



HAL
open science

Transparent electrodes based on GaAs/metal subwavelength gratings for VCSEL applications

Natan Monvoisin, Weronika Glowadzka, Franck Carcenac, Aurélie Lecestre, Benjamin Reig, Stéphane Calvez, Antoine Monmayrant, Olivier Gauthier-Lafaye, Tomasz Czyszanowski, Guilhem Almuneau

► To cite this version:

Natan Monvoisin, Weronika Glowadzka, Franck Carcenac, Aurélie Lecestre, Benjamin Reig, et al.. Transparent electrodes based on GaAs/metal subwavelength gratings for VCSEL applications. VCSEL Day 2023, Sep 2023, Turin (IT), Italy. hal-04768581

HAL Id: hal-04768581

<https://laas.hal.science/hal-04768581v1>

Submitted on 12 Nov 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Public Domain

Transparent electrodes based on GaAs/metal subwavelength gratings for VCSEL applications

N. Monvoisin¹, W. Glowadzka², F. Carcenac¹, A. Lecestre¹, B. Reig¹, S. Calvez¹, A. Monmayrant¹, O. Gauthier-Lafaye¹, T. Czystanowski², G. Almuneau¹

1: LAAS-CNRS, France, 2: Łódź University of Technology, Poland

Context

- Standard oxide-confined VCSEL with annular top-electrode geometry leads to poor injection uniformity
 - Strong interest for **efficient uniform electrical injection** whatever the emission window diameter and shape
 - Need for a **transparent electrode** scalable in size with **high transparency** with fixed **light polarization** and **good electrical conductivity**
 - Transparent conductive electrodes (TCE) already proposed/used on VCSEL : Indium Tin Oxide (ITO), silver nanostructured materials and graphene films
- => Limitations of electrical performances (compared to metal electrodes) and scarcity of In resources.

