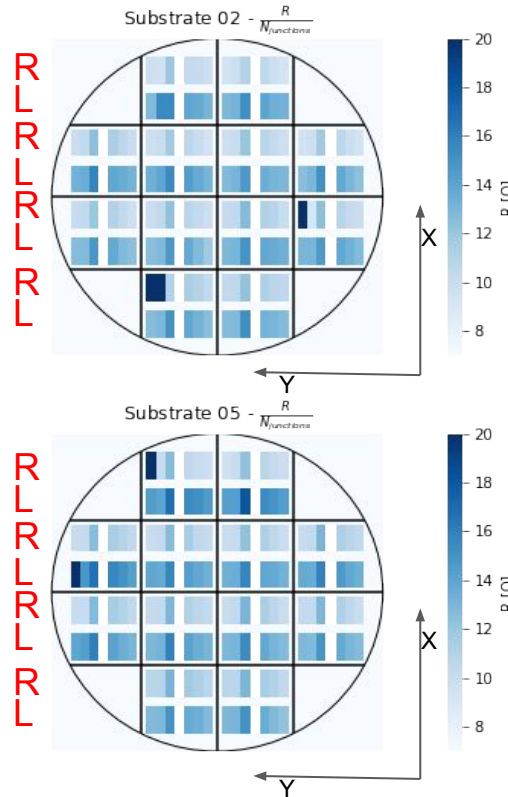
# Results of the measurements

- Resistance measurement normalized on the number of junction in each array

- 5 arrays resulted being open circuits (red circles)

- The distributions of the resistance measurements show two cores, one for 'L' arrays and one for 'R' arrays

- 'L' arrays feature higher resistance values in both substrates
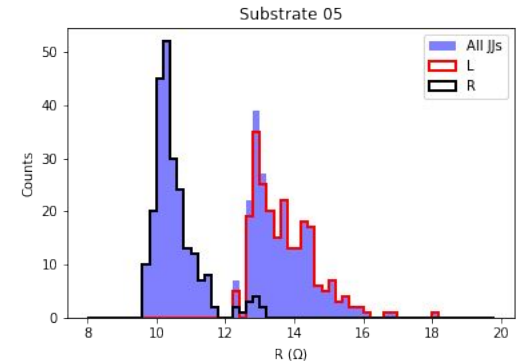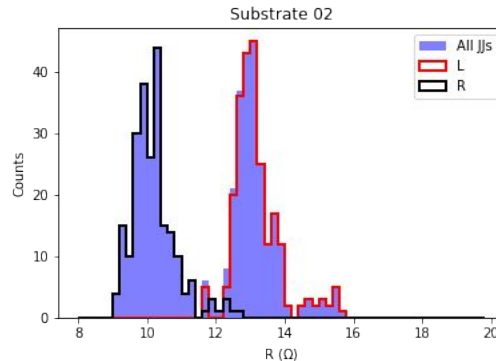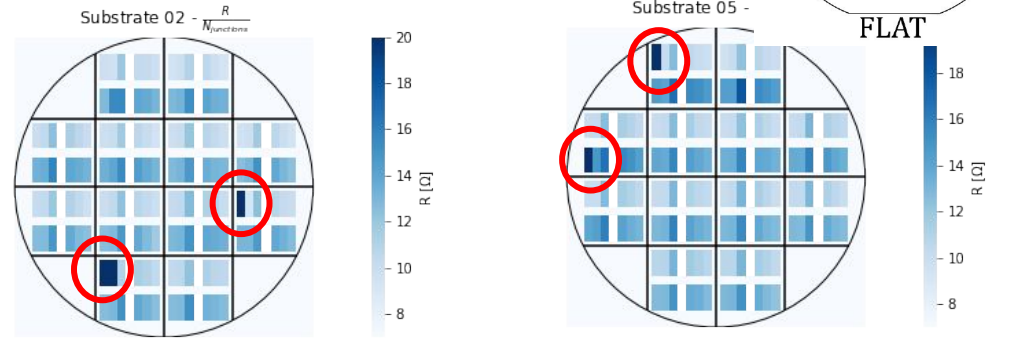
# Resistance gradient from bottom to top of substrates



