

# Floating Catalyst Chemical Vapor Deposition for Boron Nitride Nanotube Synthesis

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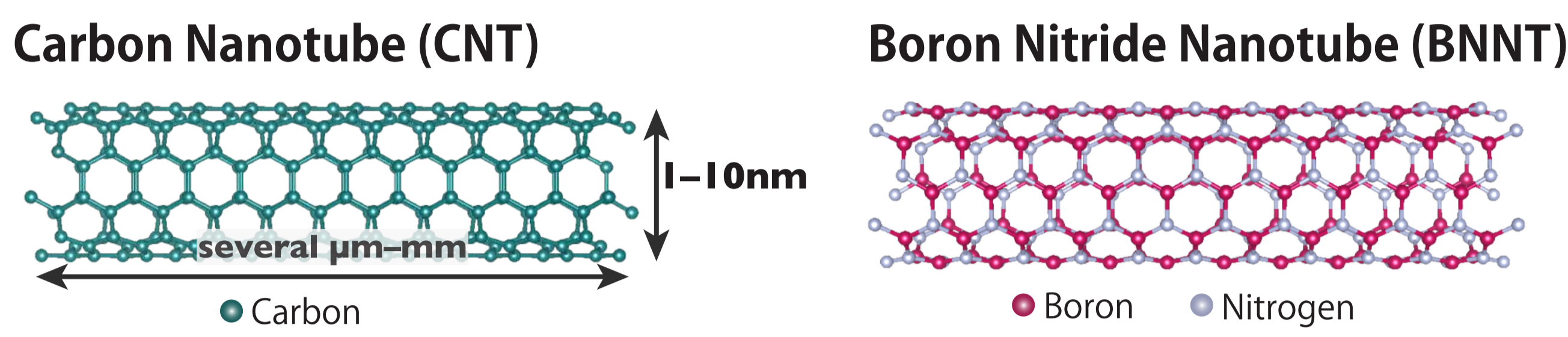
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## 1. Introduction

### Carbon Nanotube & Boron Nitride Nanotube



| CNT   |                      | BNNT   |
|---|----------------------|--|
| Semiconductor or metal (depending on its structure) | Electrical property  | Wide gap semiconductor (regardless of structure) |
| Absorb visible light                                | Optical property     | No absorption of visible light                   |
| $\Delta$ Oxidized in 400-600 °C <sup>[1]</sup>      | Oxidation resistance | $\odot$ Stable up to 900 °C <sup>[1]</sup>       |
| $\odot$ [2]   | Tensile strength     | $\odot$ [3], [4]                                 |

- CNTs exhibit distinctive properties derived from their nanostructures.  $\rightarrow$  attracting significant attention for various applications<sup>[5-8]</sup>
- BNNTs share the same structure as CNTs, with B and N replacing C.  $\rightarrow$  electrically insulating, optically transparent, higher chemical stability than CNTs, while maintaining comparable mechanical strength

**By combining with CNTs, BNNTs contributes as an enhancing and multifunctional nanotube material composite, surpassing the capabilities of carbon nanomaterials alone.**

