**CEITEC Nano user process #2**

# Levitating antenna on glass for spin wave exitation and detection

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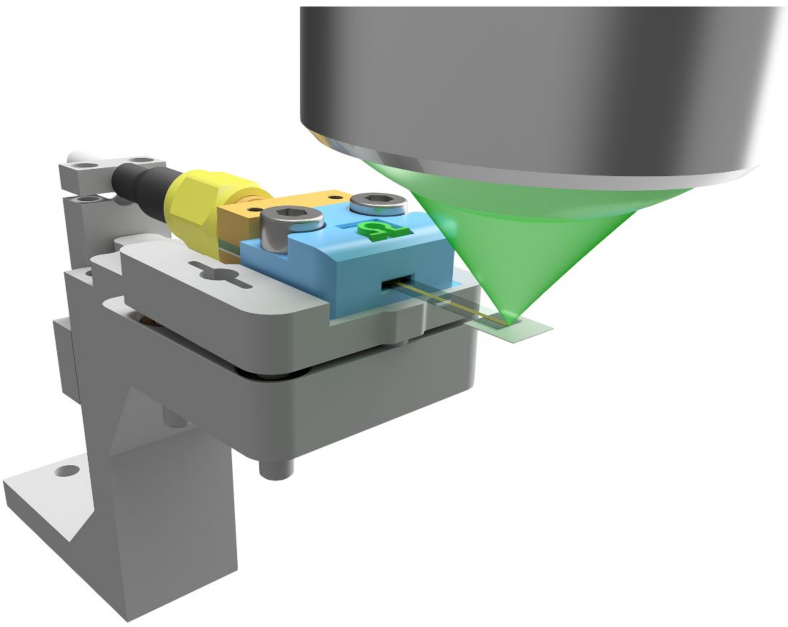
## Introduction

This document describes the fabrication of reusable and positionable microwave antenna on glass suitable for spin-wave excitation and detection. Nowadays spectroscopic techniques for the investigation of magnetization dynamics in micro and nanostructures typically use microwave antennas directly fabricated on top of the sample by electron-beam lithography (EBL). However, this approach requires often multistep EBL processes and special antenna for each structure. In contrary our approach is reusable, and antenna can be landed on multiple structures on multiple samples. Since we use flexible transparent glass as the antenna substrate, optical spectroscopy techniques like microfocused Brillouin-light-scattering microscopy (μBLS), time-resolved magneto-optical Kerr-effect measurements, or optically detected magnetic resonance measurements can be carried out at visible laser wavelengths.



*Levitating antenna device with excitation part fabricated on a glass cantilever landed on a sample with magnetic nanostructures. Example of Brillouin light scattering experiment.*