- Resistance measurement normalized on the number of junction in each array

- Ascending gradient for 'L' arrays (steeper for substrate 05 than substrate 02)

- Descending gradient for 'R' arrays

- No evident gradient on Y axis



Substrate 02 - $\frac{R}{N_{junctions}}$



Substrate 05 - $\frac{R}{N_{junctions}}$



Substrate 02 - Resistance VS X position



Substrate 05 - Resistance VS X position

# Substrates difference

- Substrate 05 (static oxidation) shows higher resistance values than substrate 02 (dynamic oxidation)

- Less pronounced in the central/lower devices due to the steeper resistance gradient in substrate 05
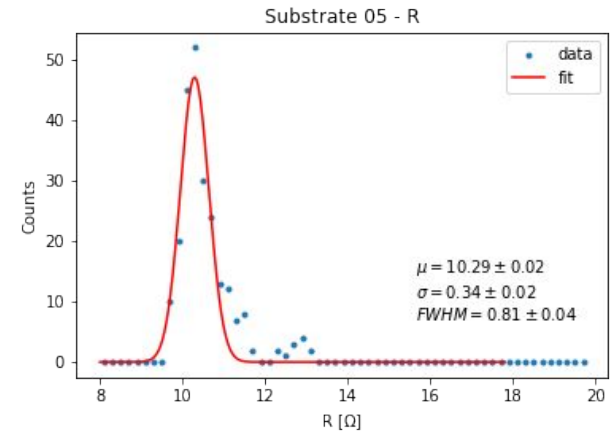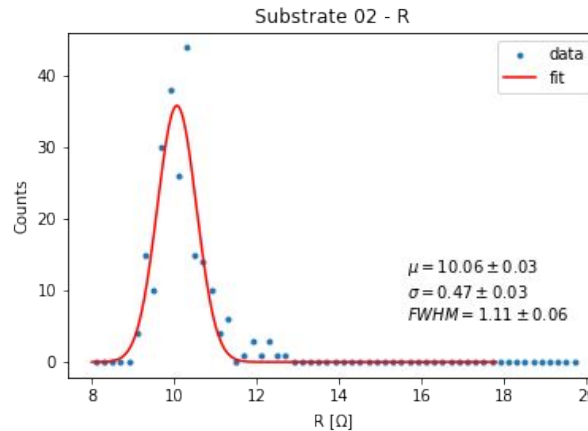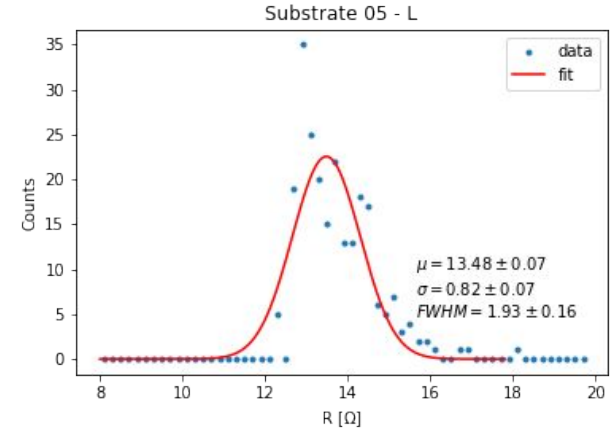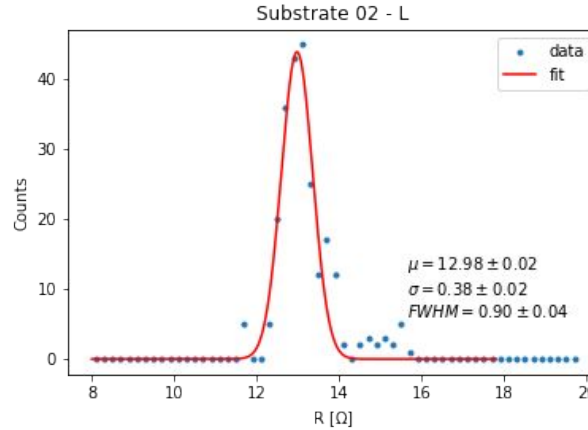


