Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary information

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1 Device and Setup

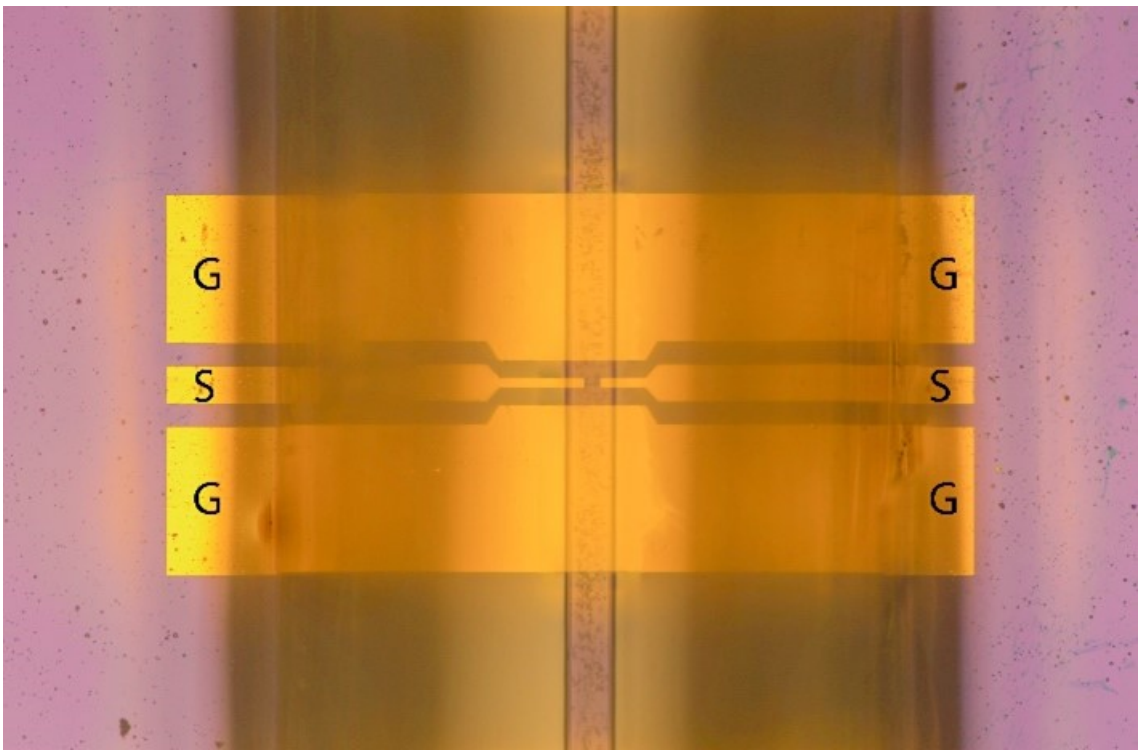


Figure 1: A focus-stacked composite image of devices in a PDMS microfluidic channel, with the two ports and the corresponding probe contacts (Ground-Signal-Ground).