Requirements for high performances TCE

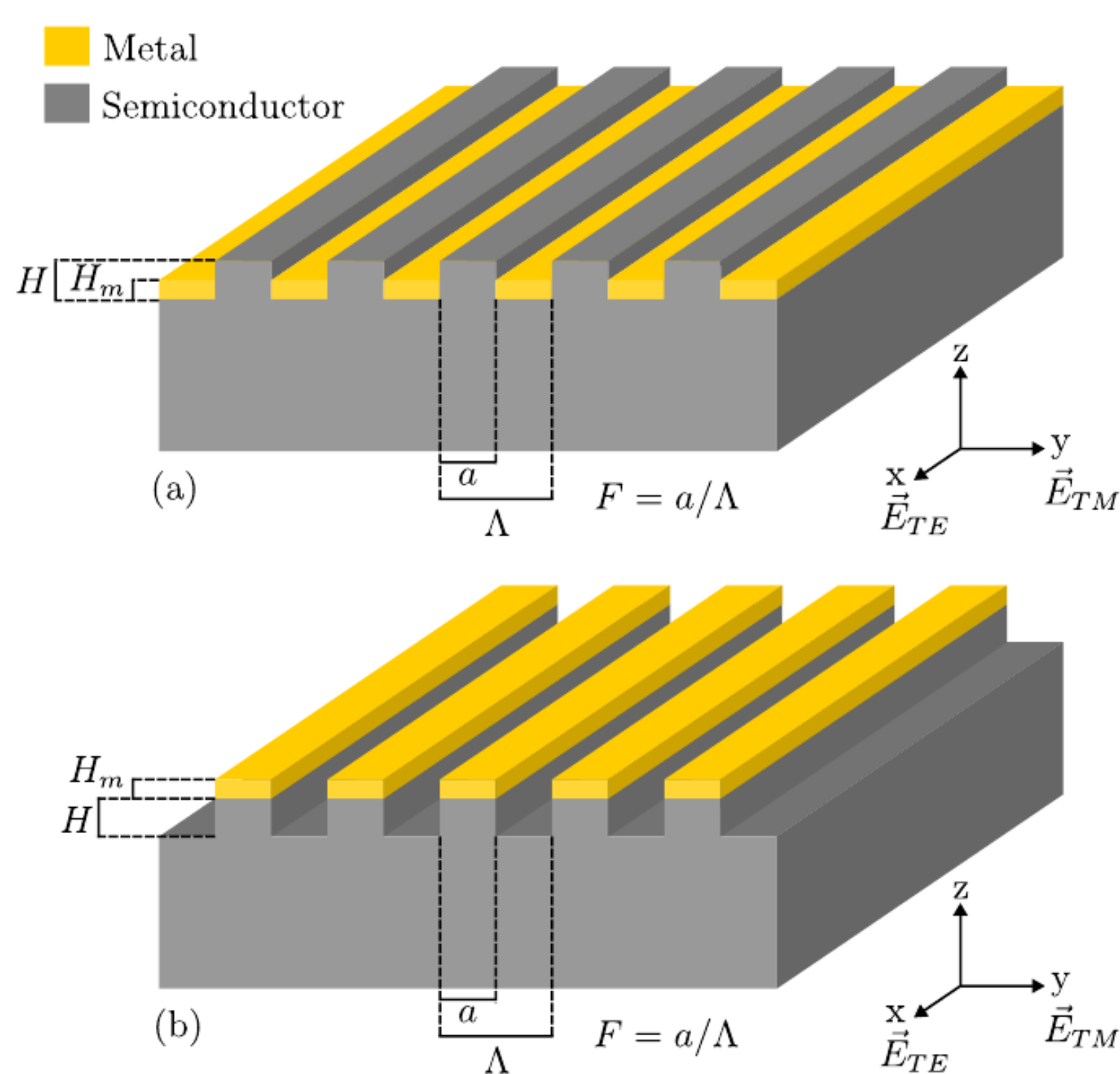
- Optical transparency as nearest as possible to 100%
- Electrical resistance as low as $1 \Omega/\square$
- Scalable to device size/geometry
- Compatible with standard VCSEL fabrication process

Methods

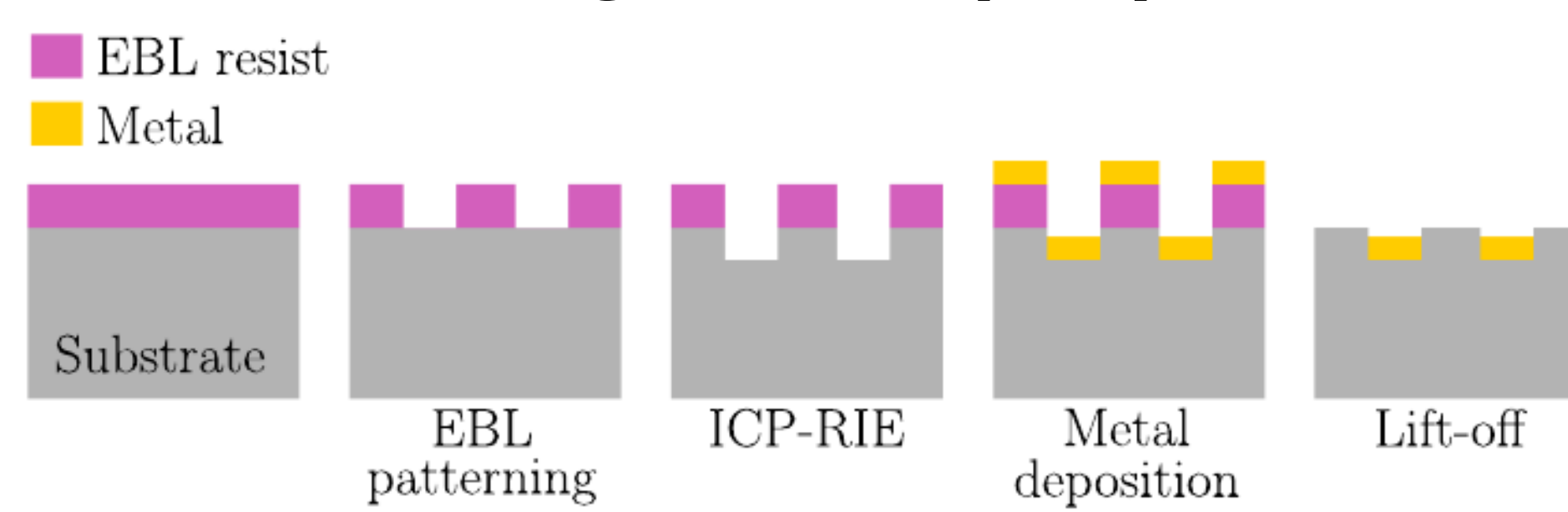
- Semiconductor-metal deep-subwavelength grating (SMDSG)**
- New TCE concept** proposed by Technical Univ. Lodz [1]
- Demonstrations in mid-infrared spectral window [2]
- This work is the **first experimental demonstration** of SMDSG in **near-infrared range** and on **GaAs platform**