Difference between two substrates (Substrate 05 - Substrate 02) - $\frac{R}{N_{junctions}}$
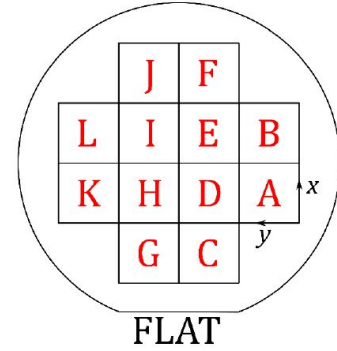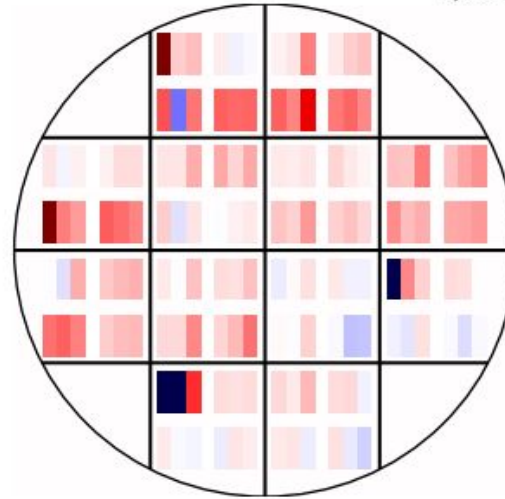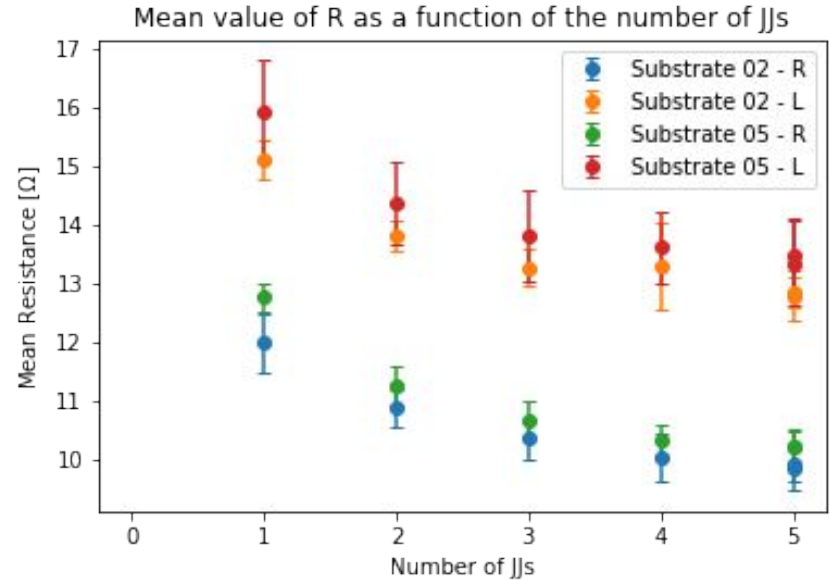
# Results of measurements

- Fit with Gaussian function → mean, std dev ad FWHM

| Substrate | Arrays L (FWHM) | Arrays R (FWHM) |
|-----------|-----------------|-----------------|
| 02 | 6.9% | 11.0% |
| 05 | 14.3% | 7.9% |

# Parasite resistance impact

- The measured resistance value per junction lowers as the number of junctions in the array increases