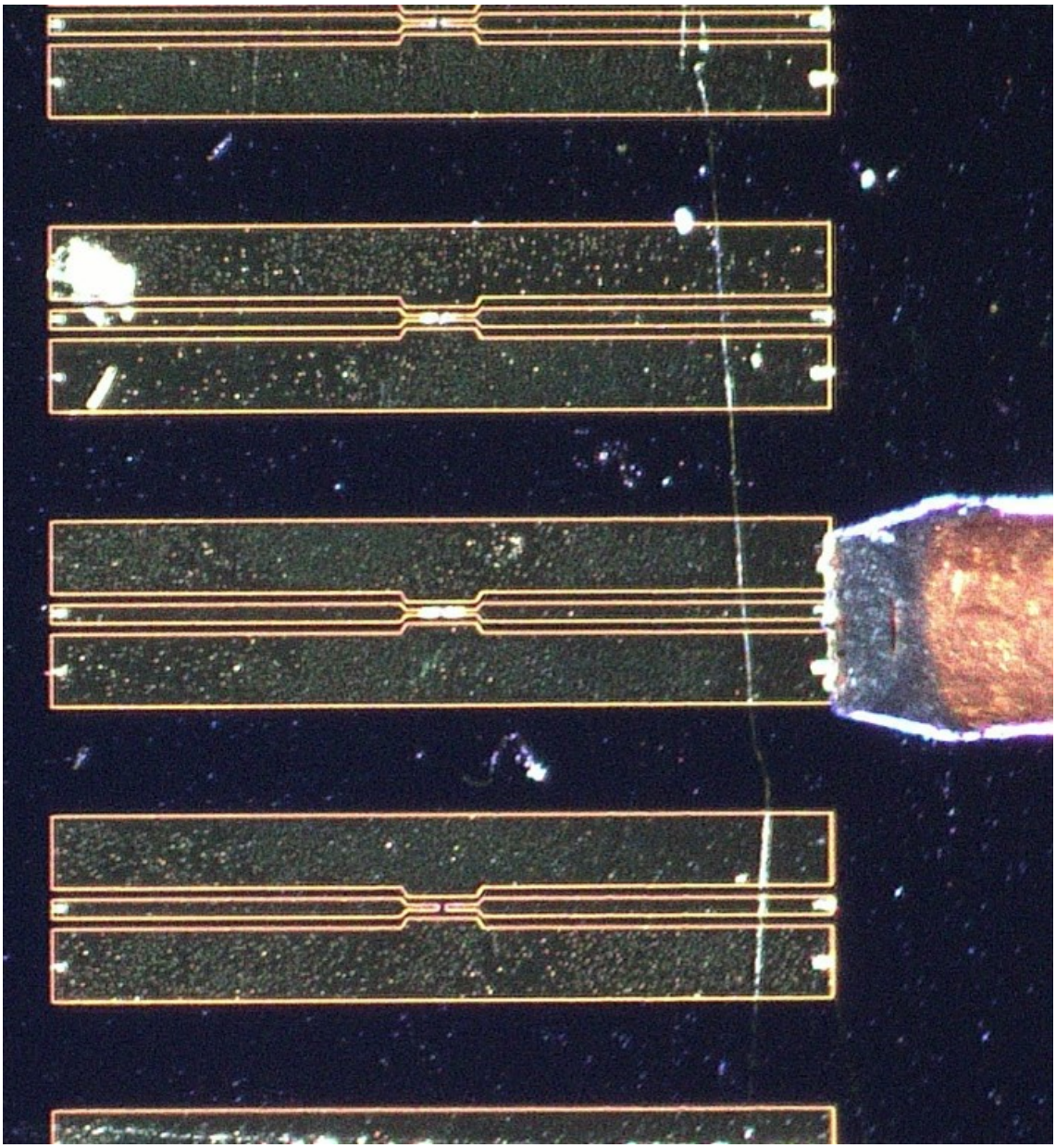


Figure 2: A landed GSG RF-probe on a graphene coplanar waveguide, before the fabrication of the microfluidic channel.