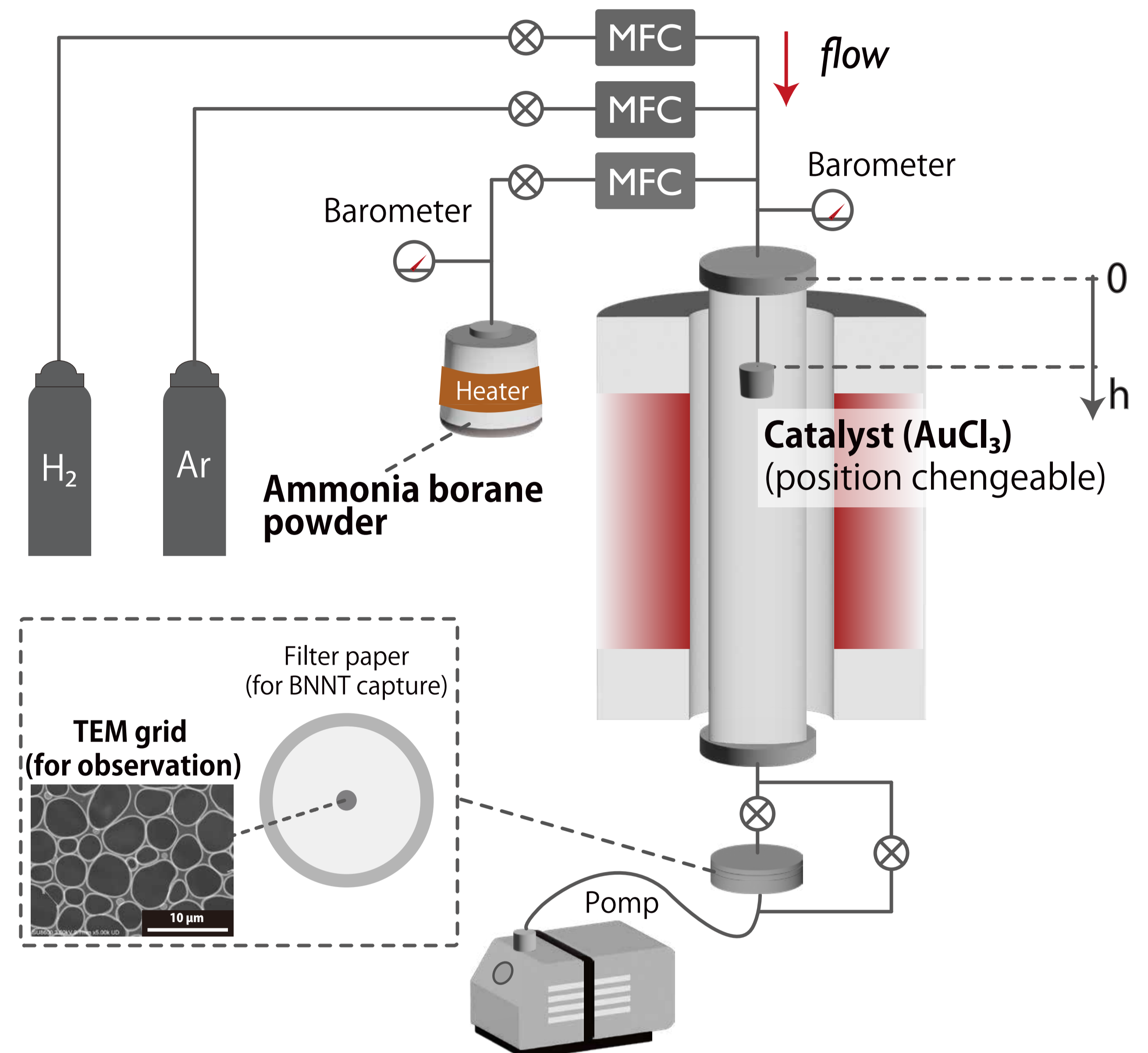
### Boron Nitride Nanotube Synthesis

- Arc discharge<sup>[9, 10]</sup> and laser ablation<sup>[11, 12]</sup> have achieved high-quality BNNT synthesis.  $\Delta$  require high temp. ( $\sim 3000^\circ\text{C}$ ), limiting scalability.
- Floating catalyst chemical vapor deposition (FCCVD) is promising method for scalable BNNT synthesis<sup>[13, 14]</sup>.  $\Delta$  toxic borazine was mainly used as the BN source.

