

# Wafer-scale epitaxial graphene

## Industrial Forum – “Materials and Production”

Ana Ballestar



**GPNT**

Graphene  
& Nanotechnologies

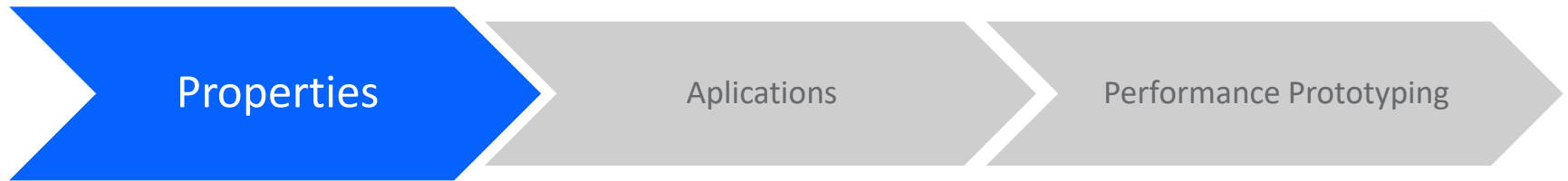
Graphene 2018

Dresden, 28th June 2018

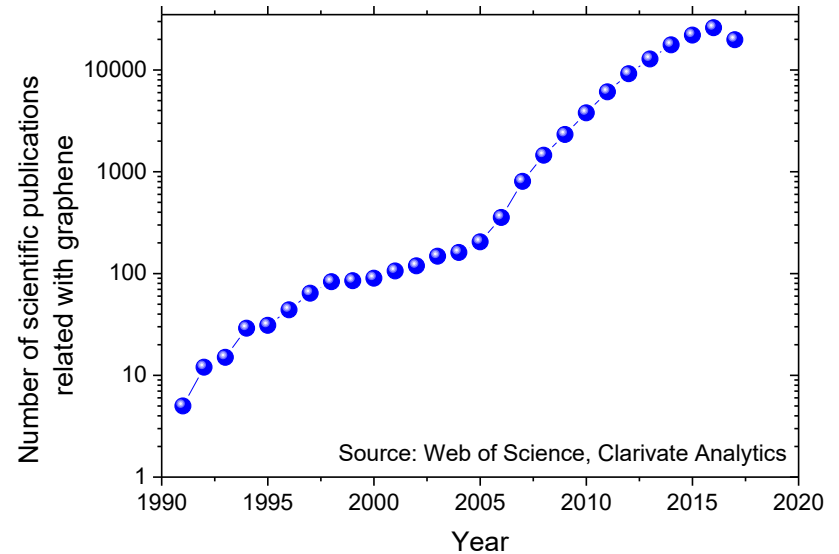
# GPNT - Innovating with epitaxial graphene



# New material → Commercialization



Universities,  
research institutions, etc.



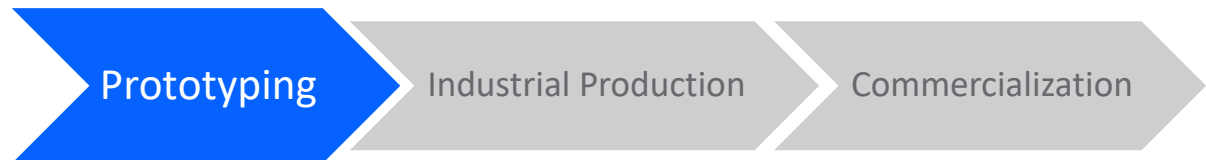
# New material → Commercialization

Universities,  
research institutions, etc.



**LINK:** Testing the performance on devices and applications **“DEMO OR DIE”**

Companies,  
Industrial partners, etc.