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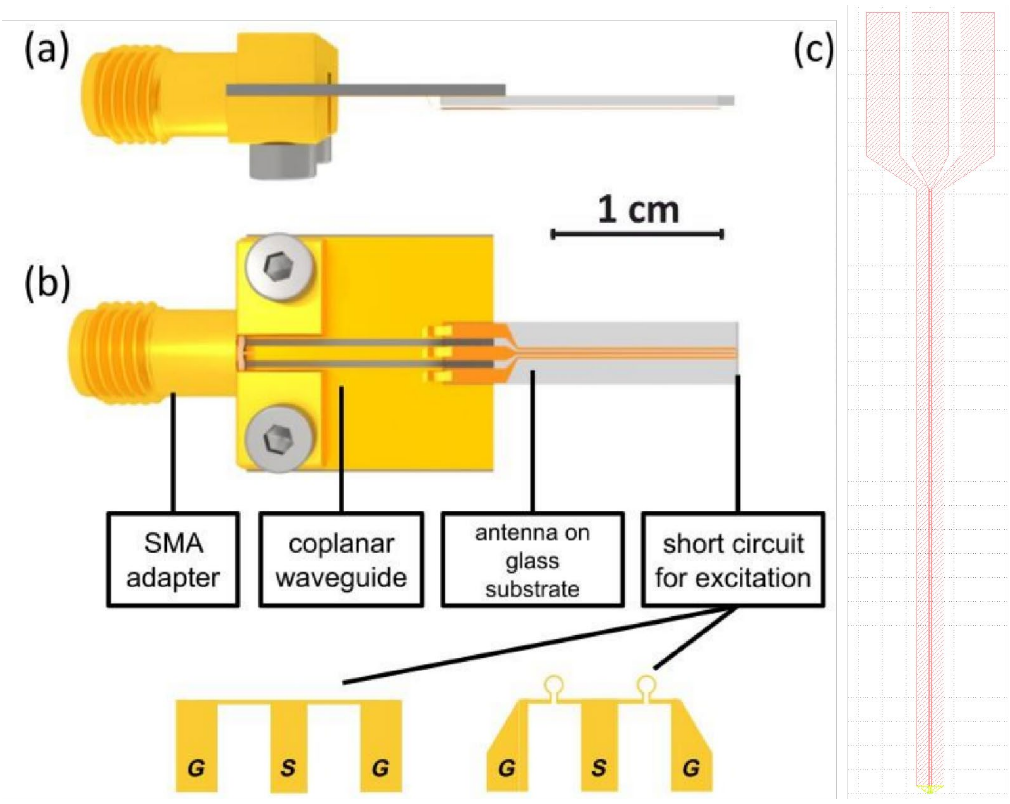
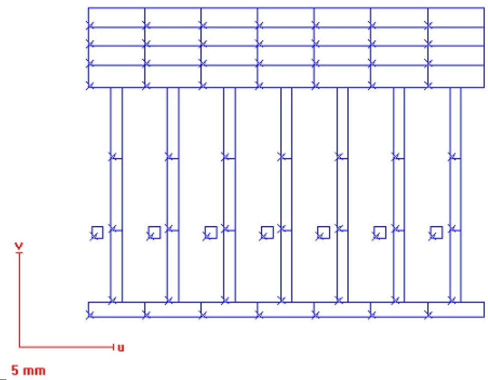
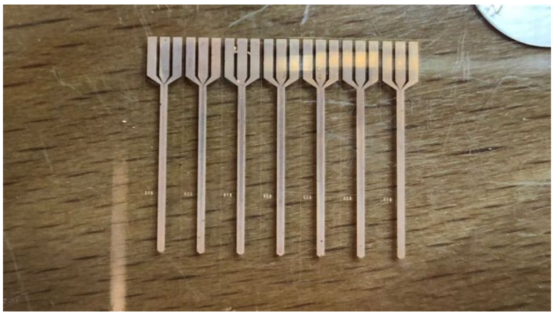
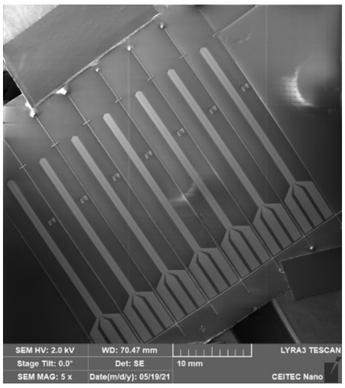
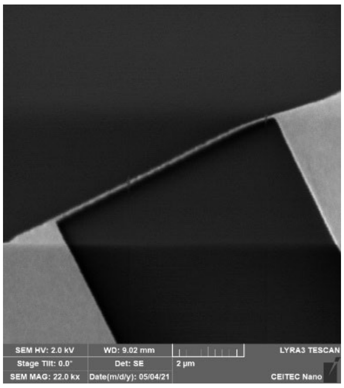
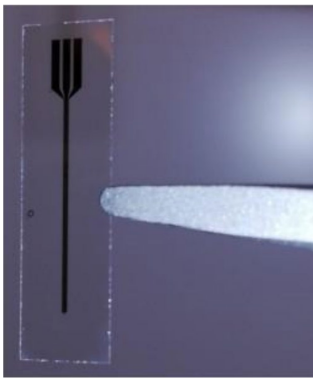
## Antenna design and description

The process was tested for fabrication of 7 antennas on glass coverslips with dimensions of (24 × 60) mm² and thickness #0, corresponding to (80 – 130) µm. The fabrication process is multi-step. In the first step, the EBL exposure of the design is executed. In the second step, the deposition of Ti/Cu/Au stack is done followed by lift-off process. In the third step, the glass is sliced with respect to the individual antennas and glued to the printed circuit board. In the fourth step, the antenna is electrically connected to the circuit board by wirebonding. Finally, the antenna is completed by soldering the SMA connector.