[1] T. Czystanowski, Adam K. Sokóła, et al. Optics Express 28.19 (Sept. 2020), p. 28383.
[2] L.Y.M. Tobing, Michał Wasiak, et al. Nanophotonics 10.15 (Nov. 2021), pp. 38233830.

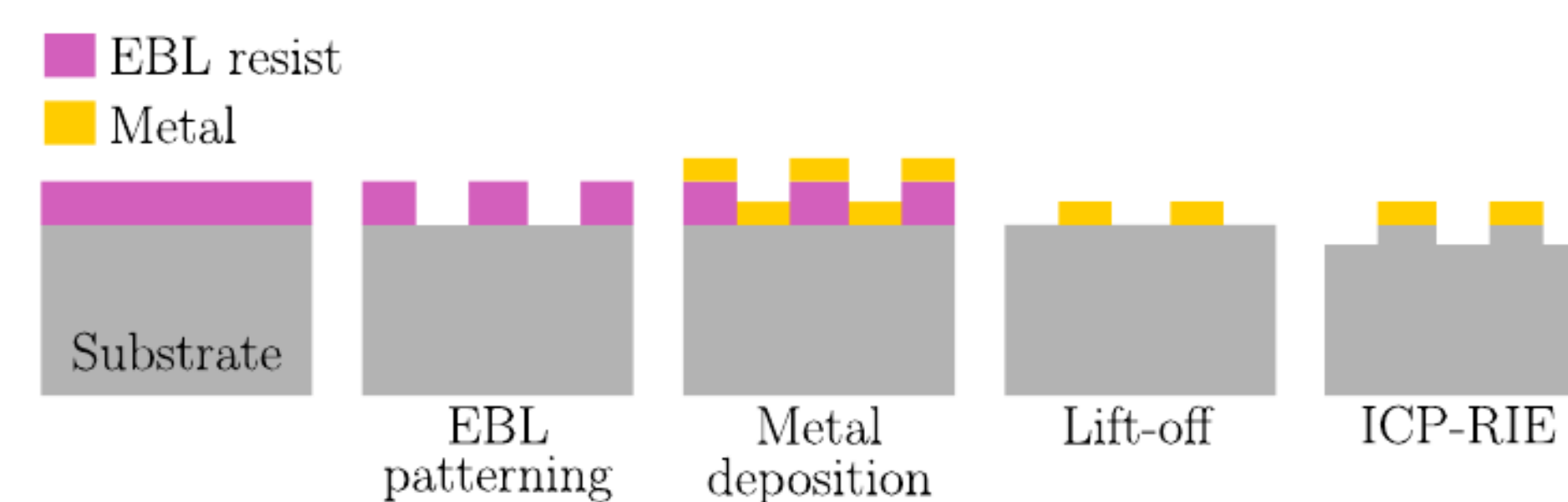
Design and nanofabrication



« Bottom » configuration (TE polarization)