- This effect is due to the difference in the aluminum band length alternating with junctions

- Overestimating the spread of resistance values → calculate the spread over the same type of array



Mean value of R as a function of the number of JJs

| Substrate | Arrays L (FWHM) | Arrays R (FWHM) |
|-----------|-----------------|-----------------|
| 02        | 4.55% - 12.91%  | 6.60% - 9.86%   |
| 05        | 10.71% - 13.26% | 4.59% - 7.31%   |



single junction     5 junctions
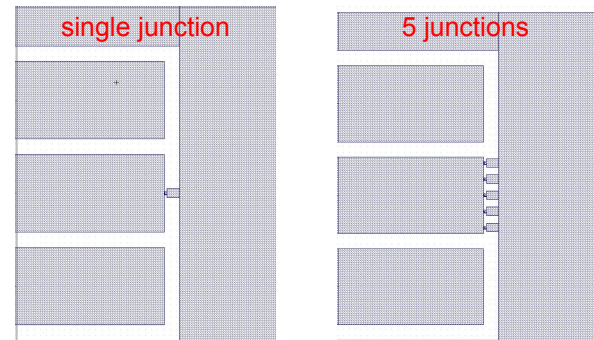
# Conclusions

- The measurements show that the dynamic oxidation process (**substrate 02**) results in lower resistance dispersion on average for **'L' arrays**, while the static oxidation process (**substrate 05**) results in lower resistance dispersion on average for **'R' arrays**

- Both substrates show a resistance value dependence on the position along the wafer
  - **Substrate 05** shows a steeper position dependence for **'L' arrays** than **substrate 02**

- The spread of the resistance values reached values below **5%** in both substrates when comparing the same types of arrays

- New JJ arrays will be fabricated and measured in the next months
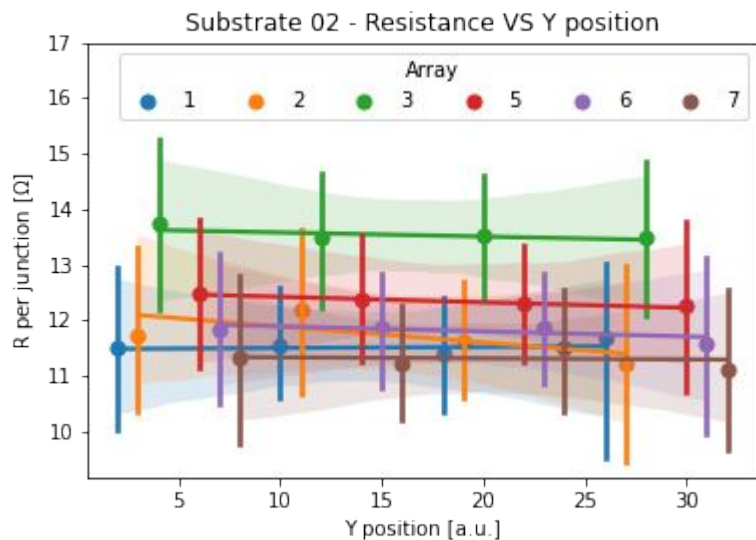
# Backup slides