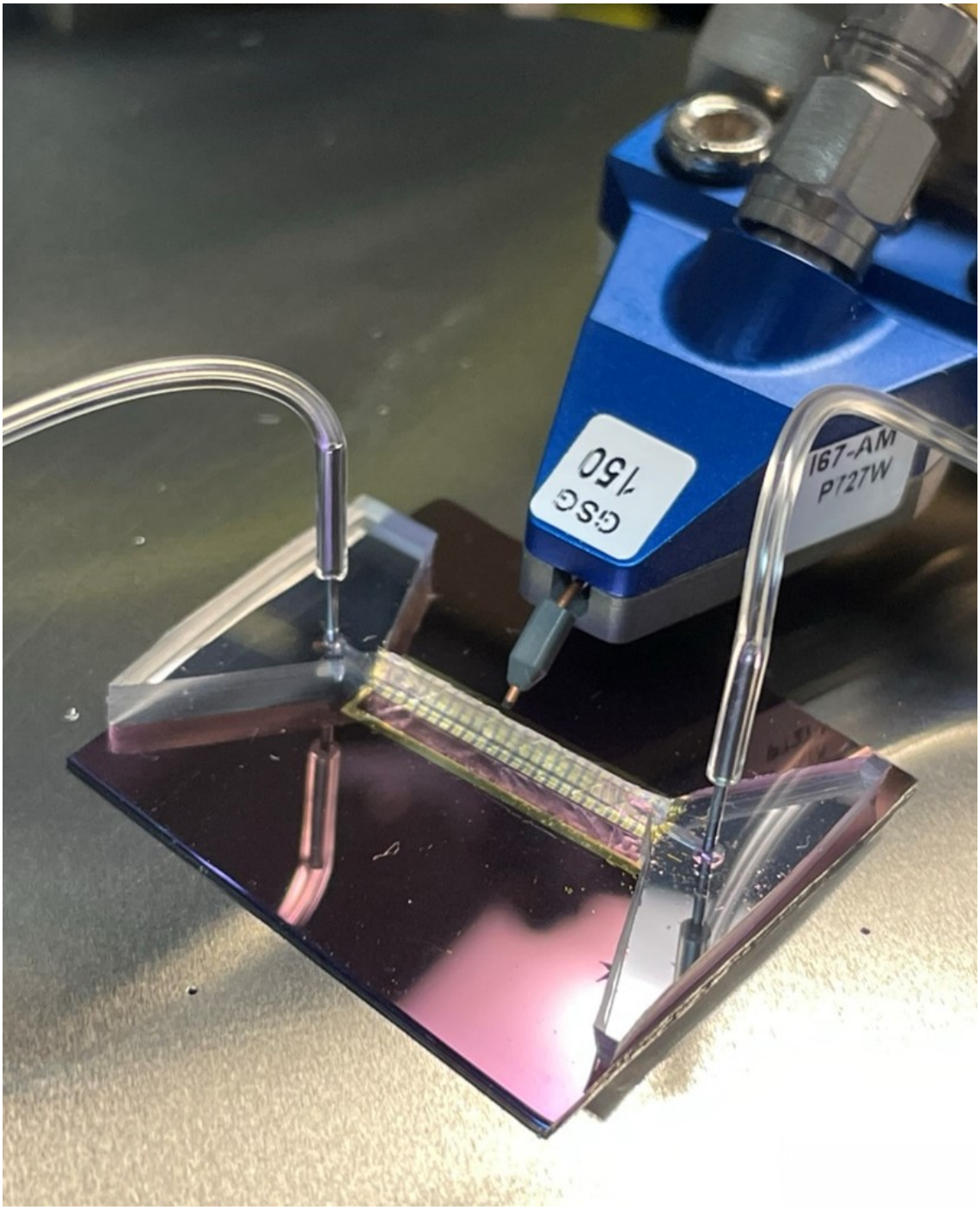


Figure 3: The array of devices with the microfluidic channel, without the DC probe and only one RF probe.