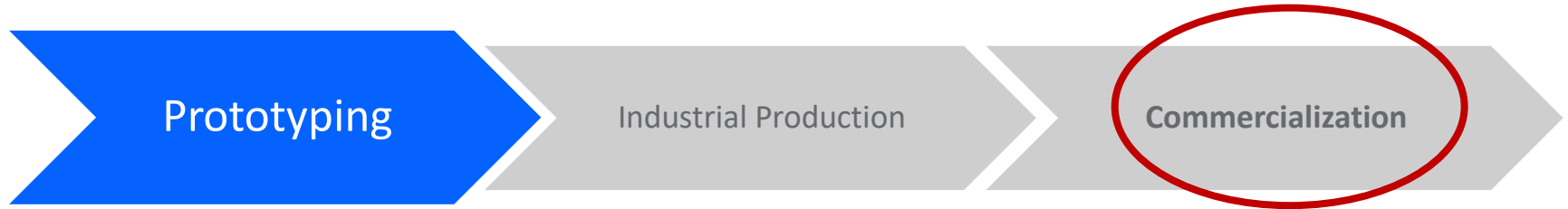
# Production



Fabrication Method	Quality	Size	Amount	Complexity	Control
Adhesive Tape	✓✓	✗	✗	✓✓	✗
Liquid Phase	✓	✗	✓✓	✓✓	✗
Sublimation Growth	✓✓	✓*	✓*	✓✓	✓✓
CVD	✓	✓✓	✓✓	✓	✓✓

- High-quality graphene
- Transfer free
- Effective
- Compatible with current processes

# Production



**Strategies to reduce  
fabrication costs:  
Wafer scale production**

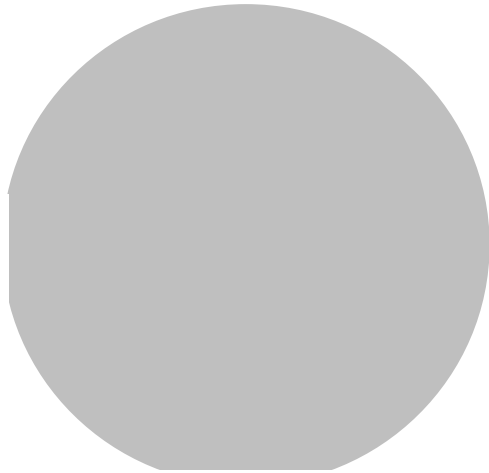
**Pricing  
Impact**

**“Attractive” end products:**

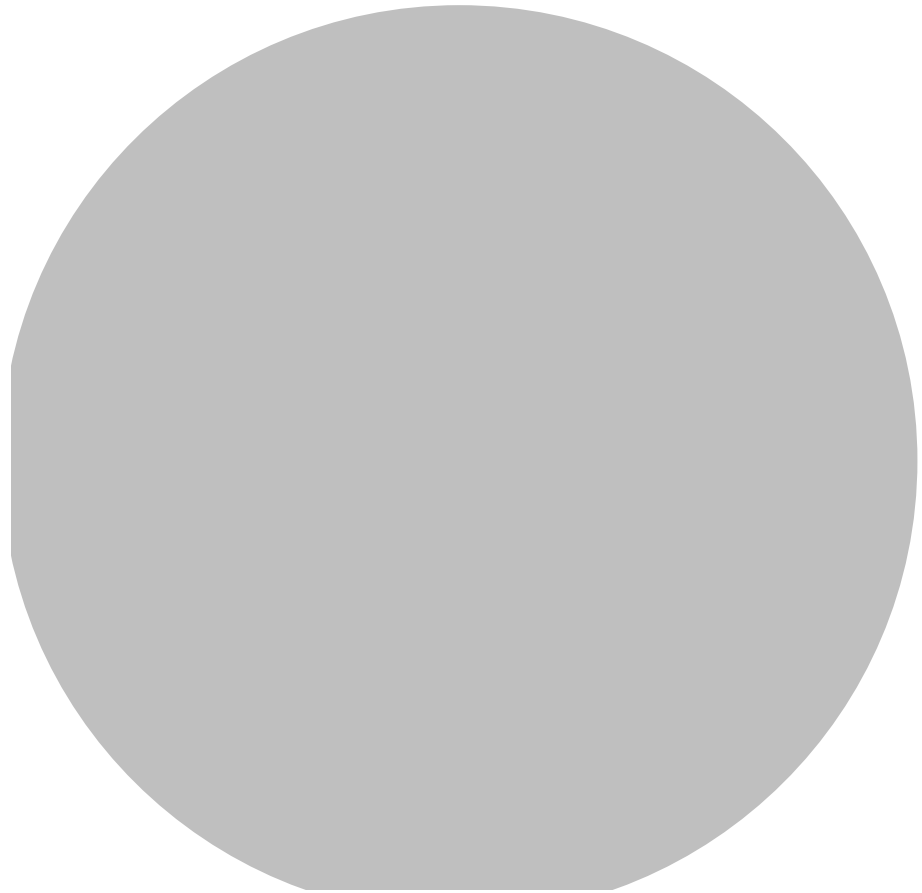
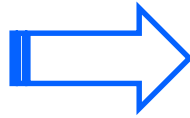
- 1. Benefits to society**
- 2. Market oriented**

