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Graphene-on-Silicon Hybrid Field- Effect Transistors

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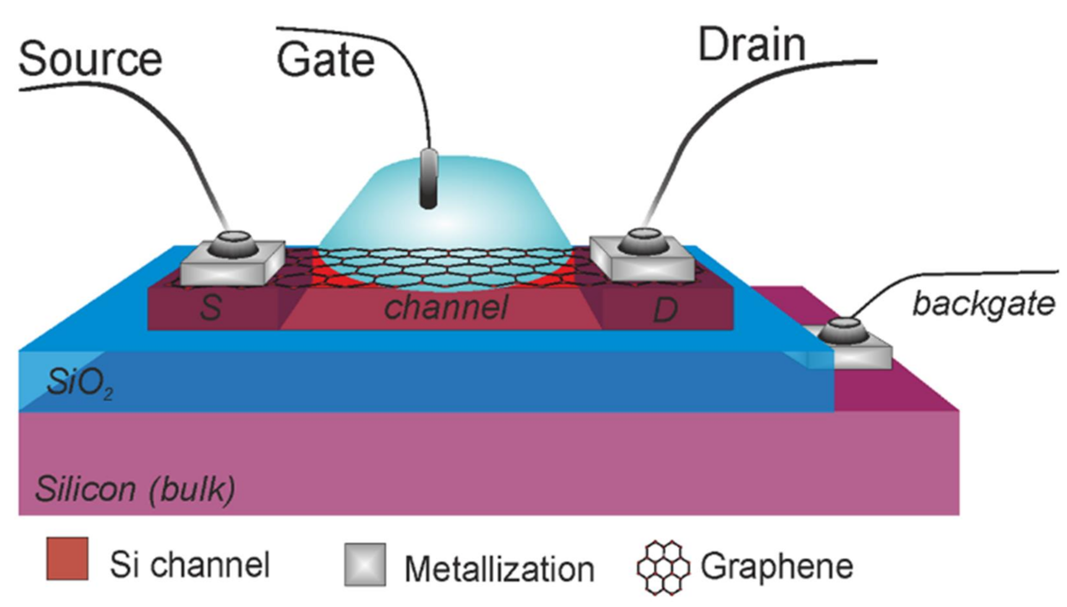
Motivation

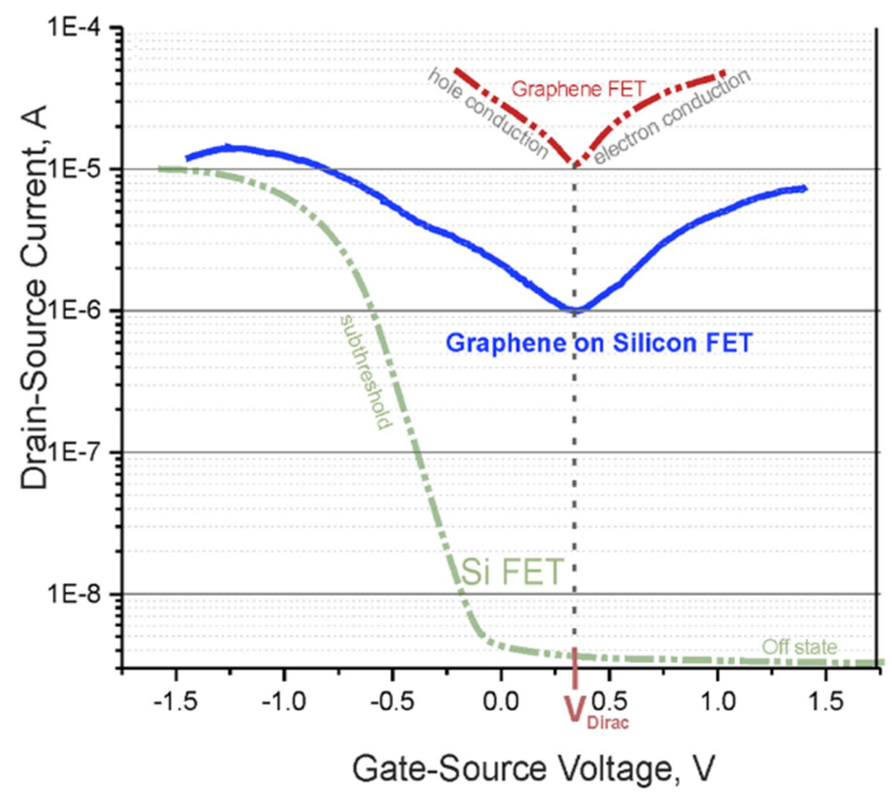
Silicon is an iconic material that has been the cornerstone of micro- and nano- electronics for the last 50 years. Si field-effect transistors (FETs) have been extensively used in biosensing applications [1,2]. However, silicon is known to be a bioresorbable material that gradually degrades when immersed in the electrolyte solution. Therefore, Si FETs suffer from a limited operating time.