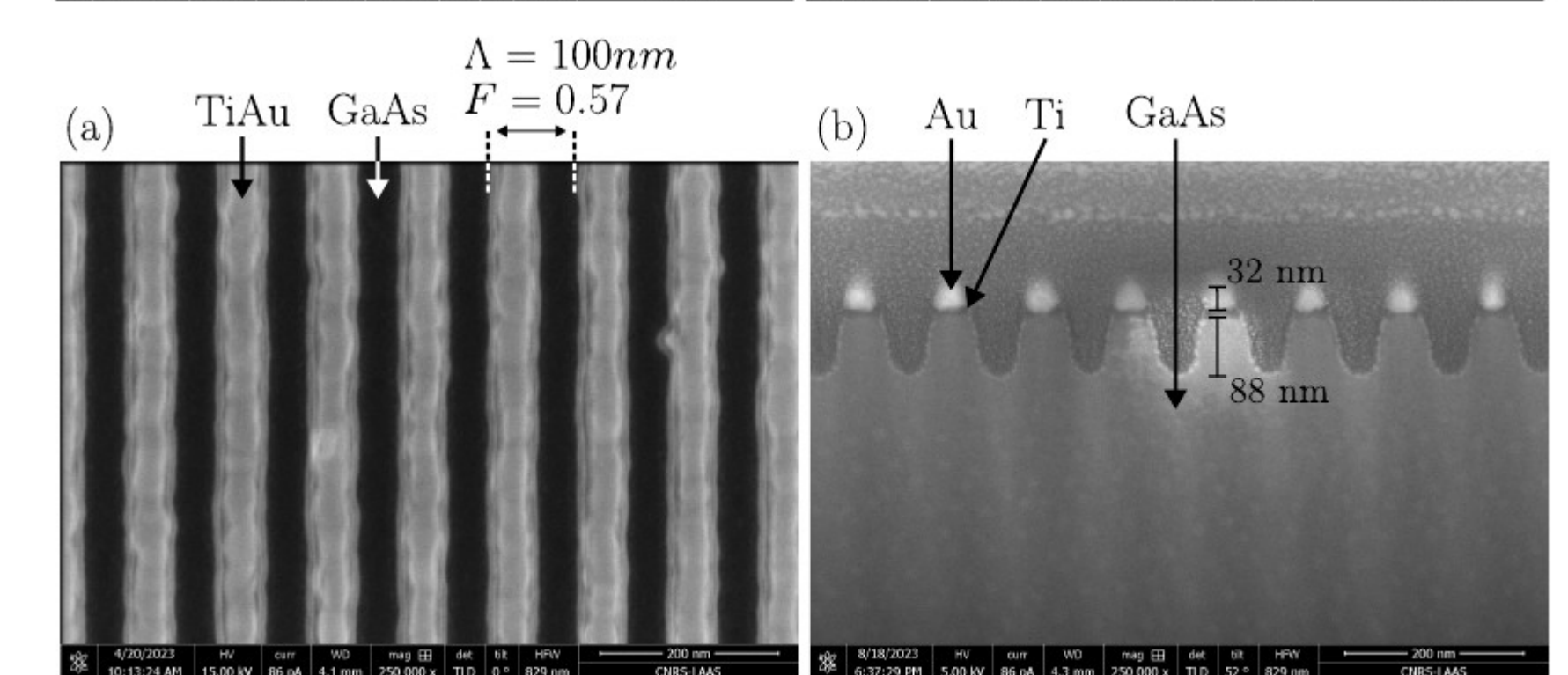
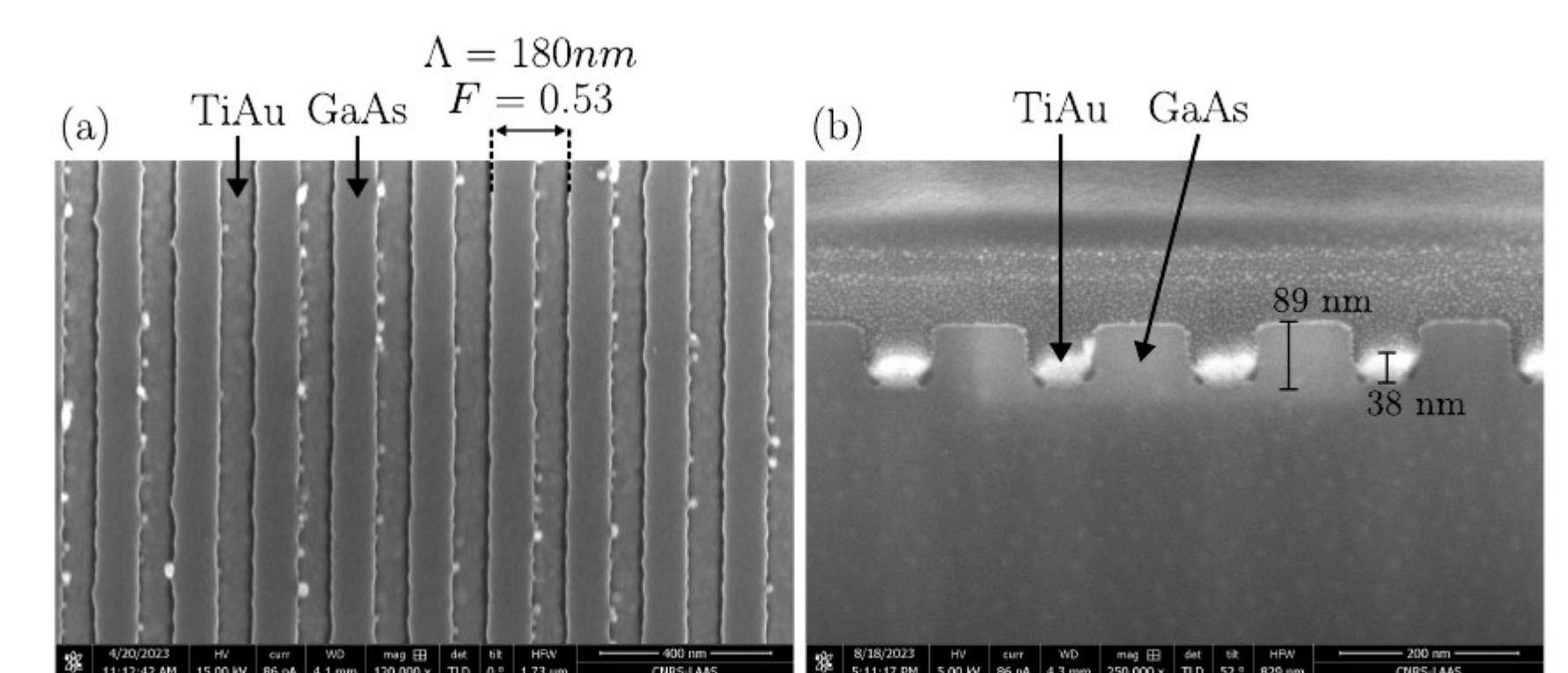