# Wafer scale fabrication at GPNT

# Wafer scale production



2" (~5 cm) diameter



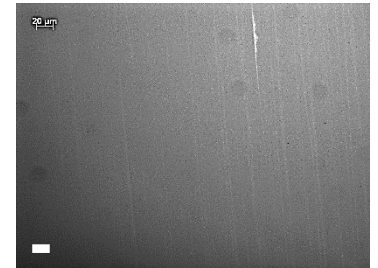
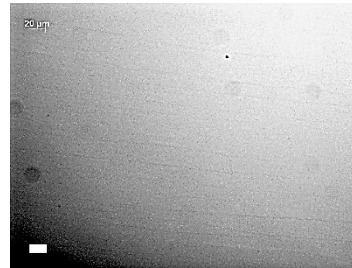
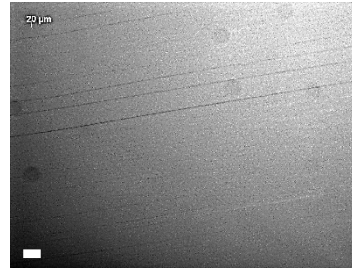
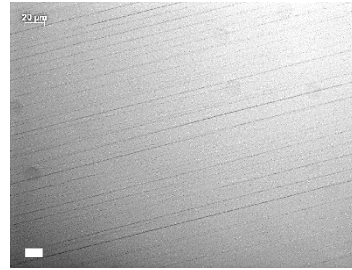
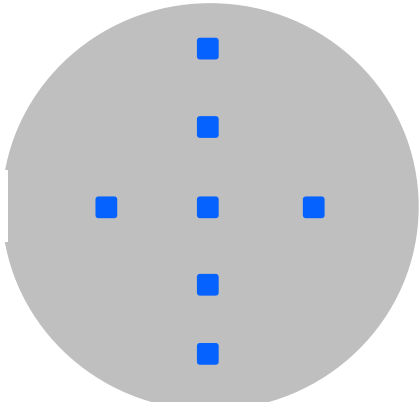
4" (~10 cm) diameter