**This work** A parametric study aiming to synthesize BNNTs by FCCVD using non-toxic ammonia borane as a BN source

## 2. Experimental method

### Floating Catalyst CVD (FCCVD)

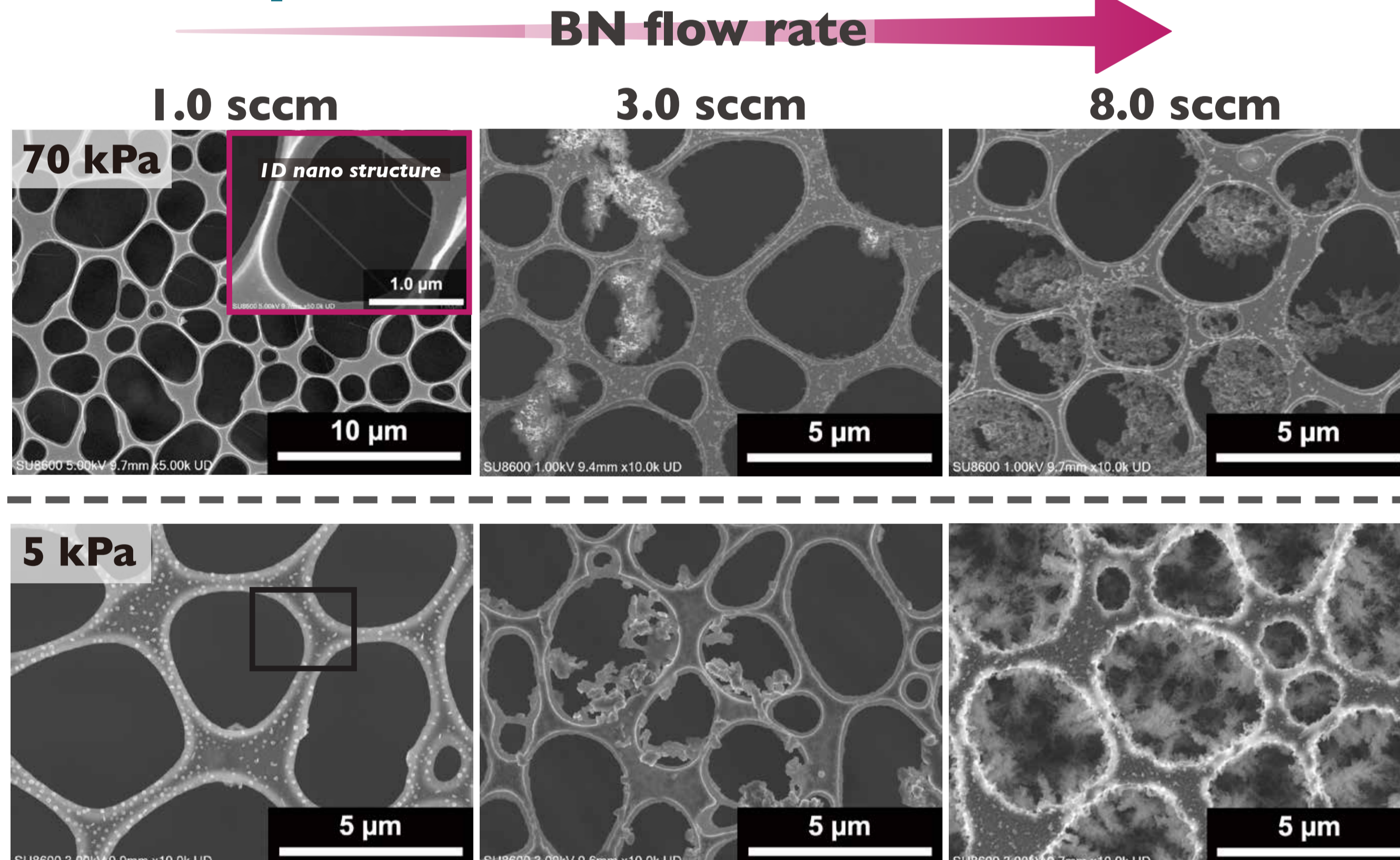


### Growth conditions

|                                   |   |                                    |               |
|-----------------------------------|---|------------------------------------|---------------|
| <b>BN source</b>                  | Ammonia borane, heated to $\sim 130^\circ\text{C}$ to sublime         |                                    |               |
| <b>Catalyst</b>                   | AuCl <sub>3</sub> (10mg), placed in a holder with adjustable position |                                    |               |
