MAY 27, 2020
CONFERENCE ONLINE

Graphene Industrial Forum &2DM 2020

Ultrafast electro-absorption graphene modulators with a 2D-3D integration of hBN and a high-κ dielectric

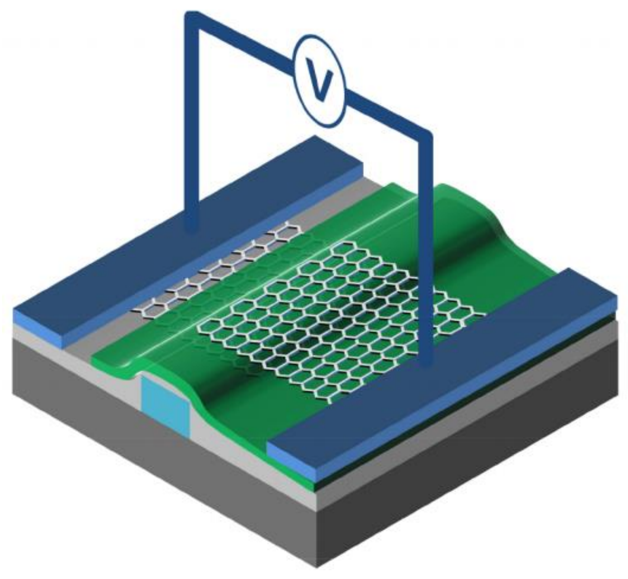
B. Terrés[1], H. Agarwal[1], L.Orsini[1], A. Montanaro[2], V. Sorianello[2], M. Pantouvaki[3], K. Watanabe[4], T. Taniguchi[4], D. van Thourhout[3], M. Romagnoli[2], F. H. L. Koppens[1, 5]

[1]ICFO – Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, Castelldefels (Barcelona) 08860, Spain
[2]Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT). Via Moruzzi,1 56124 Pisa, Italy
[3]Photonics Research Group, Department of Information Technology, Ghent University-IMEC, Sint-Pietersnieuwstraat 41, Gent, 9000 Belgium
[4]National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan
[5]ICREA-Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

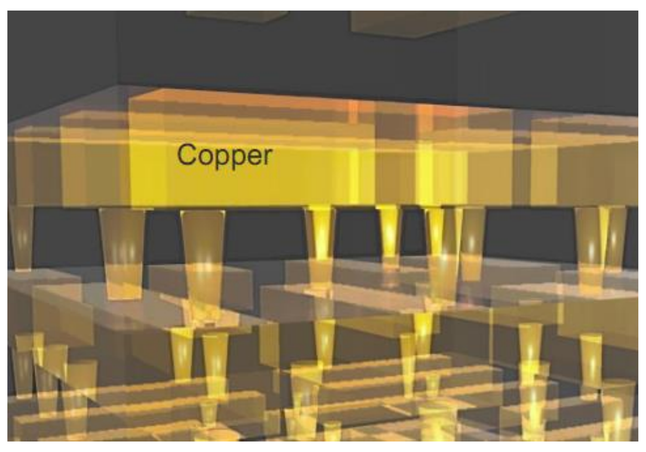
ICFO Institut de Ciències Fotòniques

INTRODUCTION

- Electro-absorption [1] (EA) and/or phase modulators [2] are the basic building blocks (transmitters) for optical interconnects.
- Double-layer (DL) graphene modulators, altough a promising configuration for graphene-based modulators, suffer from a fundamental trade-off between speed and modulation efficiency[3].
- In order to enhance both the speed (f_{3dB} bandwidth) and the modulation efficiency (β), i.e. minimize the power consumption, we integrate a high-κ dielectric material, like Hafnia (HfO_2), in between hBN flakes.
- The proposed hBN-HfO_2-hBN dielectric yields a high modulation efficiency (β=2.2dB/V) as well as a high modulation speed (BW>40GHz). Moreover, the addition of HfO_2 increases the robustness of the hBN dielectric [4], paving the way for the use of DL graphene modulators in on-chip interconnect applications.