2 S-parameters

2.1 S-parameter plots of devices with channel length from 10 to 25 μm

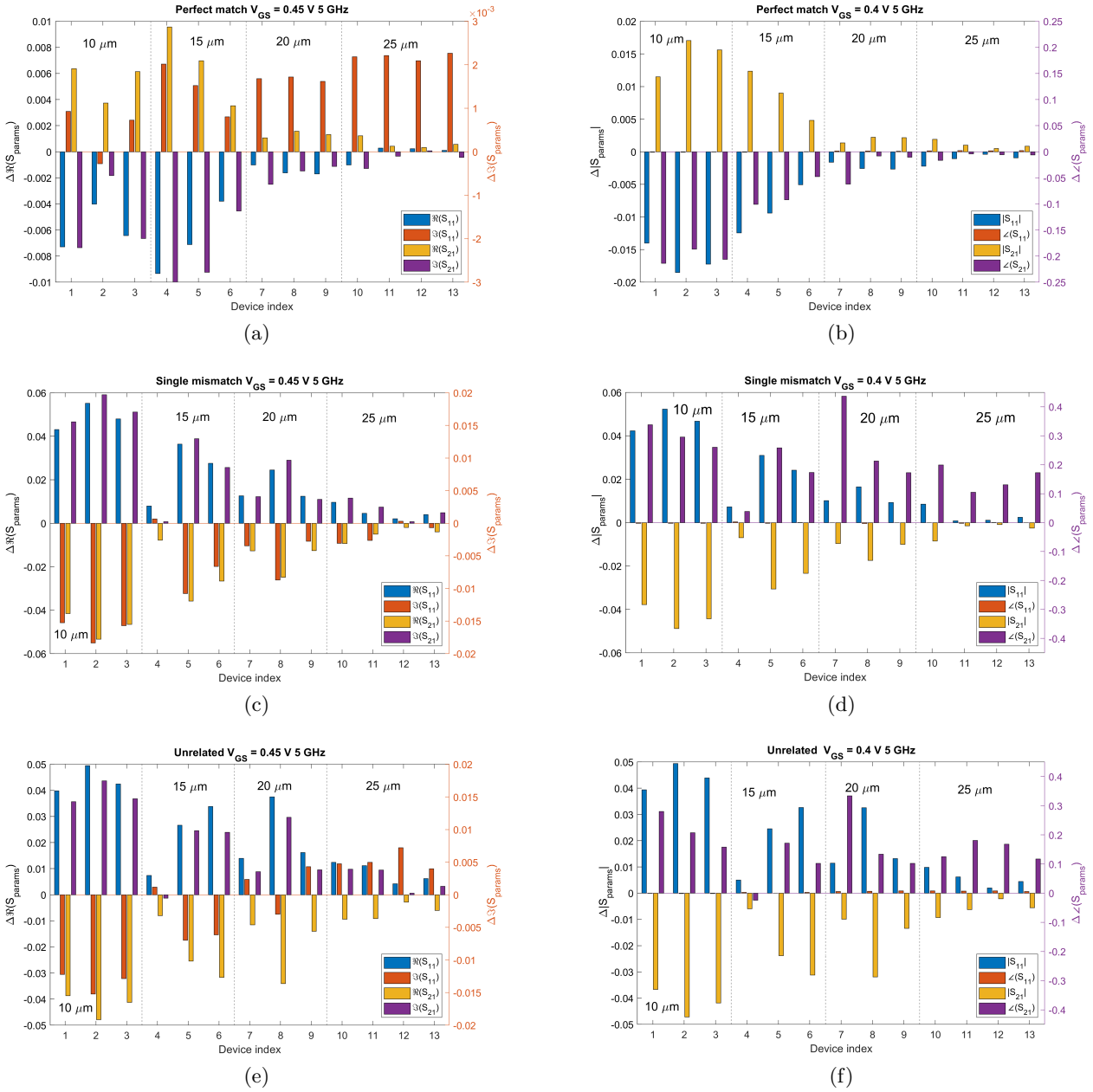
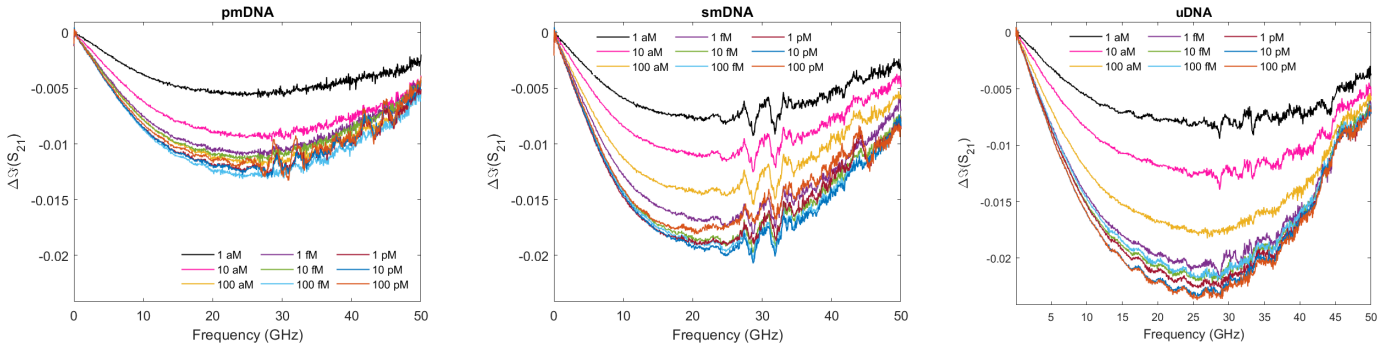


Figure 4: Bar graphs of the differences in the real, imaginary, amplitude, phase of S_{21} and S_{11} between the PBS baseline and pmDNA, smDNA, uDNA, respectively. Each group of the three/four bars is the result of an individual device. The frequency is 5 GHz. DNA concentration is 1 aM. The different colours represent different $S-parameter$ parts. For better visualisation, the y-axis on the left applies to the blue and yellow (Real and magnitude) components, while the y-axis on the right is for the orange and purple (Imaginary and phase) components.