« Top » configuration (TM polarization)



- Two configurations for TE and TM light polarization transmission
- Optical impedance matching with no impact on electrical properties
- Grating period : $\Lambda = 0,15-0,25 * \lambda$

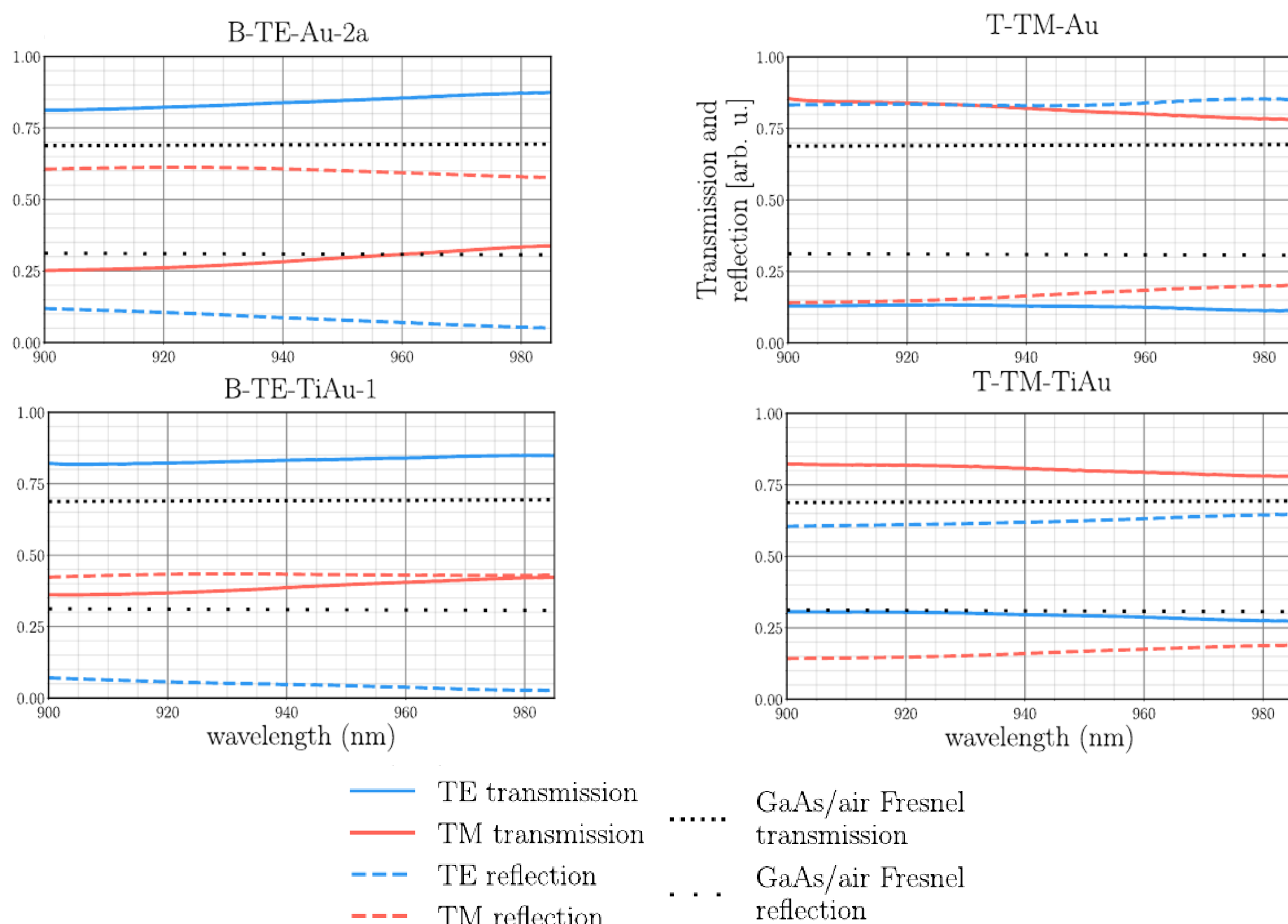
- Self-aligned process based on e-beam lithography
- Technological bottlenecks : 50-nm-wide metal line lift-off and controlled ICP etch depth