Graphene, on the other hand, has not only opened up new prospects in modern nanoelectronics applications, it also has great potential for bio- and neuro-applications as well as being biocompatible and exceptionally stable in electrolytes [3].

In this study, we present a new kind of graphene-on-silicon (GoS) structure and use it as a basis for building functional devices, such as **liquid-gated GoS FETs.**



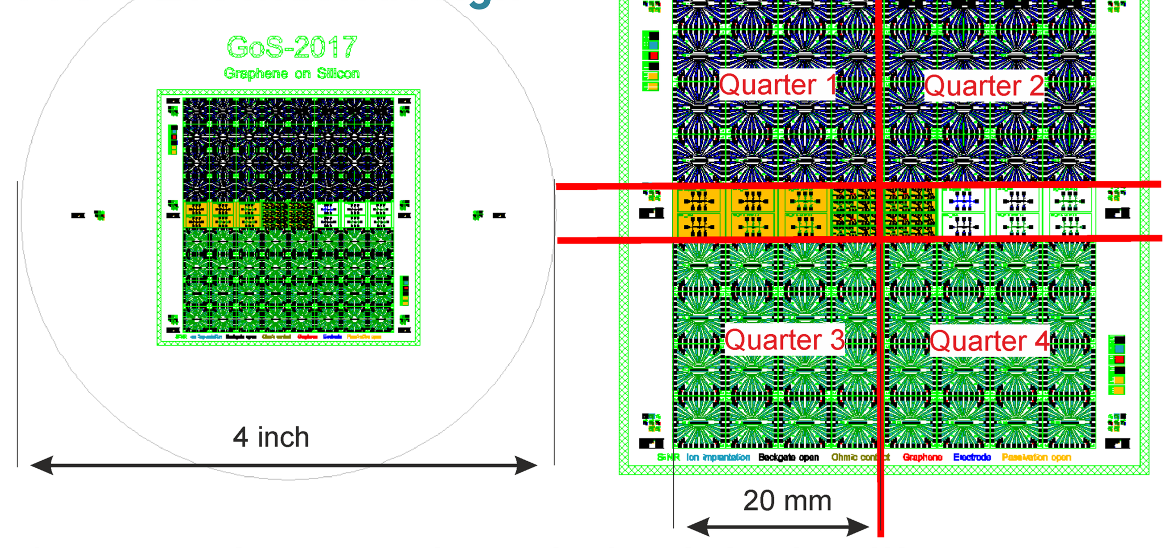
A large variety of devices were fabricated, with a general schematic shown in the Figure, while we varied the widths and lengths of the graphene and silicon channels as well as their ratio and level of silicon doping.