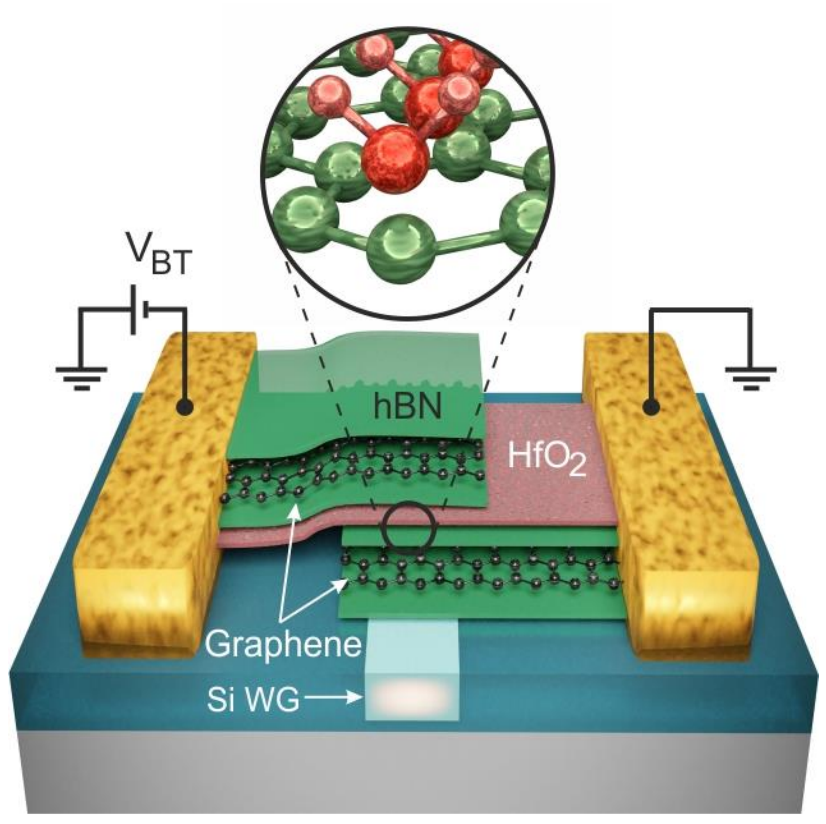
M. Mohsin et al., Optics Express Vol. 22, Issue 12. pp. 15292-15297 (2014).



Out-of-plane copper-based electrical interconnect (picture source: www.extremetech.com).

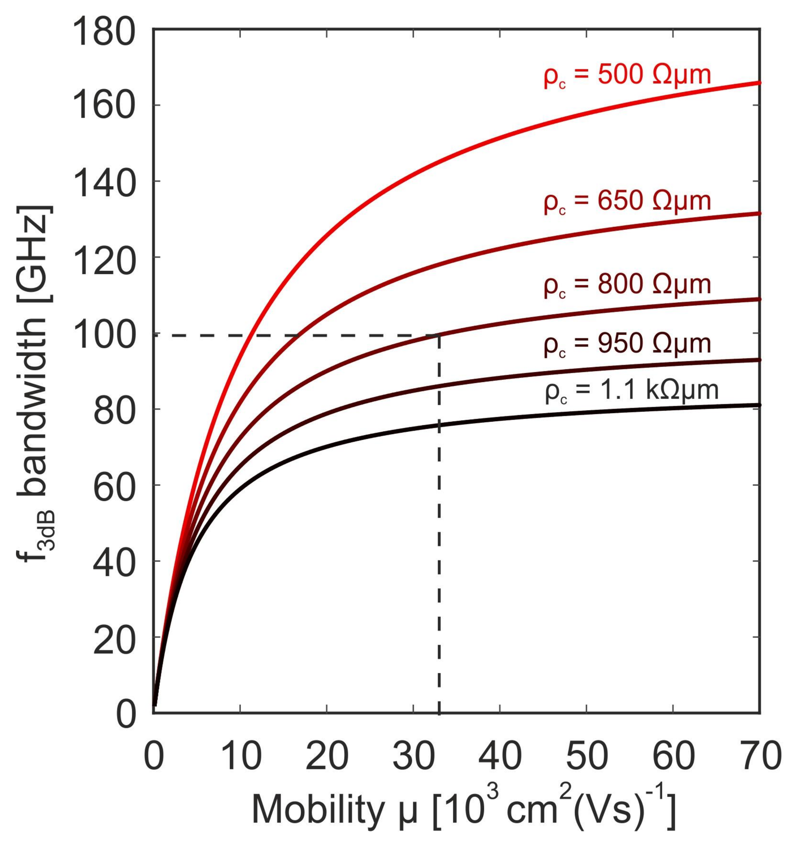
DEVICE CONCEPT & BASIC PRINCIPLE

2D-3D integration of a high-κ dielectric in between hBN



- The 2D-3D integration of hBN and a high-κ dielectric preserves the intrinsic high mobility (μ) of graphene and enhances the robustness of the insulating layer.