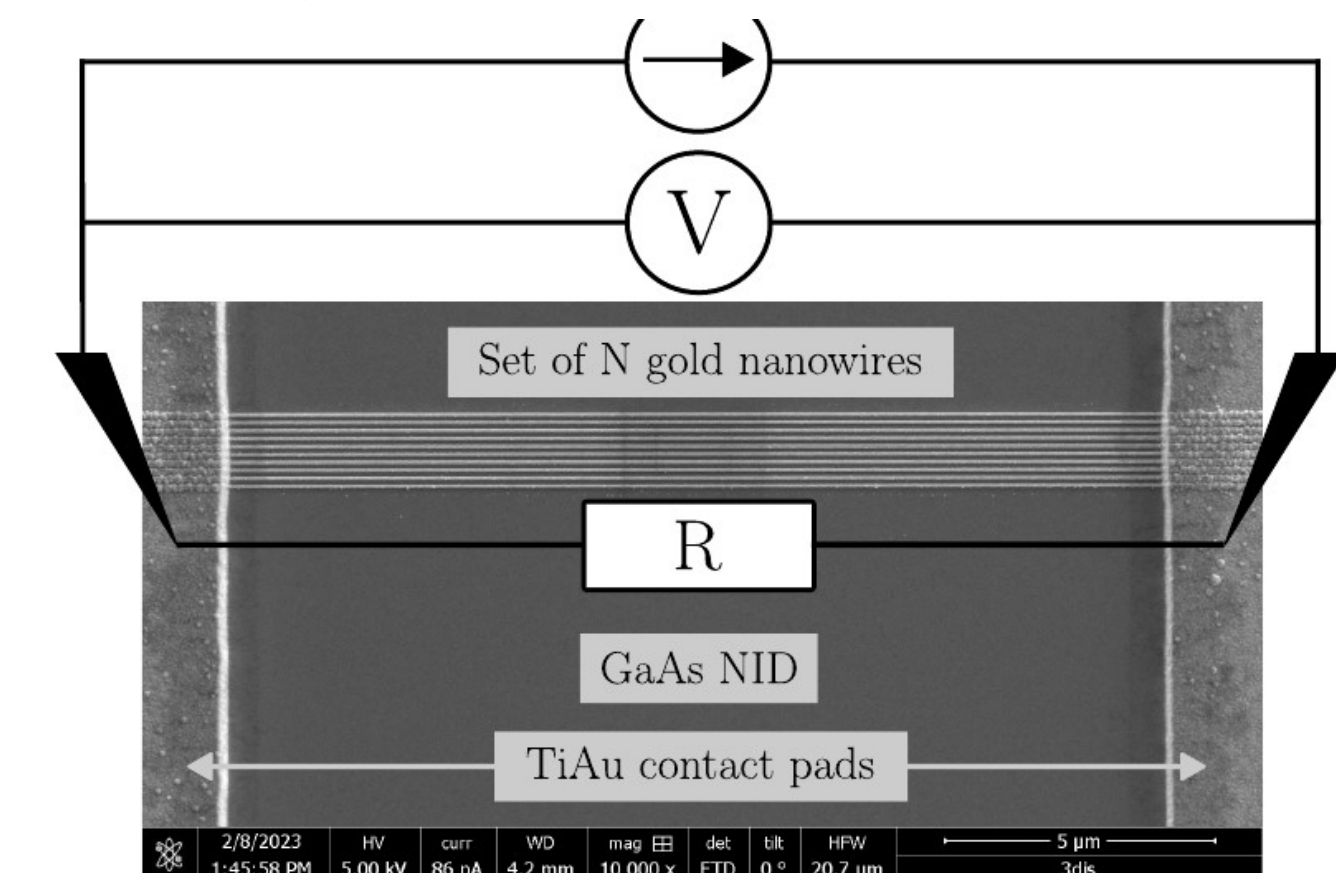
| Structure | | Λ (nm) | F | H (nm) | H_{Au} (nm) | H_{Ti} (nm) | Transmission |
|-------------|----------|----------------|-----------------|------------|---------------|---------------|--------------|
| B-TE-TiAu-1 | Theory | 180 | 0.6 | 85 | 50 | 5 | 92 % (TE) |
| | Measured | 180 | 0.53 ± 0.01 | 89 ± 6 | 33 ± 5 | 5 ± 1 | 82 % (TE) |
| T-TM-TiAu | Theory | 100 | 0.5 | 80 | 50 | 5 | 83 % (TM) |
| | Measured | 100 | 0.57 ± 0.01 | 88 ± 6 | 27 ± 4 | 5 ± 1 | 81 % (TM) |