## Graphene characterization – Quality control:

- Optical microscopy
- AFM
- Raman

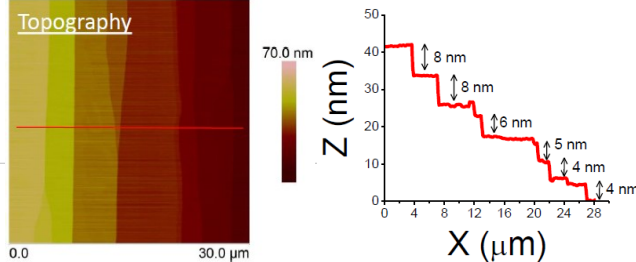
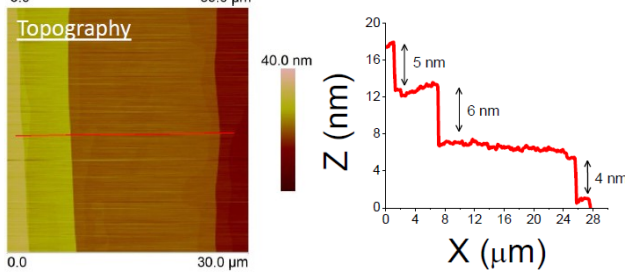
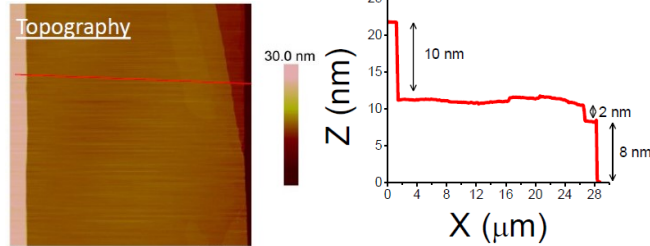
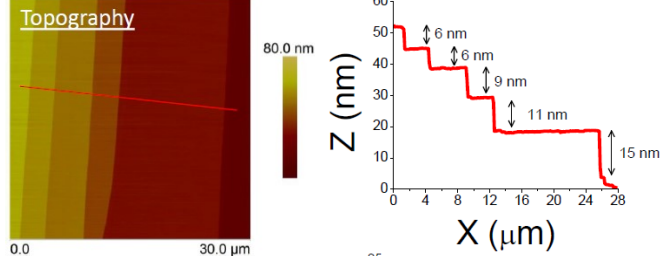
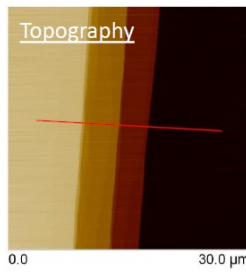
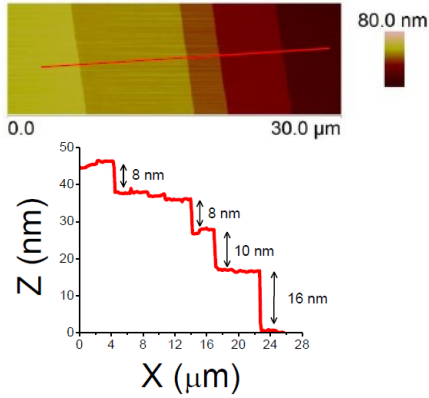
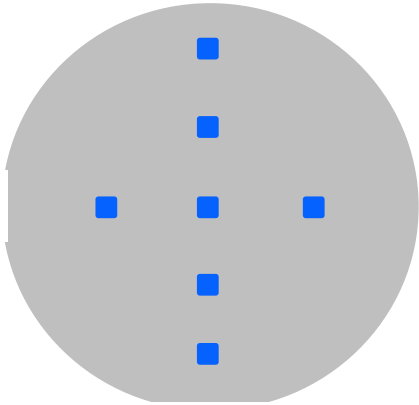