2.2 S-parameters at different DNA concentrations



(a) (b) (c)

Figure 5: A representative set of the difference in $\Im(S_{21})$ between the $\Im(S_{21})$ at nine different DNA concentrations and the $\Im(S_{21})$ at 0.01× PBS for a representative device with a graphene channel length of $25\mu m$ for (a) pmDNA (b) smDNA and (c) uDNA. Graphene channel length is 25 μm at the gate voltage is 0 V.

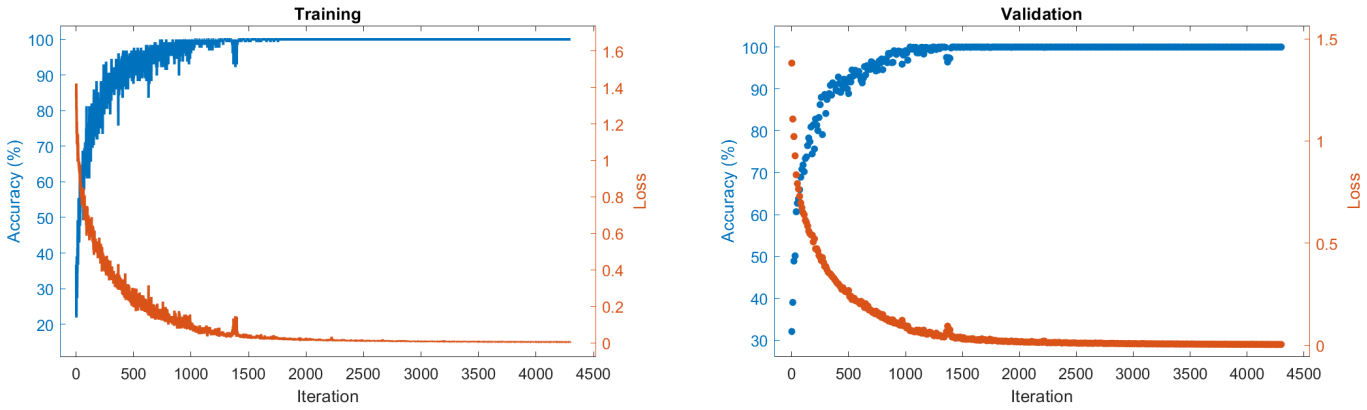
3 Machine learning

Table 1: ML model classification accuracy of pmDNA at nine concentrations: 1 aM, 10 aM, 100 aM, 1 fM, 10 fM, 100 fM, 1 pM, 10 pM, and 100 pM. Whole dataset: 2583 (7 devices * 41 gate voltages * 9 concentration classes) $\times$ 4 (4 principal components), training set: 2070 $\times$ 4, testing set: 171 $\times$ 4.

Algorithms	Accuracy (%)	Accuracy with 30 dB Gaussian noise (%)
LDA	100	100
SVM	100	87.99
Tree	99.75	98.04
KNN	99.75	14.71
ANN	100	100

Table 2: ML model classification accuracy of pmDNA, smDNA, and uDNA using the data at nine concentrations. Whole dataset: 6888 (7 devices * 41 gate voltages * 9 concentrations * 3 DNA classes) $\times$ 9 (9 principal components), training set: 5520 $\times$ 9, testing set: 1368 $\times$ 9.

Algorithms	Accuracy (%)
LDA	76.46
SVM	85.67
Tree	92.03
KNN	100
ANN	100



(a) (b)

Figure 6: Accuracy and Loss curves of Training and Validation of ANN for the classification of pmDNA, smDNA, and uDNA using data at nine different concentrations. The validation accuracy is evaluated every ten iterations. Both validation and training accuracy increase with iterations and converge to 100%. Therefore, the model is capable of classifying the three classes of DNA even at different concentrations.