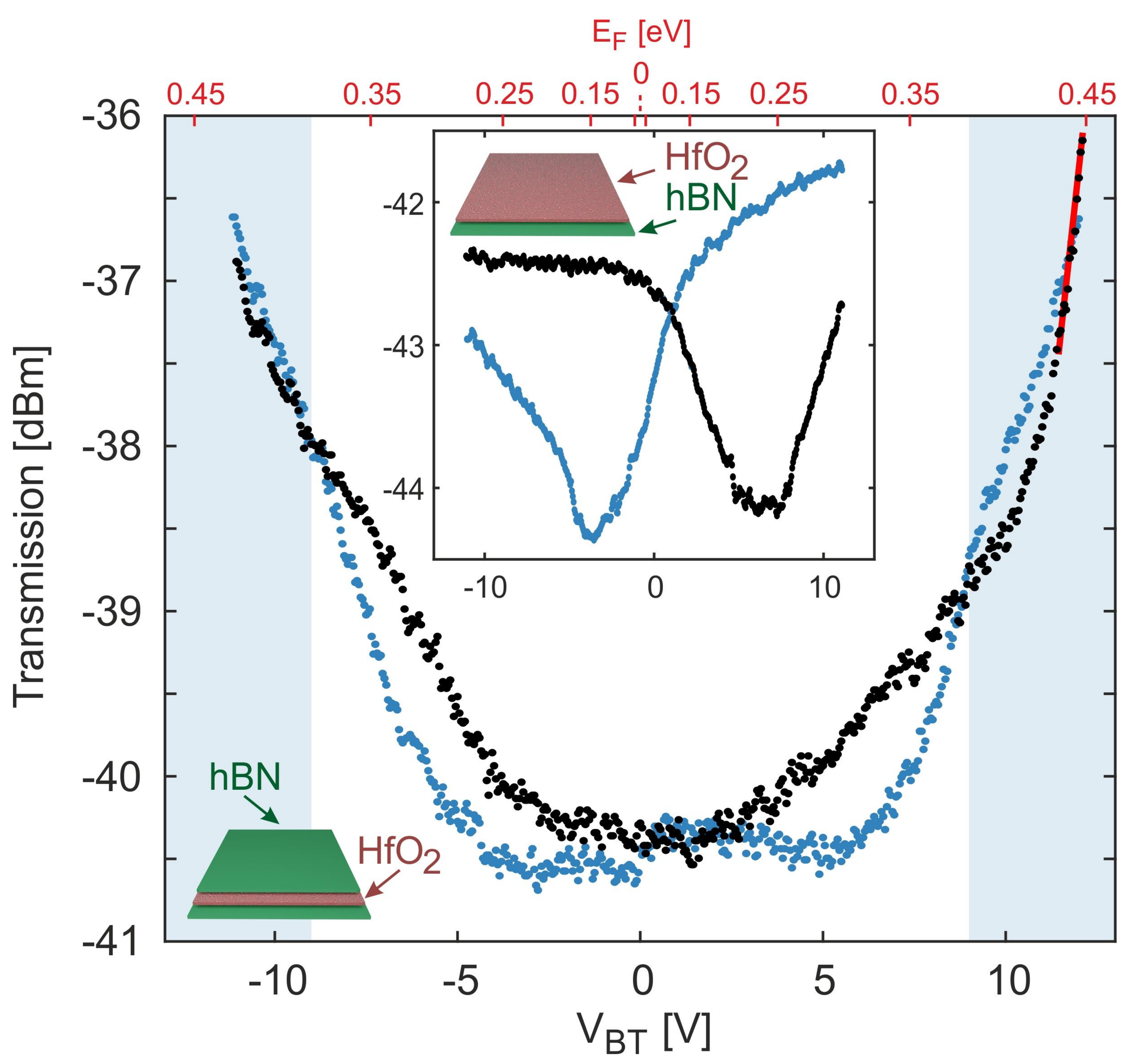
Effects of an hBN-HfO_2-hBN dielectric on the f_{3dB} bandwidth



- The graphene mobility (μ) together with the contact resistivity (ρ_c) are crucial to achieve a high f_{3dB} bandwidth in a DL graphene modulator.