- Optical microscopy



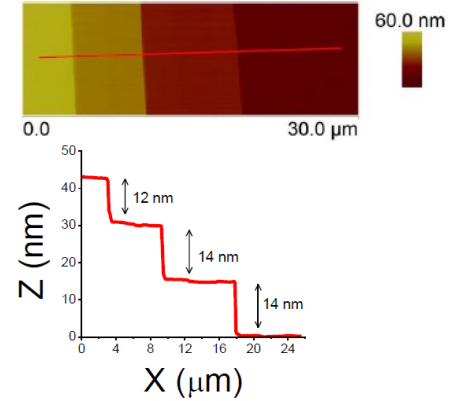
Scale bar 20 μm

• AFM

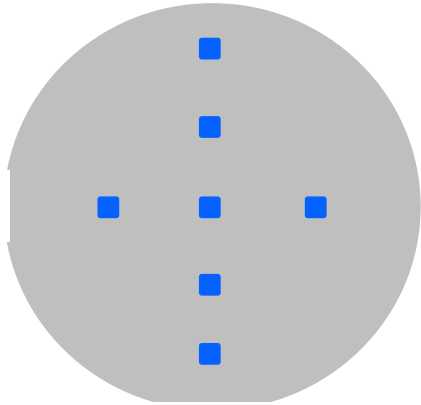


Terraces up to  
20 μm width

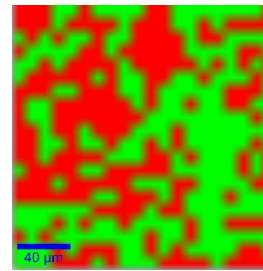
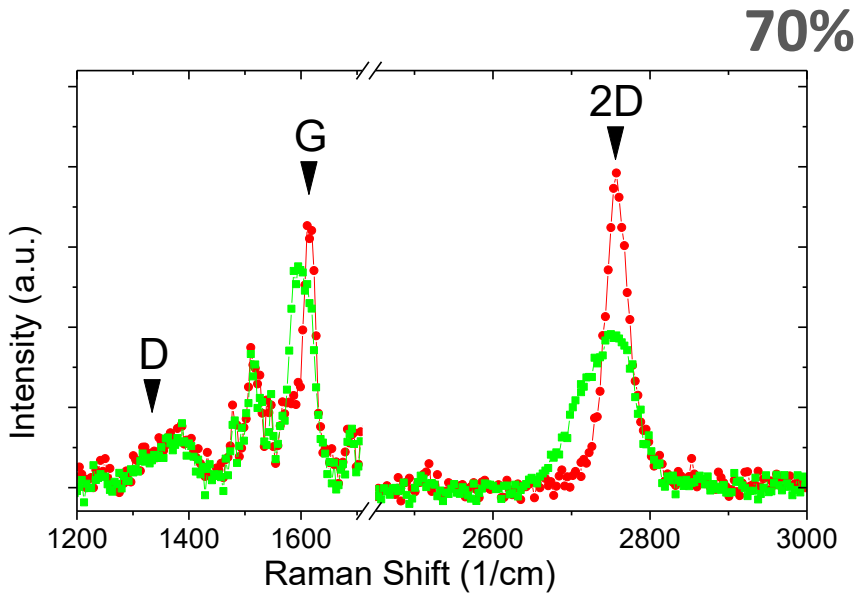
Step height 10-  
15 nm or less



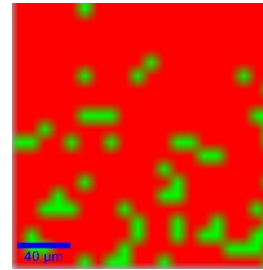
# Raman Spectroscopy



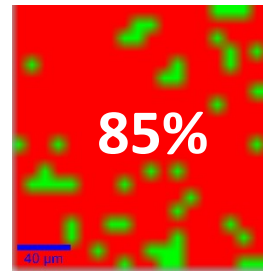
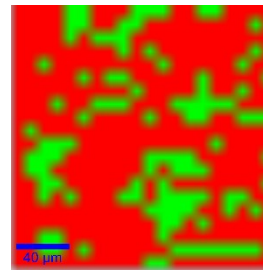
■  $\equiv 200 \times 200 \mu\text{m}^2$