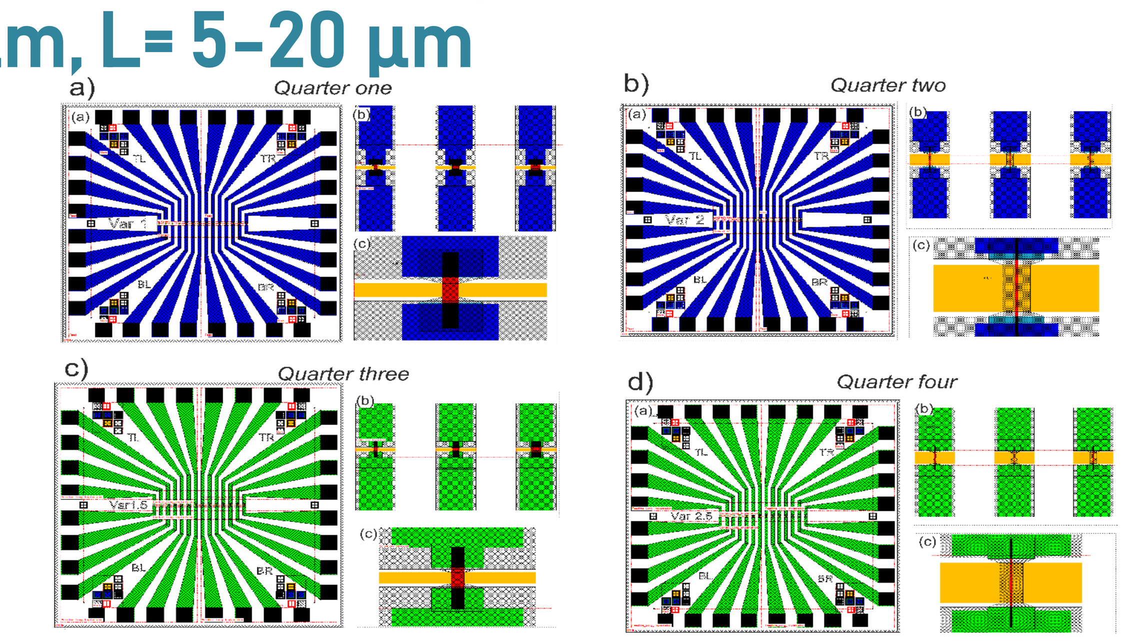
Typical I-V characteristics obtained for bare Si FET, bare G FET, and hybrid GoS-FET structure.

GoS-FETs. Varied the widths and lengths of the graphene and silicon channels : W= 1-4 µm, L= 5-20 µm