# Results of the measurements
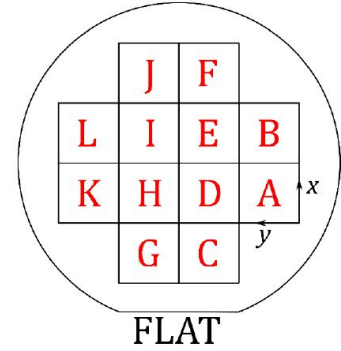


FLAT

Resistance measurement normalized on the
number of junction in each array



Substrate 02 - $\frac{R}{N_{junctions}}$
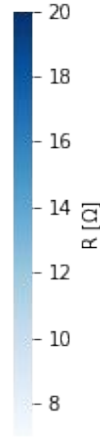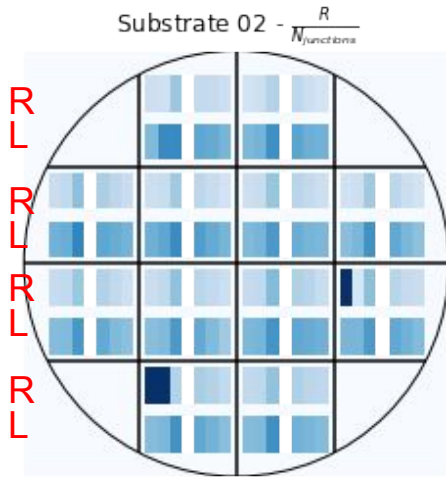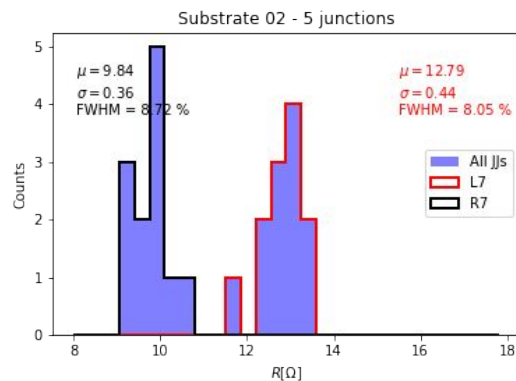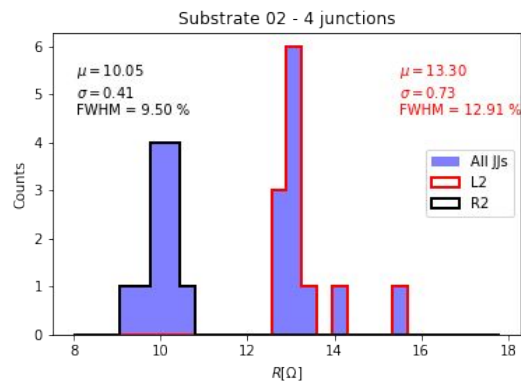