



# Extending HELIPORT for Clean Room Process Tracking at HZDR

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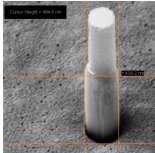
*HELIPORT Workshop 2023*

June 13, 2023

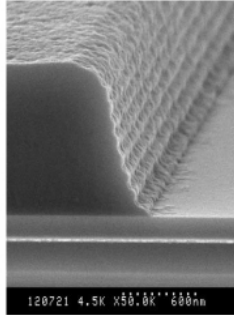
- Sample processing in Cleanroom at HZDR
- Prototype Implementation (HELIPORT)
- Outlook: Future steps and ideas

# Nanofabrication in Cleanroom at HZDR

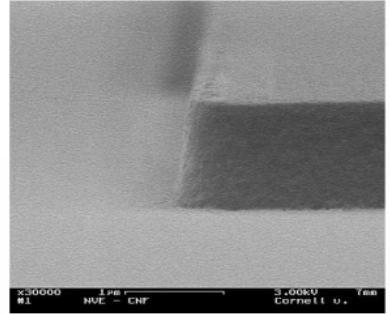
- Similar to microchip production
- Custom processes
- Written plans
- Things can break
- Equipment for each step



Photonic device [4]



Shipley 1813 no PEB



Shipley 1813 115°C 60 sec. PEB

post-exposure bake

# Process logs

- Sample passed around together with Paper
- Entries for each step
- Current step is first one without signature
- Project, sample series, sample number
- Manually transferred to wiki

Post-exposure bake

- Bake at 120°C 2 min for resist reflow

20.04.21 CF

Oxide etching

- Bottled BOE (buffered oxide etch) - 90nm/min
- Measured thickness = 102 nm
- Etch time = 90 sec
- All oxide is etched when backside of wafer is hydrophobic
- Rinse heavily in DI water at chemistry bench

1m30s

Lift-off

- Acetone 1, ultrasonic bath 5 minutes
- Acetone 2, ultrasonic bath 5 minutes
- Ethanol rinse, 1 minute
- DI water wash
- Spin dry in [[SPS Spin Dryer]]
- Slowly accelerate from 0 to 3000
- Dry at 3000 rpm for 1 minute
- Visually confirm the transfer of etch mask to the substrate

12.5.21 G.S

12.5.21 G.S

Spin negative resist for UV Lithography - V2

- spin negative photoresist [[Cleanroom Chemicals maN1400/maN1420]] at 2000rpm for 30s
- Baking at 100°C for 2 minutes on hotplate

12.05/

UV Lithography

- Exposure of NCP Mask 2 - Contact pads and alignment system
- Vacuum of Hart contact for 10 seconds
- Lamp intensity = 20 mW/cm² / 295 W

Soft contact 10s

Development

- Developed in maD533s for 1m15s
- DI water rinse

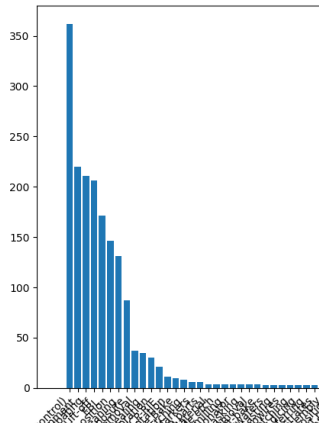
12.05.21 CF

post-exposure bake

# Automation is Difficult

Example: Find most common steps

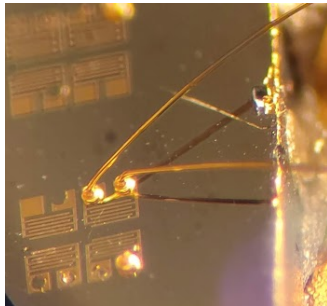
```
mappings = {  
    "substrate cleaning": "cleaning",  
    "sample cleaning": "cleaning",  
    "piranha cleaning": "cleaning",  
    "piranha sample cleaning": "cleaning",  
    "development of pmma resist": "development",  
    "development of hsq resist": "development",  
    "developing": "development",  
    "ebl exposure": "ebl",  
    "electron beam lithography": "ebl",  
    "fabrication of top gates": "ebl",  
    "patterning of nanowires": "ebl",  
    "patterning of s/d/g contact pads": "ebl",  
    "uv exposure": "uv lithography",  
    "exposure": "uv lithography",  
    "uv light exposure": "uv lithography",  
    "photolithography": "uv lithography",  
    "liftoff": "lift off",  
}
```