GoS-FETs mask design

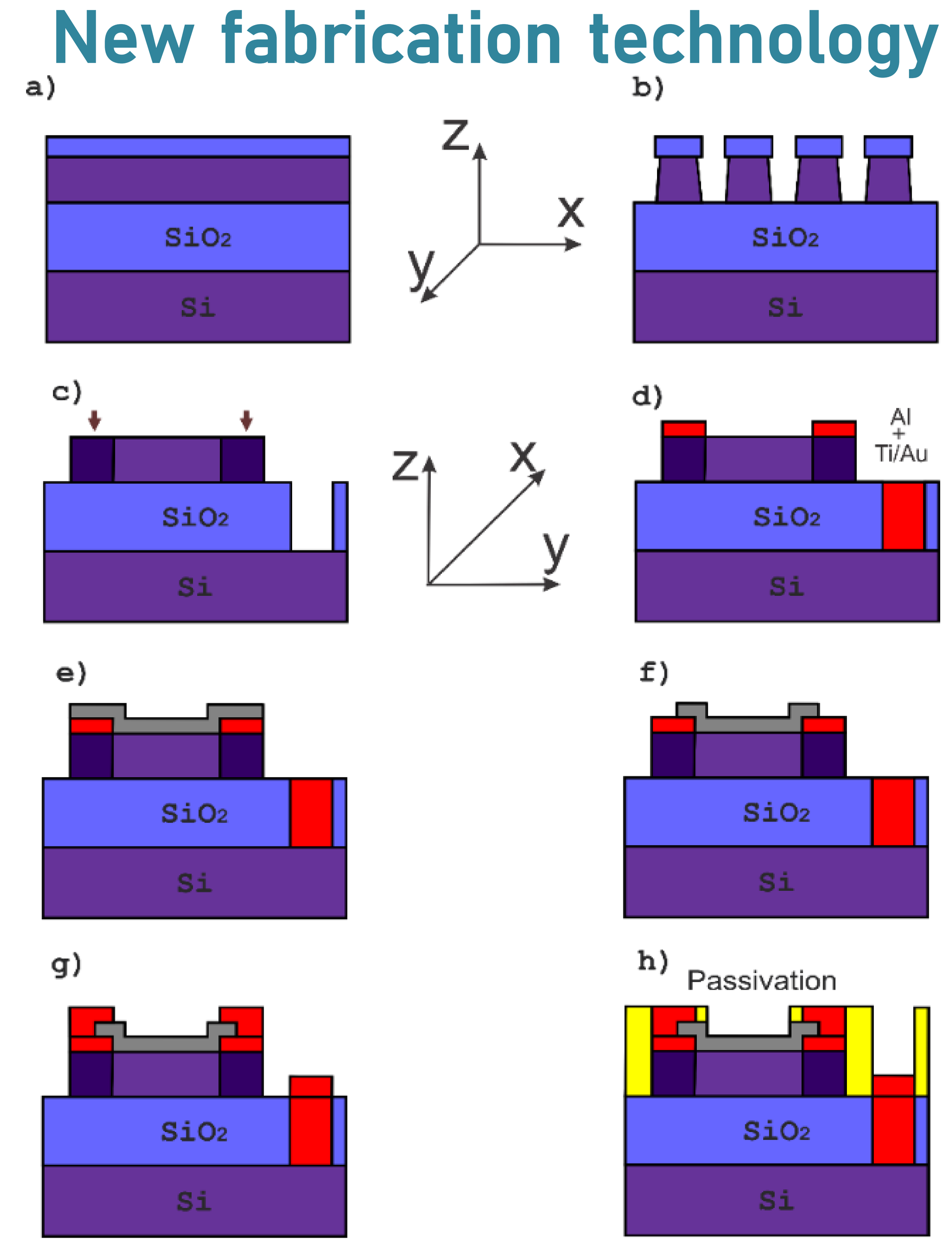


An overview on the whole 4-inch silicon-on-insulator (SOI) wafer with a zoom into the middle region featuring four regions that have different geometries of GoS-FET structures.



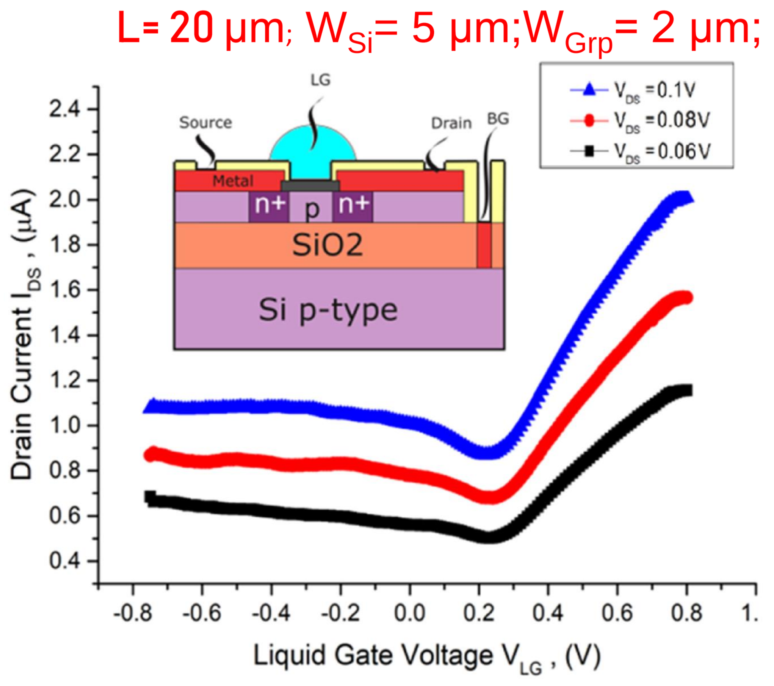
Enlarged details of designed GoS-FET devices:
blue – metallization;
white-black squares - silicon meza-structure;
green - ion implantation profile;
yellow - passivation openings.