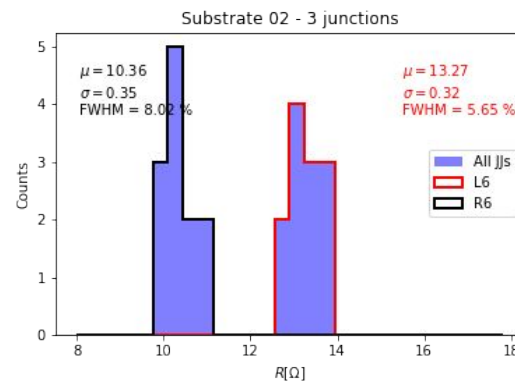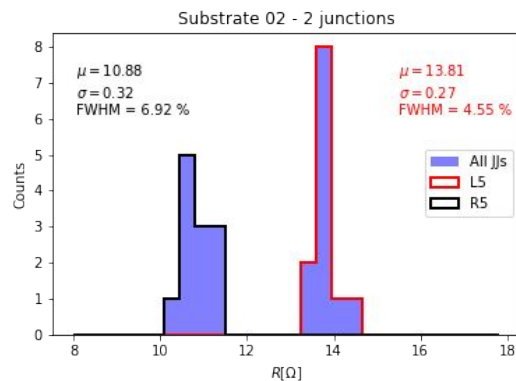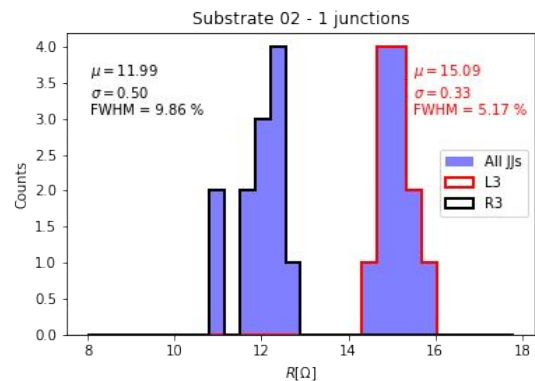
- "L" arrays show
  resistance values
  higher than "R"
  arrays
- Slight gradient from
  top to bottom
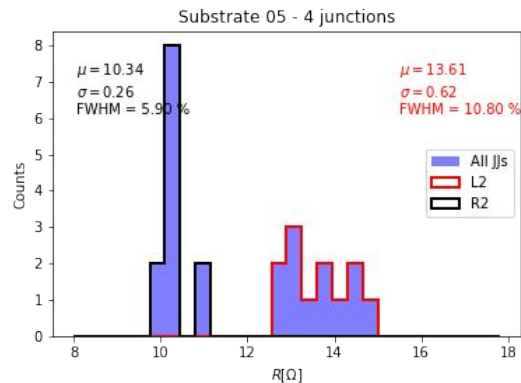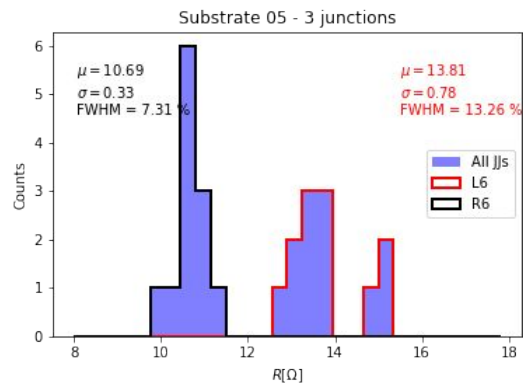
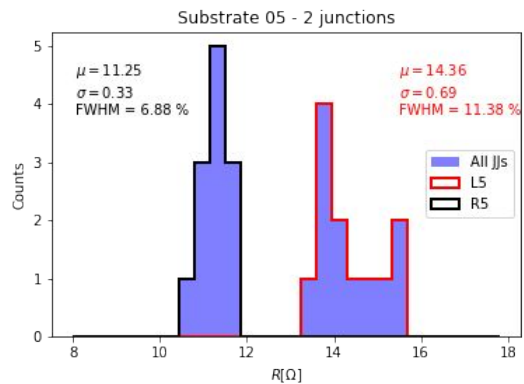