*Panel (a) side view and panel (b) top view of the completed antenna with designation of its components. Reprinted from [Hache20]. (c) GDS design of the antenna for EBL.*

## Process outline

| STEP | PROCESS | Detail | Image from fabrication |
|---|---|---|---|
| 1–10 | **Preparation and electron beam lithography** | Typical layout of (650 × 200) µm² working areas for electron lithography |  |
| 11–13 | **Deposition and lift-off process** | (24 × 60) mm² glass coverslip with 7 antennas |  |
| 14 | **SEM inspection** | SEM images – overview of whole glass and detail of the excitation stripline |   |
| 15– | **Slicing** | Single atenna after slicing |  |

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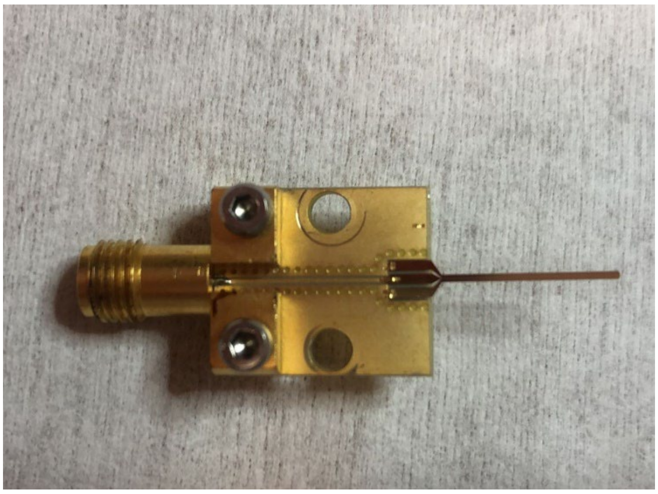
|---|---|---|---|
| 18–21 | Sticking, wirebonding, soldering | Final device |  |

## Fabrication process

### Substrate selection

As a substrate we recommended to use glass coverslips for optical microscopes with dimensions of (24 × 60) mm² and thickness #0. This solution is cheap and provides enough flexibility of glass cantilever during landing to the sample.

### Lithography

| STEP | PROCESS | |
|---|---|---|
| 1 | Substrate cleaning | 5 minutes ultrasound in acetone (green glass)<br>5 minutes ultrasound in IPA (green glass)<br>Drying by compressed nitrogen |
| 2 | Substrate pretreatment | HMDS (HexaMethylDiSilazane) athmosphere for better resist adhesion (SUSS-WETBENCH)<br>110°C, 2 cycles |
| 3 | Spin coating of resist | PMMA resist AR-P 672.08 (SUSS-WETBENCH)<br>3000 rpm ~ 1 μm thickness |
| 4 | Softbake | 150°C for 90s hot plate |
| 5 | Spin coating of conductive layer | PMMA Electra 92 AR-PC 5090.02 (SUSS-WETBENCH)<br>4000 rpm |
| 6 | Softbake | 100°C for 90s hot plate |
| 7 | Electron exposure | 20 kV; 10.5 nA; write field (650 × 200) μm² (RAITH)<br>Area dose 200 μC, step size 50 nm<br>For thinner stripe lines (~100 nm) we use 10 nm step size and area dose 135 μC |

| | | |
|---|---|---|
| | | For auxiliary cutting lines we use Fix beam moving stage approach (FBMS) |
| 8 | **Water rinsing and drying** | 20 s water rinsing to remove electra<br>Drying by compressed nitrogen |
| 9 | **Development** | 120 s in MIBK AR 600-56 (green glass)<br>30 s in IPA (stopper) (green glass) |
| 10 | **Optical inspection** | Using optical microscope ZEISS-A2<br>To check the exposure and development process |
| 11 | **RIE etching** | 15 s the recipe for PMMA etching (RIE-FLUORINE)<br>50 W, 20 sccm $O_2$<br>to remove resist residues in exposed areas |
| 12 | **Deposition by e-beam evaporation** | Ti(5 nm)/Cu(500 nm)/Au(20 nm) (EVAPORATOR)<br>For thinner stripe lines we use 180 nm of Cu for better aspect ratio |
| 13 | **Lift-off process** | 2 hours or more in acetone bath (red glass)<br>5 s of ultrasound<br>30 s in IPA (stopper) (red glass) |
| 14 | **Optical/SEM inspection** | For optical inspection we use optical microscope ZEISS-A2<br>For SEM inspection we use SEM Tescan LYRA3<br>Low electron current and voltage are needed to prevent sample charging |
| - | **RIE etching of glass** | *Optional step for etching of the surrounding glass to be able to have better excitation efficiency due to closer proximity to the sample*<br>*$CHF_3$ 50 sccm, Ar 30 sccm, $O_2$ 3 sccm, 200 W, DC Bias 250 V, etching rate ca. 7.27 Å/s* |