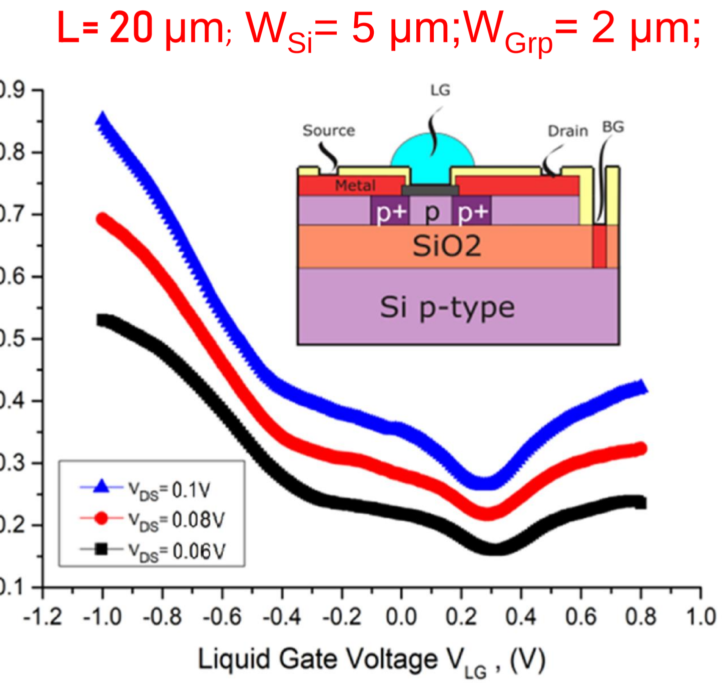
New fabrication technology



a) SOI wafer with SiO_2 hard mask on the top
b) Etched silicon working area, through the patterned hard mask for Si ribbons
c) Ion implantation and back gate opening etching
d) Metallization
e-f) Graphene transfer and patterning
g) Second metallization
h) Passivation