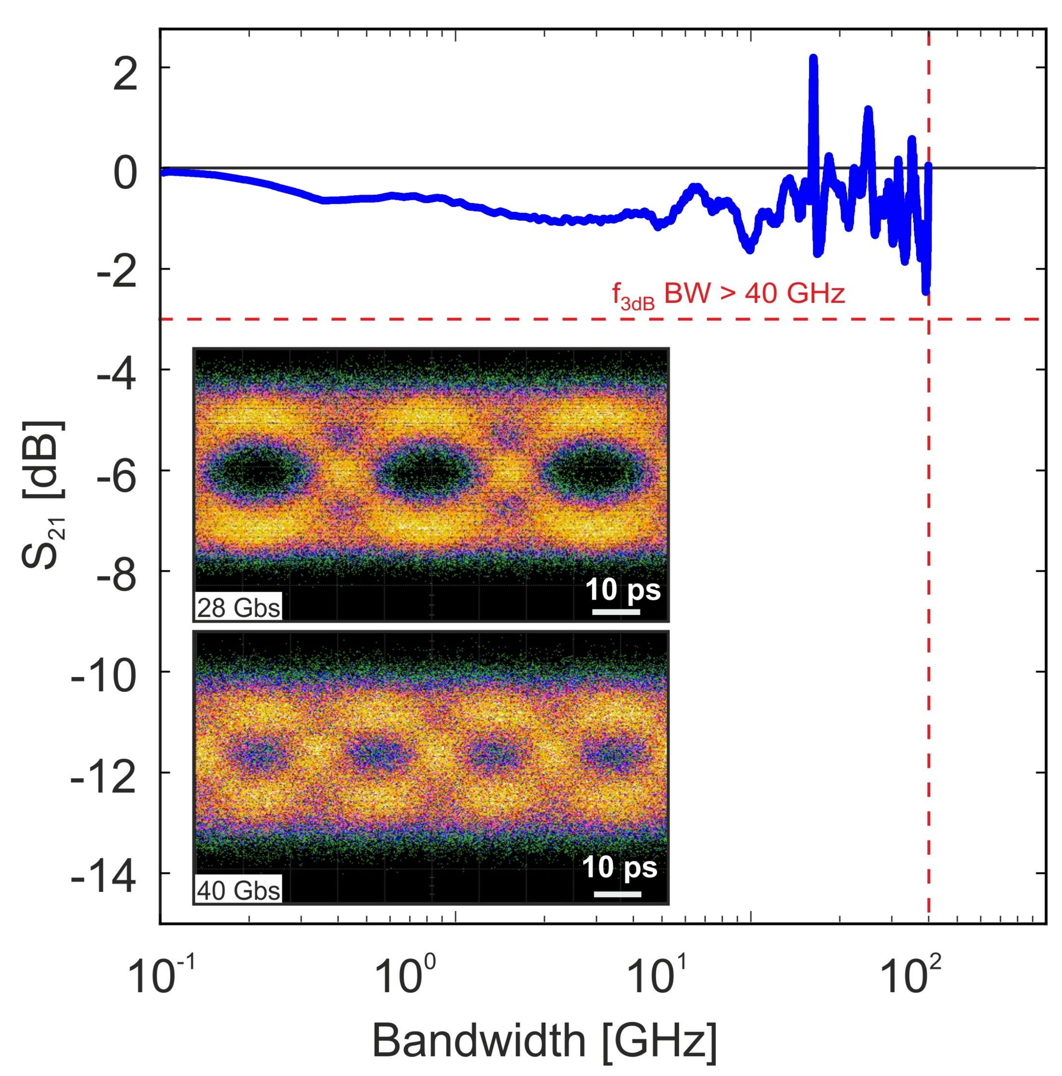
DEVICE CHARACTERIZATION

Transmission curves:



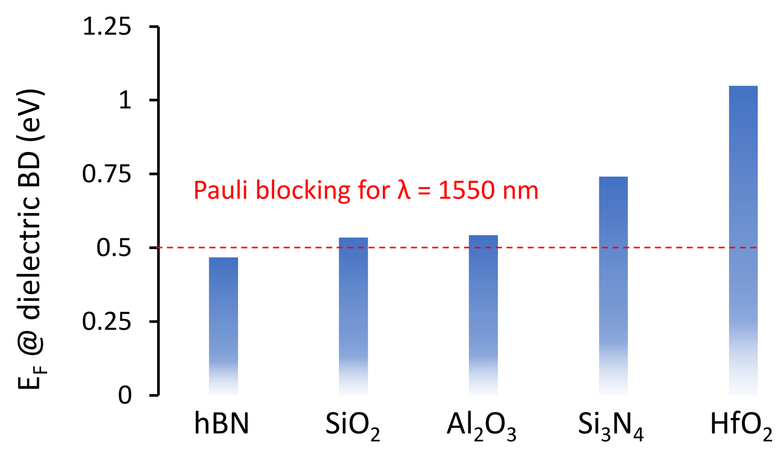
- We obtain a modulation efficiency β =2.2dB/V (red fit).
- We obtain a reduced hysteresis compared to hBN-HfO_2 dielectric (see inset).