| <b>BN flow rate</b>               | 1.0-8.0 sccm  | <b>Pressure</b>                    | 5 kPa, 70 kPa |
| <b>Ar+H<sub>2</sub> flow rate</b> | 200 sccm  | <b>H<sub>2</sub> concentration</b> | 3%, 10%       |
| <b>Growth temp.</b>               | 1100 °C   | <b>Growth time</b>                 | 1 hour        |

## 3. Result & Discussion

### Effect of pressure and BN source flow rate



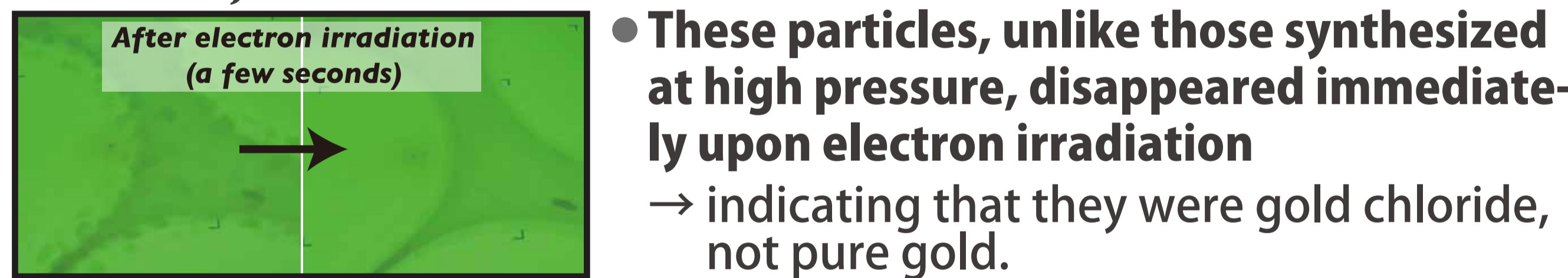
#### High pressure (70 kPa)

- At a BN flow rate of 1 sccm, **one-dimensional nanostructures were obtained.**
- As the BN flow rate increased, the morphology changed  $\rightarrow$  mainly because the growth rate was too fast.

#### Low pressure (5 kPa)

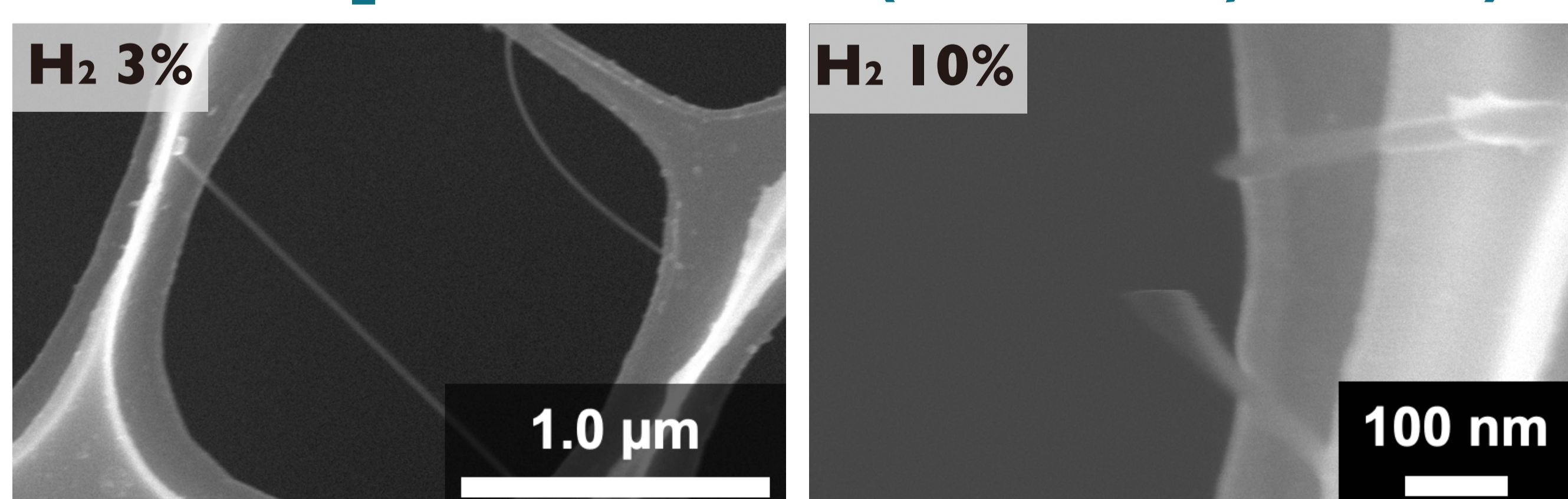
- At a BN flow rate of 1 sccm, many particles were observed on the grid.
- Increasing the BN flow rate resulted in larger deposits.