## Packaging & testing

| | | |
|---|---|---|
| 15 | **Preparation for slicing** | Arbitrary PMMA resist (SUSS-WETBENCH) as protective layer on top of antennas<br>150°C for 90 s hot plate<br>Placement of the protective foil to the bottom side of the glass |
| 16 | **Slicing of the glass** | Diamond saw dicer (DICING-SAW)<br>To have antennas on individual glass pieces |
| 17 | **Removing of the foil and protecting resist** | Removing the foil by hot air gun from soldering station<br>Acetone bath to remove PMMA resist (red glass) |
| 18 | **Sticking to the PCB** | Using standard cyanocrylate glue |
| 19 | **Wire bonding** | Wirebonding antenna pads to the PCB using 25 μm thick and 250 μm wide ribbon wires (WIRE-BONDER) |

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|---|---|---|
| | | Stage temperature 120 °C<br>Program 68 Marek_Ribbon (1st bond US 1900 time 200 ms force 650 mN, 2nd bond US 2000 time 300 ms, force 1400 mN) |
| 20 | **Soldering the SMA connector** | Using $Sn_{63}Pb_{37}$ solder paste QY-309A and hot air gun from soldering station |
| 21 | **Measuring of the resistance** | Final check by measuring the resistance of completed antenna device, typical resistance for 100-nm-wide antenna is in the range of 5-50 ohm, depending on its exact shape. |

# References

## Related publications

[Hache20] HACHE, T., et al. Freestanding positionable microwave-antenna device for magneto-optical spectroscopy experiments. *Physical Review Applied*, 2020, 13.5: 054009.

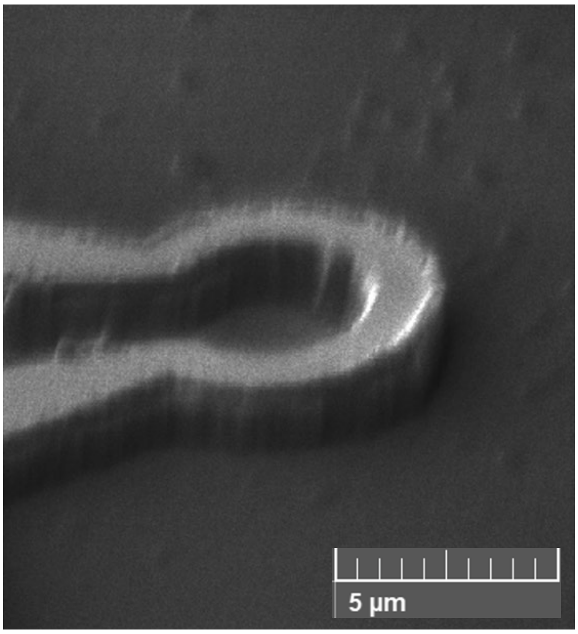
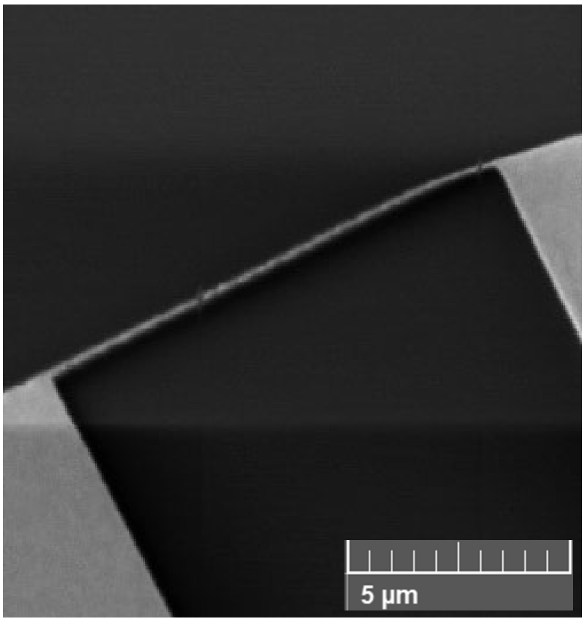
## Used chemicals