Optical and electrical characterizations

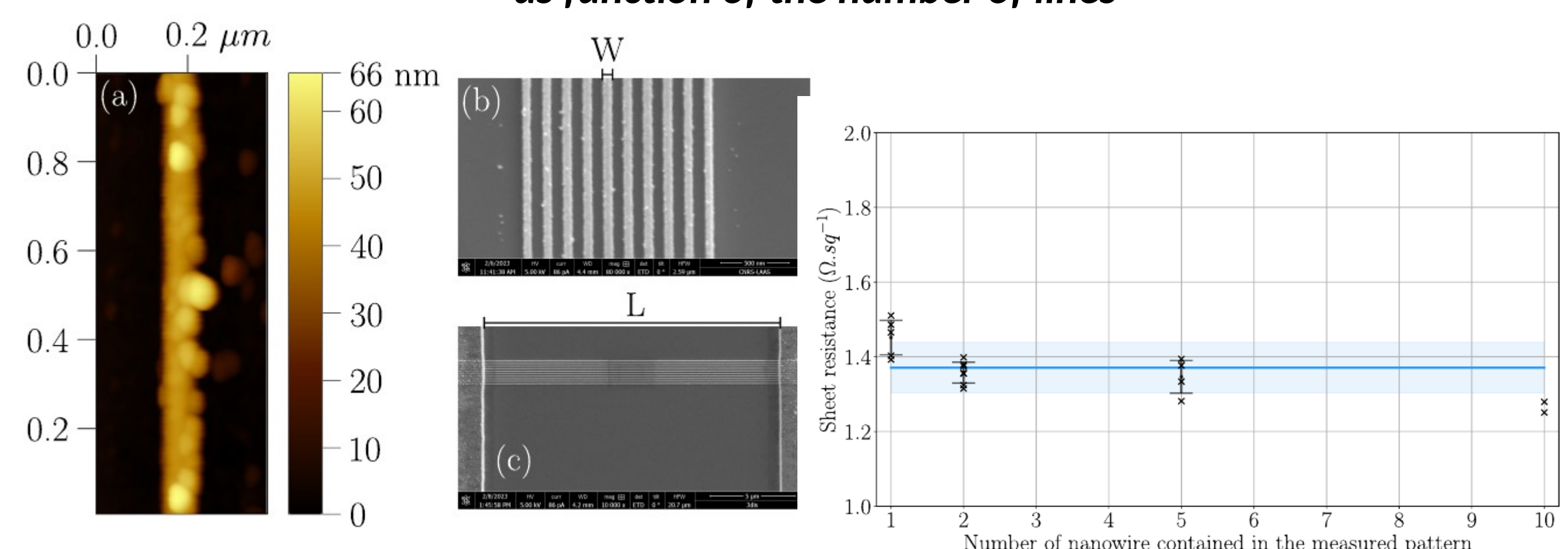
Experimental spectroscopy measurements of polarized transmission and reflection of fabricated SMDSG



Schematic of the two-probes measurement of nanowire set resistance



AFM and SEM images of nanowires and sheet resistance measurements as function of the number of lines



Acknowledgments: - RENATECH (French Network of Technology Platforms) at LAAS-CNRS
- Project TRAVEL funded by an M-ERA.NET grant from the Agence Nationale de la Recherche (ANR-20-MERA-0002)