#### 1.0 sccm, 5 kPa



$\rightarrow$  Under low pressure, the flow was too fast for complete reduction of AuCl<sub>3</sub>, thus possibly not allowing 1D structure growth.

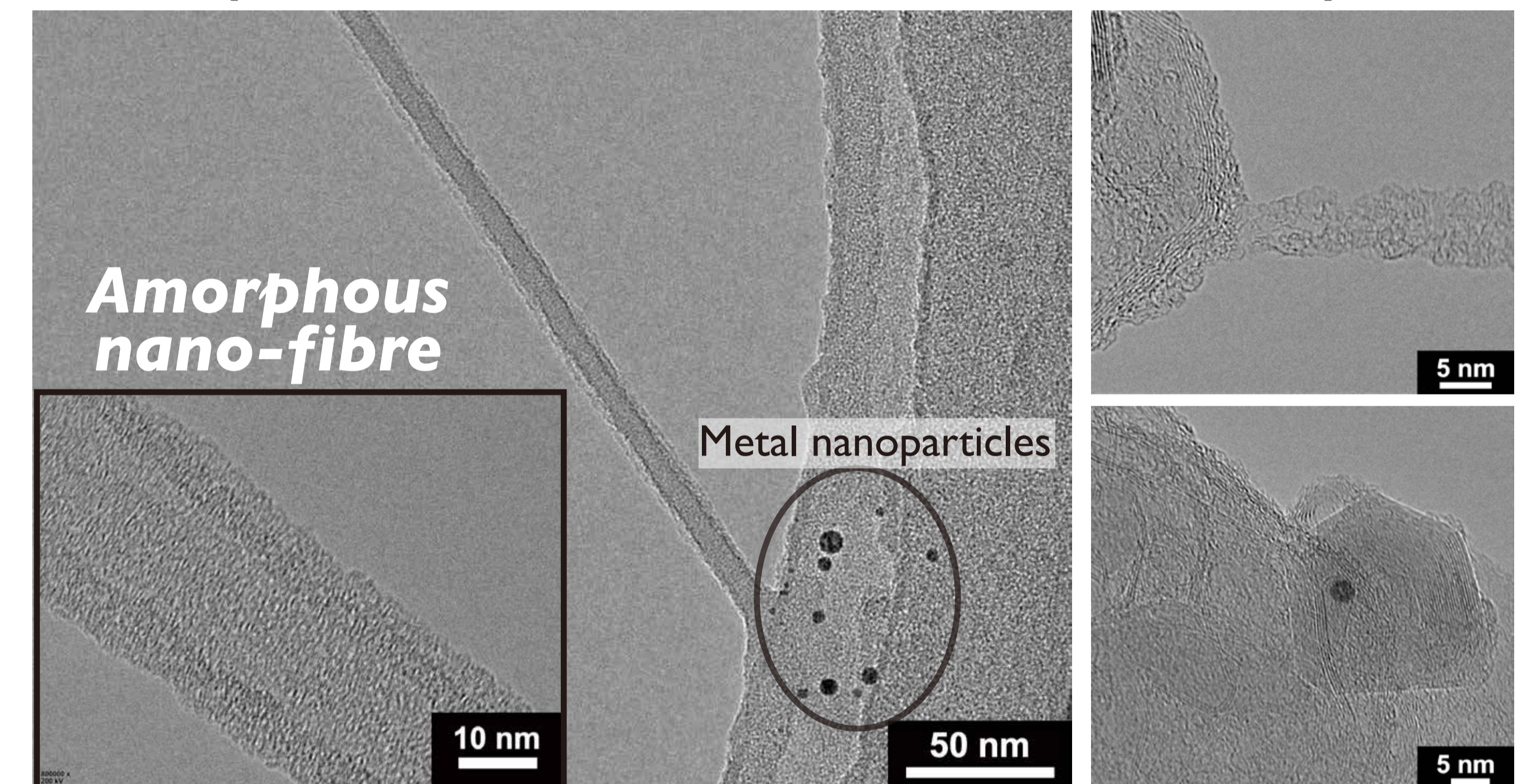
### Effect of H<sub>2</sub> concentration (BN 1 sccm, 70 kPa)