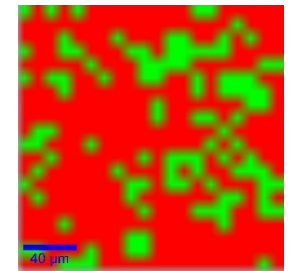
45%



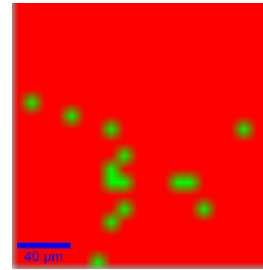
84%



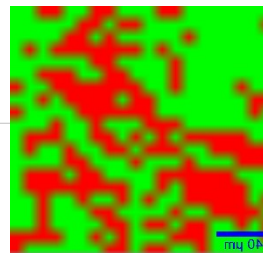
85%



65%

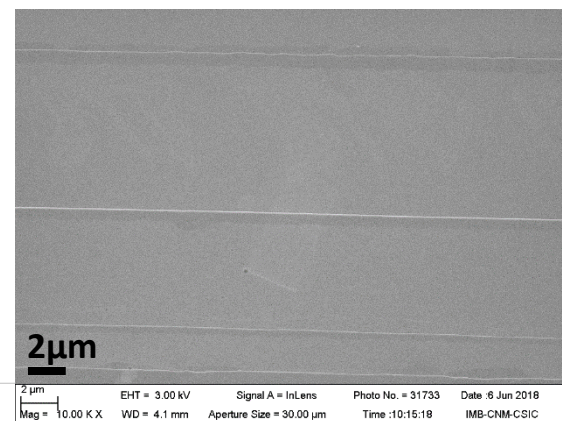
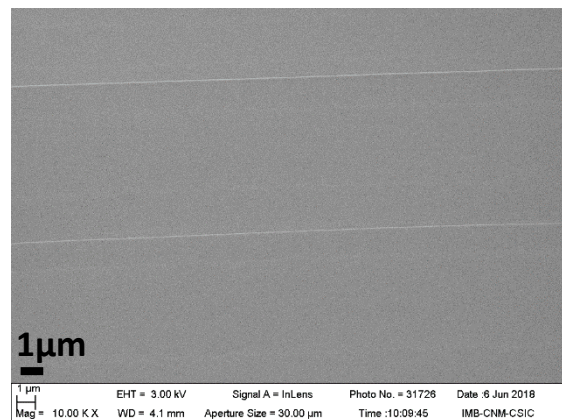
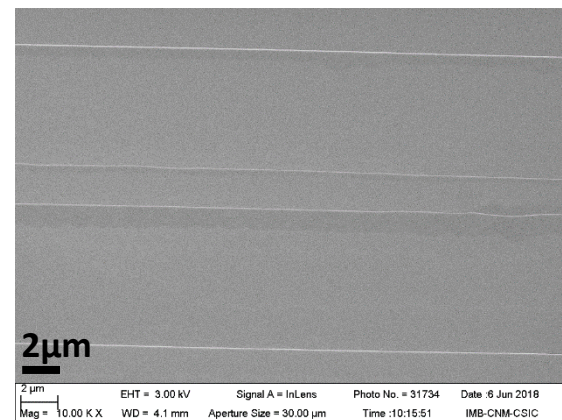
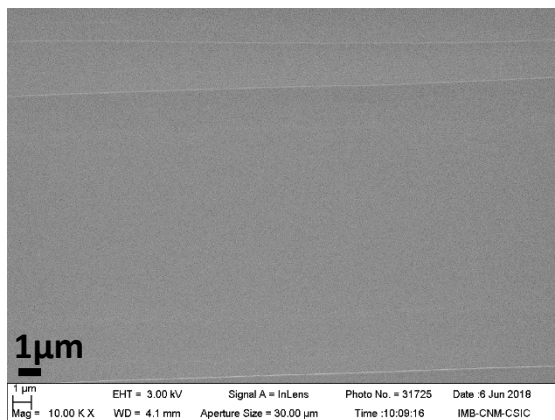
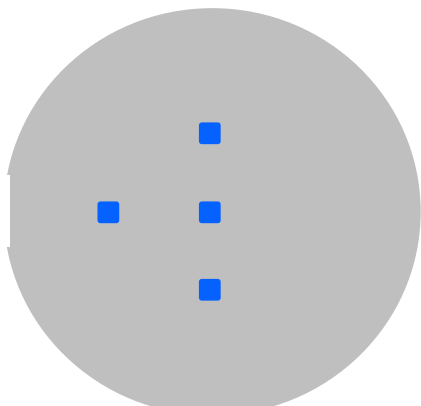


96%

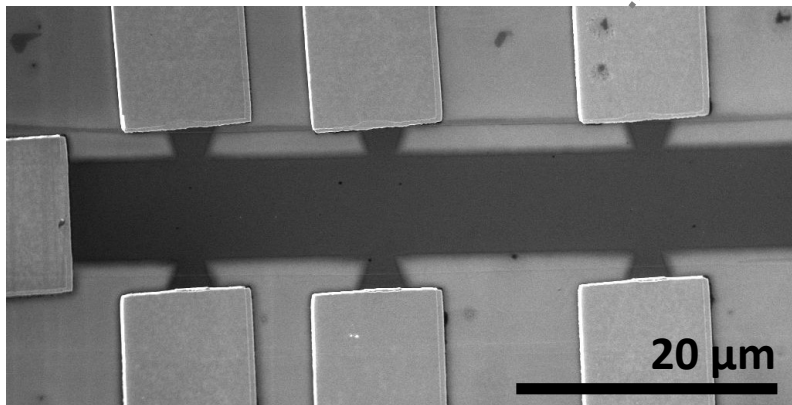
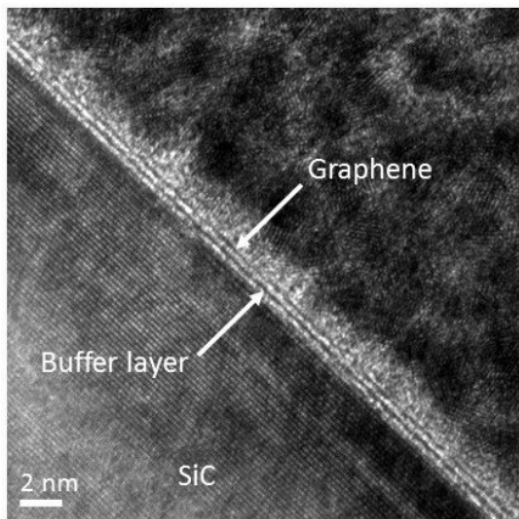