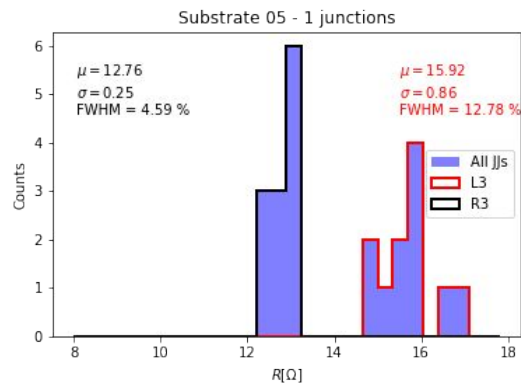Substrate 05 - $\frac{R}{N_{junctions}}$
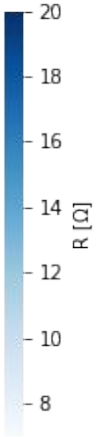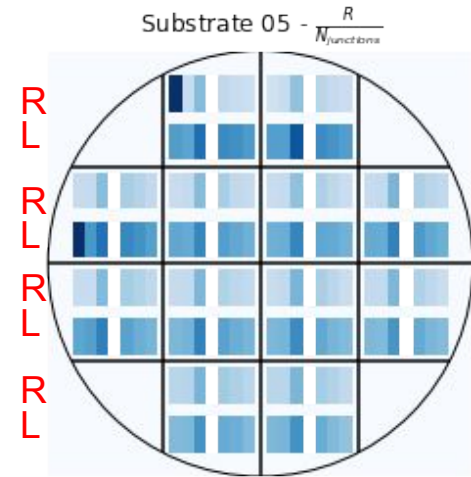
# Gradient along Y axis
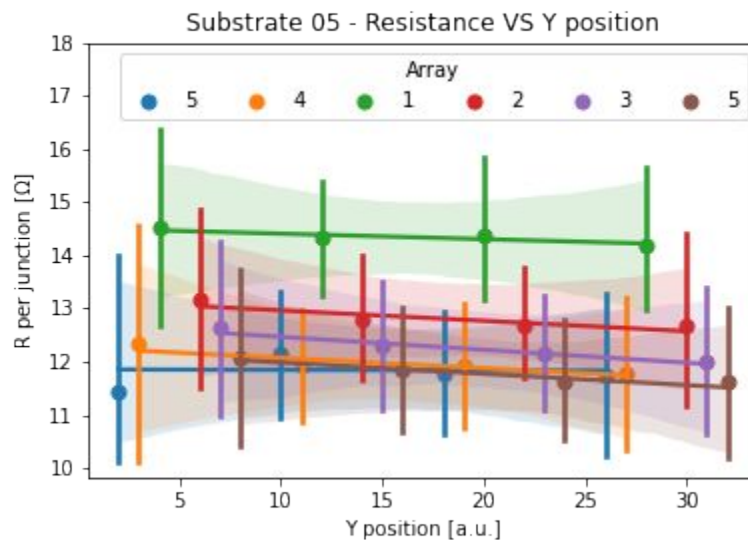
# Categorized histograms - Substrate 02
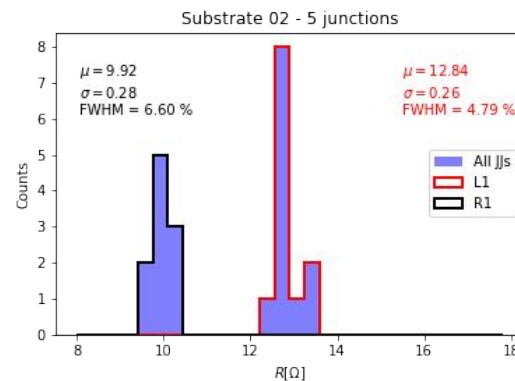
# Categorized histograms - Substrate 05
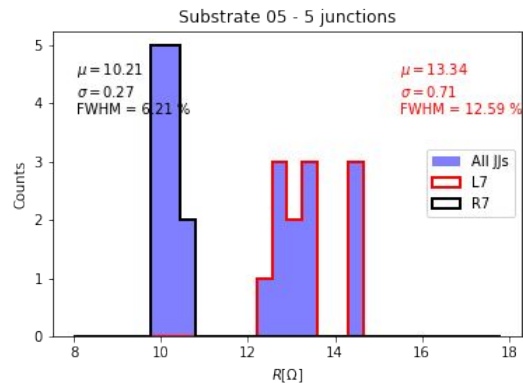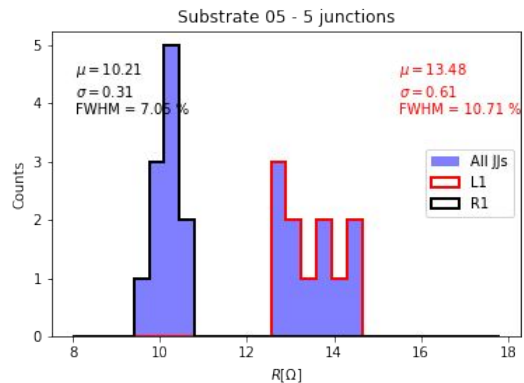
# Results of measurements

- The distributions of the resistance measurements show two cores, one for 'L' arrays and one for 'R' arrays

- 'L' arrays feature higher resistance values in both substrates as already pointed out before