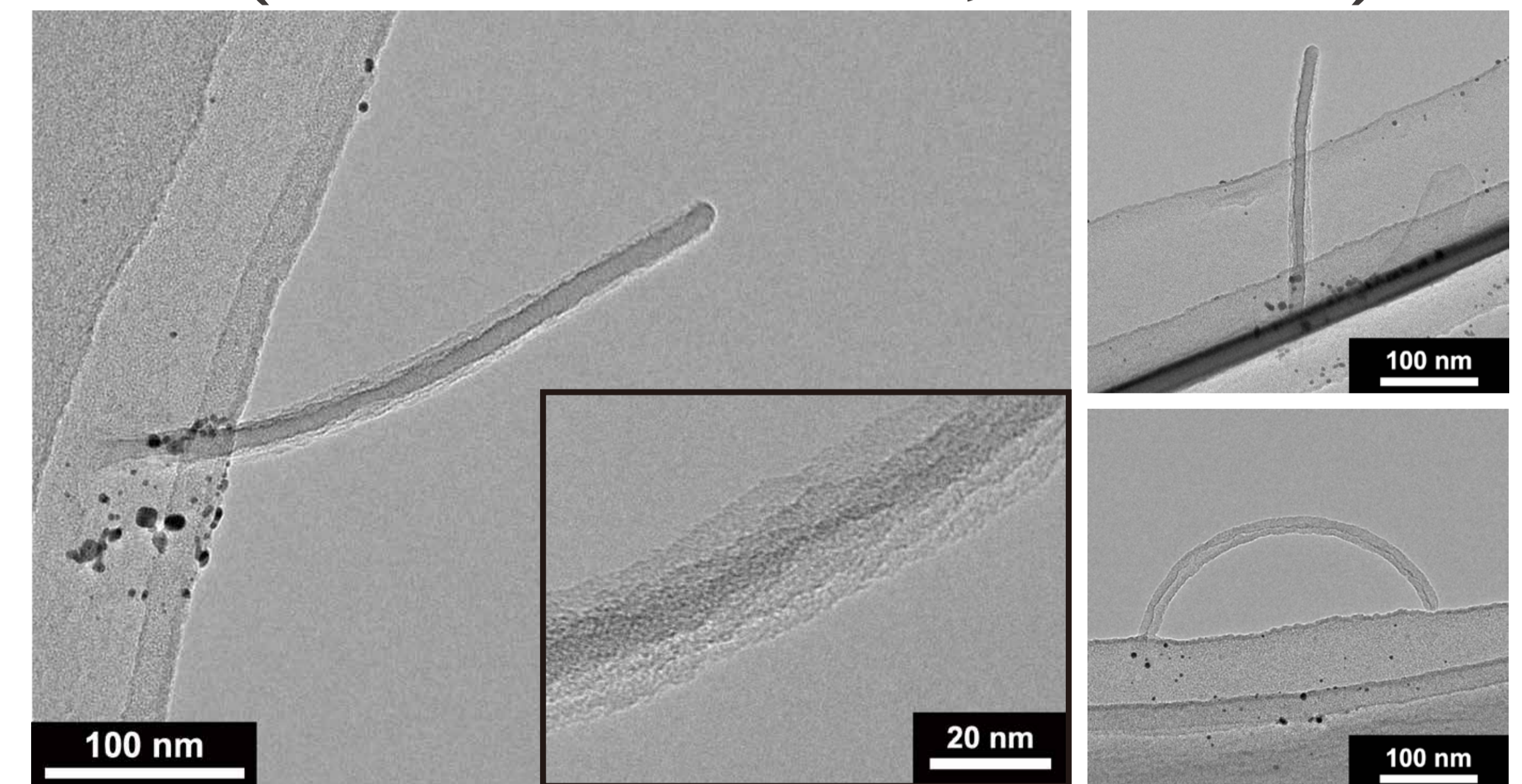
- Increasing H<sub>2</sub> concentration results in shorter nanostructures.  $\rightarrow$  suggesting H<sub>2</sub> acted as an etchant for boron nitride.