Mapping titles and histogram of most common step types

# Automatic Information Processing

- Search
- Statistics
- Error detection scripts
- Show progress
- $\Rightarrow$  Paperless process tracking
- ELN based on MediaWiki [5]



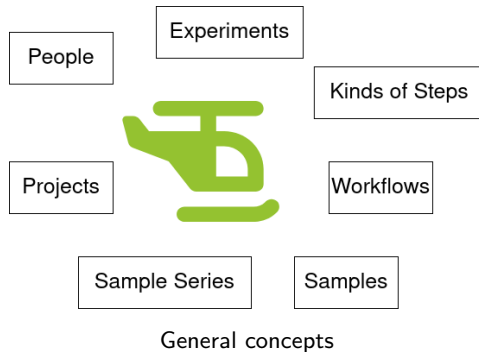
Gold Wirebonds



Piranha cleaning

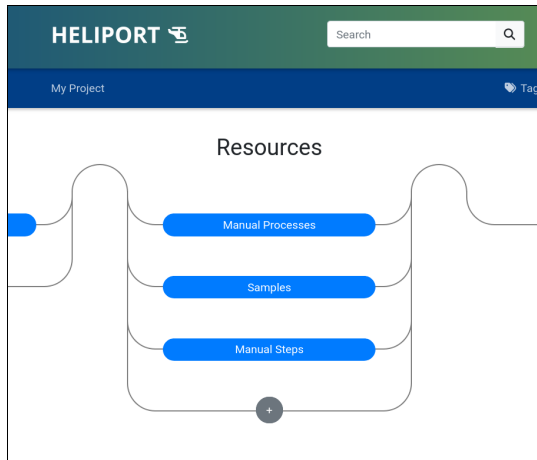
# Relation to HELIPORT

- HELIPORT is not for detailed experimental data
- A lot of high-level information relevant
- Use Digital Object concept in HELIPORT
- Interaction with other Systems



# Current State

- What is needed?
- How could it be achieved?
- Look through existing Processes
- Prototype



Project graph with Samples / Workflows



# Samples

- Workflows and samples go together
- Sample as entry point for taking actions
- Different actions possible based on context e.g. currently performing workflow
- Relation workflows and samples

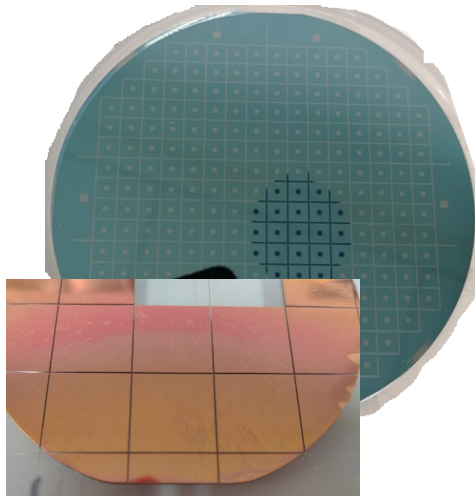
The screenshot shows the HELIPORT web interface. At the top is a dark green header with the 'HELIPORT' logo and a search bar. Below the header is a blue navigation bar with the breadcrumb 'Test Project > Samples > highly-doped Si 2021-2' and a 'Ta' icon. The main content area is titled 'Relation Properties (with autocomplete)' and includes a checkbox for 'advanced editing'. Below the title is a form with four rows, each with a label and a text input field:

Project	Nano-Contact Platform
Sample Series	highly-doped Si
Substrate Material	Si
Substrate orientation	1 0 0

## Sample Description

# Collections of Samples

- Step on collection = step on each sample
- Reduces management overhead
- Cutting can create collections



Wafers are cut

# Process History

- This is the main goal
- Who did what where and when?
- What plans / steps were performed?
- What were the parameters?
- What were the measured values?

highly-doped Si 2021-2

Name: Voigt, Martin (FWCC-D) - 141575 E-mail: m.voigt@hzdr.de Phone: 1234	Name: Fowley, Dr. Claran (FWO-F) - 6176 E-mail: c.fowley@hzdr.de Phone: 3253
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Project: Nano Contact Platform Sample Series: highly-doped Si Sample Number: 2021-2  
Substrate Material: Si Substrate orientation: 1 0 0 Substrate thickness: 525 µm  
Doping: Resistivity 1-5 mOhm.cm Dimensions: 100 mm