40%

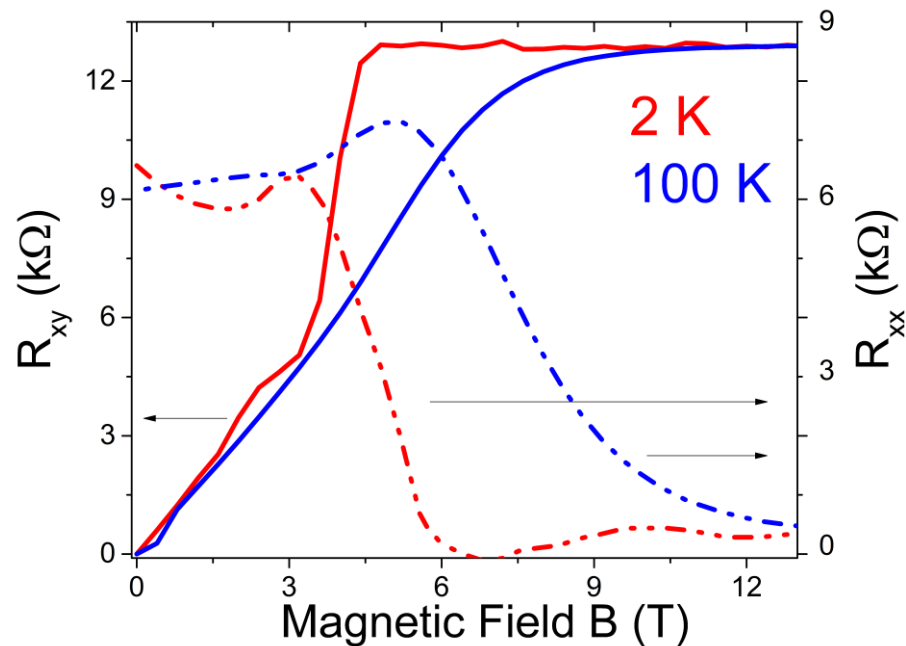
- Extra characterization - SEM



- HRTEM



- Electrical characterization



Sheet Resistance @RT	Electron mobility @RT	Carrier density @RT
2-5 kΩ□	2000-3000 cm <sup>2</sup> V <sup>-1</sup> s <sup>-1</sup>	10 <sup>11</sup> -10 <sup>12</sup> cm <sup>-2</sup>

# Additionally

- Graphene films on **Si-face** of SiC (8x8 mm<sup>2</sup>, 2" and 4" diameter wafers).
- Graphene films on **C-face** of SiC
- **Multilayer** graphene on SiC
- **Doped** graphene on SiC
- Transferring methods under development

Visit us at  
booth 34!

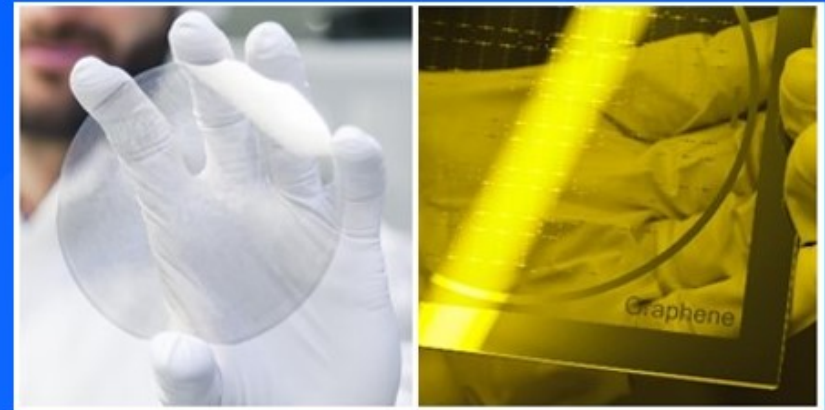
Flexibility ↔ Application ↔ Impact

# Thank you very much for your attention



## GPNT

Graphene  
& Nanotechnologies



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