### TEM observation

#### H<sub>2</sub> 3% (at a BN flow rate of 1 sccm, under 70 kPa)



#### H<sub>2</sub> 10% (at a BN flow rate of 1 sccm, under 70 kPa)



- Amorphous phase nanofibres rather than crystalline nanotubes were obtained,** under both H<sub>2</sub> concentrations.

$\rightarrow$  To date, amorphous BN nanofibre synthesis has not been reported. It is possible that a **new material has been successfully synthesized** (elemental analysis by EELS will be performed soon).

$\rightarrow$  These could be utilized as **1D nanoscale thermal insulators**, given that the phonons responsible for heat transfer are absent in amorphous materials.

- Metal nanoparticles are concentrated at the root of the nanofibres**  $\rightarrow$  indicating that metal catalysts activated the growth of nanofibres.

**Summary** • Synthesis at a BN flow rate of 1 sccm under 70 kPa resulted in successful formation of 1D nanostructures.  
 • TEM observation revealed these are amorphous nanofibres.

## References

- [1] Y. Chen et al. *Appl. Phys. Lett.*, **84**, 2430 (2004) [2] M. B. Jalubinek et al. *J. Mater. Res.*, **37**, 4403 (2022) [3] R. Arenal et al. *Nanotechnology*, **22**, 265704 (2011) [4] N. G. Chopra and A. Zettl. *Sol. St. Commun.*, **105**, 297 (1998) [5] T. Nishihara et al. *Nat. Commun.*, **9**, 3144 (2018) [6] T. Nishihara et al. *Nanophotonics*, **11**, 1011 (2022) [7] R. S. Jones et al. *Nanoscale Adv.*, **2**, 4996 (2020) [8] T. A. Abdullah et al. *Mater. Res. Express*, **10**, 122005 (2023) [9] A. Loiseau et al. *Phys. Rev. Lett.*, **76**, 4737 (1996) [10] A. Loiseau et al. *Carbon*, **36**, 743 (1998) [11] D. Golberg et al. *Chem. Phys. Lett.*, **279**, 191 (1997) [12] M. Xie et al. *J. Phys. Chem. C*, **114**, 16236 (2010) [13] S. Chatterjee et al. *Chem. Mater.*, **24**, 2872 (2012) [14] M. J. Kim et al. *Nano Lett.*, **8**, 3298 (2008)