Liquid-gated GoS-FETs: Experimental Results and Discussion

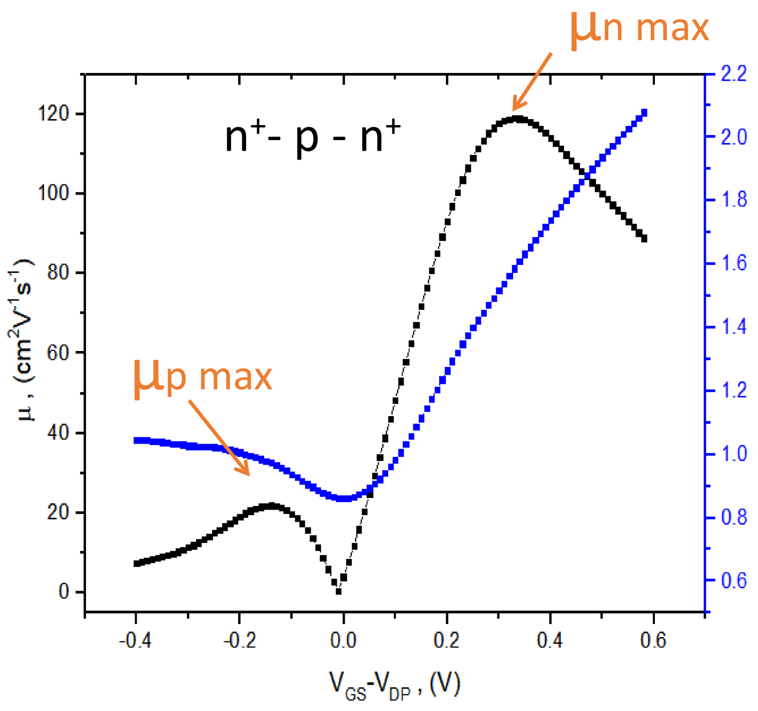


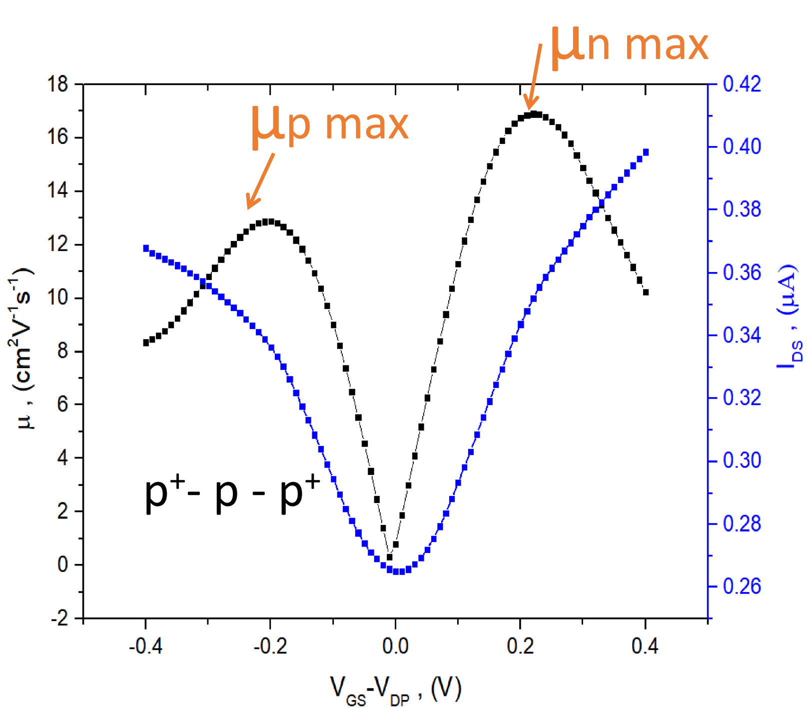


Transfer characteristics of hybrid GoSFETs with a different types of doping of drain and source regions: **n+- p - n+** and **p+- p- p+.**

The principle of work such devices is based on the parallel involvement of materials in charge transfer.

$$\mu = \frac{L}{W} \cdot \frac{g}{C_{ox} V_{DS}}$$





The estimated carriers mobility for liquid-gated FET structures reflects scattering on charged impurities [4] introduced in the native SiO_2 dielectric material due to the technological peculiarities of the devices.

Extraction of mobility for liquid-gated GoS-FET is a challenge, which requires consideration of several capacitances.

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Conclusions

- ✓ Established and optimized fabrication technology for new Graphene-on-Silicon field-effect transistors
- ✓ Dirac point and threshold voltage are well separated in p+- p - p+ structures . These results open prospects for high-sensitive biosensing applications.
- ✓ A new working principle of the hybrid device functionality based on the parallel involvement of materials in charge transfer is described.

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REFERENCES

[1] Y.Kutovyi et al. Biosensors and bioelectronics. 154, 112053-1-8 (2020).
[2] I. Zadorozhnyi, et al., Biosensors and Bioelectronics, 137 229-235 (2019).
[3] D. Kireev, et al., Sciientific Reports, 7 , 6658-1-12 (2017)
[4] T. Stauber, et al.Physical Rewiev B 76, 205423-1-10, (2007)

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