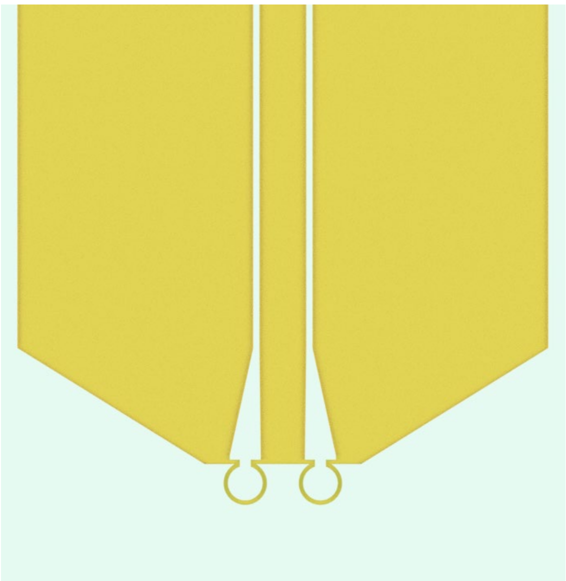
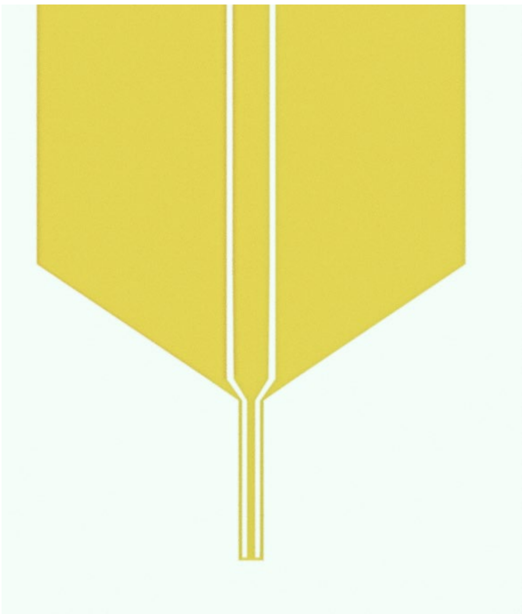
- PMMA resist AR-P 672.08 – https://www.allresist.com/portfolio-item/e-beam-resist-ar-p-672-series/
- PMMA Electra 92 AR-PC 5090.02 – https://www.allresist.com/portfolio-item/protective-coating-ar-pc-5090-02-electra-92/
- MIBK AR 600-56 - https://www.allresist.com/portfolio-item/developer-ar-600-56/

## Equipment (CEITEC Nano links)

- SUSS-WETBENCH – https://nano.ceitec.cz/lithographic-wetbench-for-coating-suss-wetbench/
- RAITH – https://nano.ceitec.cz/e-beam-writer-raith150-two-raith/
- EVAPORATOR – https://nano.ceitec.cz/electron-beam-evaporator-bestec-evaporator/
- ZEISS-A2 microscope – https://nano.ceitec.cz/optical-microscope-zeiss-axio-imager-a2-zeiss-a2/
- RIE-FLUORINE – https://nano.ceitec.cz/rie-by-f-chemistry-and-pecvd-of-hard-c-based-films-oxford-instruments-plasma-technology-plasmapro-80-rie-fluorine/
- LYRA – https://nano.ceitec.cz/focused-ion-beam-scanning-electron-microscope-tescan-lyra3-lyra/
- DICING SAW – https://nano.ceitec.cz/semiautomatic-dicing-saw-esec-8003-dicing-saw/
- WIREBONDER – https://nano.ceitec.cz/wire-bonder-tpt-hb-16-wire-bonder/

## Gallery of images

| | |
|---|---|
|  |  |
| Side view at the antenna after RIE Etching | 100-nm-wide stripline antenna |

| | |
|---|---|
|  |  |
| Omega-type end antenna | Coplanar waveguide type antenna |

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