

## **MINERVA**

#### MakIng New ElectRonic deVices from Amorphous materials

FLAG-ERA JTC 2021 - Graphene - Basic Research

Growth and device integration of two-dimensional amorphous materials





#### **2D** materials => promising properties for "high-tech" applications



Mechanically flexible batteries, flexible & transparent optical sensors High frequency optoelectronic devices, compact modulators and photodetectors



#### BUT some limitations =>

- Synthesis
- Properties / structure / defects



#### **BUT some limitations =>**

• Synthesis : high temperature growth, high cost methods





#### **Alternative => structurally disordered 2D materials**

- Produced at much lower temperatures
- Have been shown to manifest a large degree of uniformity over large areas
- Performant properties for device applications
  - ✓ Functionalisation
  - Sheet resistance
  - ✓ Electrons scattering
  - ✓ Ultrathin seed for ALD
  - .....





# Amorphous BN presents overall superior performances compared to all benchmarked materials !

ŚAMSUNG  $\Rightarrow$  Ultra-low dielectric-constant UNIVERSITY OF UNIST CAMBRIDGE  $\Rightarrow$  Excellent field emission performance International journal of science Article Ultralow-dielectric-constant amorphous  $\Rightarrow$  Mechanical stability at high T boronnitride  $\Rightarrow$  Strong adhesion feature https://doi.org/10.1038/s41586-020-2375-9 Seekmo Hong<sup>1</sup>, Chang-Seek Lee<sup>2</sup>, Min-Hyun Lee<sup>2</sup>, Yeongdong Lee<sup>24</sup>, Kyung Yeol Ma<sup>4,3</sup>, Gwangwoo Kim<sup>1</sup>, Seong in Yoon<sup>4,8</sup>, Kyuwook Ihm<sup>6</sup>, Ki-Jeong Kim<sup>6</sup>, Tae Joo Shin<sup>12</sup>, Received: 16 November 2019 Sang Won Kim<sup>2</sup>, Eun-chae Jeon<sup>a</sup>, Hansol Jeon<sup>a</sup>, Ju-Young Kim<sup>2</sup>, Hyung-Ik Lee<sup>a</sup>,  $\Rightarrow$  Large thermal conductance (?) Zonghoon Lee<sup>14</sup>, Aleandro Antidormi<sup>10</sup>, Stephan Roche<sup>118</sup>, Manish Chhowalla<sup>1188</sup> Accepted: 25 March 2020 Hypon-Jin Shin<sup>258</sup> & Hypon Suk Shin<sup>1,4,1,258</sup> Published online: 24 June 2020

S. Hong et al. Nature 582, 511-514 (2020)

Suitable for interconnects technologies and high performance electronics (flexible dielectric devices or conductive bridging RAM)



#### How will the degree of amorphicity impact the properties?







### MINERVA Objectives

- **1.** Synthesize amorphous Boron Nitride (aBN) on various substrates with controlled degree of amorphicity, dimensionality, sp₂/sp₃ ratio.
- 2. Study its mechanical and thermal properties as a function of its amorphicity.
- **3. Study its electronic properties** to establish its potential as integrable component in electronic devices.
- 4. Standardize aBN as reference material for the Graphene Flagship Samples and Materials Database: providing specification of produced aBN following the characterization protocols.



5. Study and realize its integration and scalability into target devices: resistive switching devices, magnetic tunnel junction, spin-injection tunnel barriers.



### MINERVA Consortium



Country	Institution/ Department	Name of the Principal Investigator (PI)
FRANCE ( <b>UCBL</b> )	LMI / Université Claude Bernard Lyon 1 (UCBL)	Catherine Journet <b>Coordinator</b>
SPAIN ( <b>ICN2</b> )	Catalan Institute of Nanoscience and Nanotechnology (ICN2)	Marianna Sledzinska
SWEDEN (UU)	Department of Physics and Astronomy / Uppsala University (UU)	Venkata Kamalakar Mutta
BELGIUM ( <b>UCLouvain</b> )	IMCN / Université catholique de Louvain (UCLouvain)	Jean-Christophe Charlier

Duration: 36 months (2021/12/31 – 2024/12/30) Total cost: 847 900 €



## MINERVA Organization





# MINERVA Scientific skills

LMI / Université Claude Bernard

Lyon 1 (UCBL) UCBL UCBL

Expert in boron nitride synthesis with different structures by:



• CVD

ALD and LOCALD

• PDCs







Catalan Institute of Nanoscience and Nanotechnology (ICN2) ICN2

### MINERVA Scientific skills



Expert in mechanical and thermal characterization as well as modelling via classical molecular dynamics





# MINERVA Scientific skills

Department of Physics and Astronomy / Uppsala University (UU)

UU



UPPSALA UNIVERSITET

Expert in electrical and spin transport characterization, realization of novel 2D amorphous memristors, magnetic tunnel junctions and spin valves





# MINERVA Scientific skills





Expert in first-principles techniques and DFT-enriched TB methods





# Thank you for your attention !