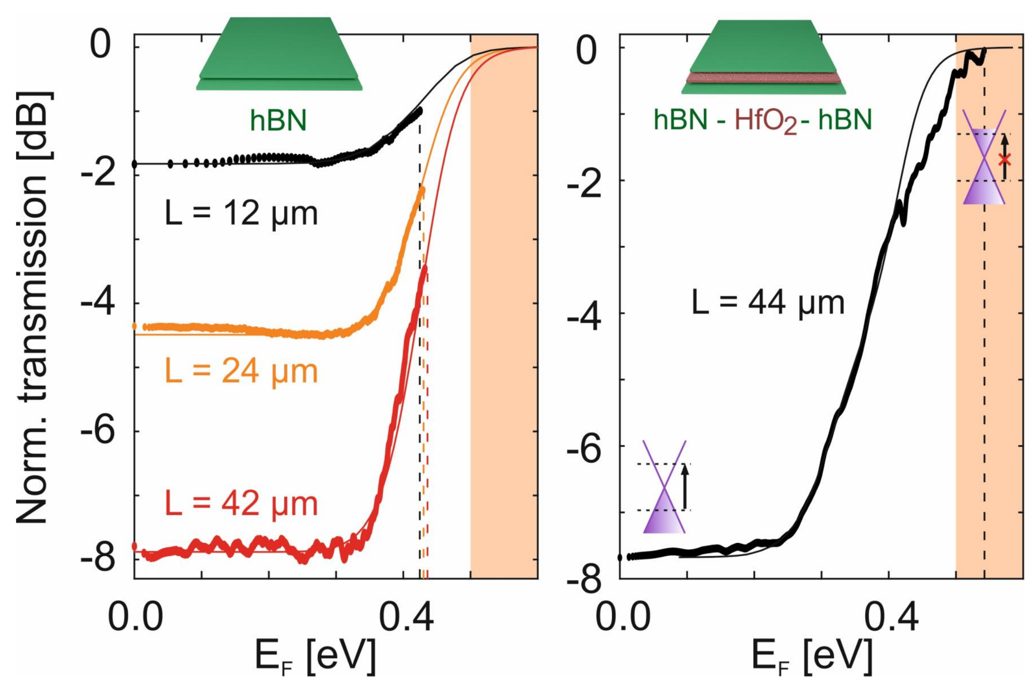
Speed measurements:



- The f_{3dB} bandwidth (BW>40GHz) is setup limited.
- We measure an open eye-diagram at modulation speeds as high as 40Gbps (inset).

Robust dielectric material:





- The hBN-HfO_2-hBN dielectric allows a higher E_F (vertical dashed lines) enabling Pauli blocking operation.

CONCLUSIONS & OUTLOOK

- We have experimentally demonstrated the integration of a high-κ dielectric with hBN in a electro-absorption DL graphene modulator.
- The EA modulators with a hBN-HfO_2-hBN dielectric combination conserve the outstanding properties of hBN-encapsulated devices (high electronic mobility) while improving the robustness of the dielectric.
- The 2D-3D integration of HfO_2 and hBN paves the way for interconnects applications and more specifically for phase modulators working in the Pauli blocking regime.

CONTACT PERSON

Bernat Terrés Güerri

bernat.terres@icfo.eu

REFERENCES

[1] M. Liu et al. "*Double-Layer Graphene Optical Modulator*", *Nano Lett.* **12** (3), 1482–1485 (2012).
[2] V. Sorianello et.al. "*Graphene-Silicon phase modulators with gigahertz bandwidth*", *Nature Photonics* **12**, 40–44 (2018).
[3] C. Phare et al. "*Graphene electro-optic modulator with 30GHz bandwidth*" *Nature Photonics* **9**, 511–514 (2015).
[4] Y. Hattori *et al.* "*Anisotropic Dielectric Breakdown Strength of Single Crystal Hexagonal Boron Nitride*", *ACS Appl. Mater. Interfaces* **8** (41), 27877–27884 (2016).

Graphene Industrial Forum &2DM 2020