Toggle Future

Oxide etching

- Buffed BOE (buffered oxide etch) ~ 90min
- Measured thickness =  nm
- Etch time =  sec
- All oxide is etched when backside of wafer is hydrophobic
- Rinse heavily in DI water at chemistry bench
- Equipment used:

Done

Toggle Past

6. Post-exposure bake ✓ Fowley, Dr. Claran (FWO-F) - 6176 Jun 09, 23

- Bake at 120°C 2 min for resist reflow

5. Development ✓ Fowley, Dr. Claran (FWO-F) - 6176 Jun 09, 23

- Develop in [MF-319] for 45s
- DI water stopper
- Spin dry in [SPS Spin Dryer]
- 3000 rpm for 1 minute
- Equipment used: None

4. UV Lithography ✓ Fowley, Dr. Claran (FWO-F) - 6176 Jun 09, 23

- Exposure of NCP Mask 1 - Demarcation to define SiO<sub>2</sub> etching pattern
- Soft contact for 3 seconds
- Lamp intensity = 20 mW/cm<sup>2</sup> 324 W
- Equipment used: MAB

3. Spin positive photoresist for UV Lithography ✓ Fowley, Dr. Claran (FWO-F) - 6176 Jun 09, 23

## Process history

# Manual Workflows

- Typically linear sequence of steps
- Basic looping and branching (user selects alternative step)
- Sub Recipes
- Merge similar consecutive steps
- Workflow with all parameters specified (template → instance → execution)

Baking at 100 °C for 2 minutes on hotplate	
<b>UV Lithography</b>	
<ul style="list-style-type: none"><li>- Exposure of NCP Mask 2 - Contact pads and alignment system</li><li>- Vacuum of Hard contact for 10 seconds</li><li>- Lamp intensity = <u>20</u> mW/cm<sup>2</sup> / <u>295</u> W</li></ul>	
<b>Development</b>	
<ul style="list-style-type: none"><li>- Developed in maD533s for 1m15s</li><li>- DI water stopper</li><li>- Spin dry in [[SPS Spin Dryer]]</li><li>- Slowly accelerate from 0 to 3000</li><li>- Dry at 3000 rpm for 1 minute</li></ul>	
<b>Deposition</b>	
<ul style="list-style-type: none"><li>- Deposition 5nm Cr / 125nm Au</li><li>- Rates = <u>2</u> Ang/s, <u>5</u> Ang/s</li><li>- Thickness = <u>5</u> nm, <u>125</u> nm</li></ul>	
<b>Lift-off</b>	
<ul style="list-style-type: none"><li>- Acetone 1 in ultrasonic bath, 5 minutes</li><li>- Acetone 2 in ultrasonic bath, 5 minutes</li><li>- Ethanol rinse, 1 minute</li><li>- DI water wash</li><li>- Spin dry in [[SPS Spin Dryer]]</li><li>- Slowly accelerate from 0 to 3000</li></ul>	

Merged Deposition Steps

# The current Prototype - Implementation

- **HeliportObjectListView:**  
Typical heliport lists
  - **WorkflowsView**
  - **SamplesView**
  - **ManualActionsView**
- **WorkflowDetailView:**  
Workflow editing
- **ActionPerformView:**  
Select workflow for sample
- **SampleLogView:**  
Workflow execution and log
- **SampleMetadataView:**  
Show/Edit sample metadata


The screenshot displays the HELIPOINT web application. The header is green with the HELIPOINT logo, a search bar, and user information (mv141575). The main navigation bar is blue and shows 'Test Project > Manual Processes' along with icons for Tags, Project Timeline, Object Graph, and Project. The main content area is titled 'Processes' and contains a table with the following data:


ID	Name	Description	
2	CF NCP Fabrication 2021-2 Zahra 90nm	Si; 525µm; 100	<div><button>Add Tag</button><button>Open</button><button>Plan for</button><button>Edit</button><button>Delete</button></div>




Below the table is a section titled 'Add a new Process' with a form containing a 'Name' field and a 'Description' text area. An 'Add' button is located at the bottom left of this section.

Workflow List

# Metadata Export

**HELIPORT** 

Search 

 About  Docs  eilmiv ▾

## Landing Page



 Download

### Metadata Export:

Select Metadata Format

Datcite JSON

Datcite XML

JSON-LD

Turtle

RDF XML

N-Triples

Default Landing Page

Specific Landing Page

### Identifier

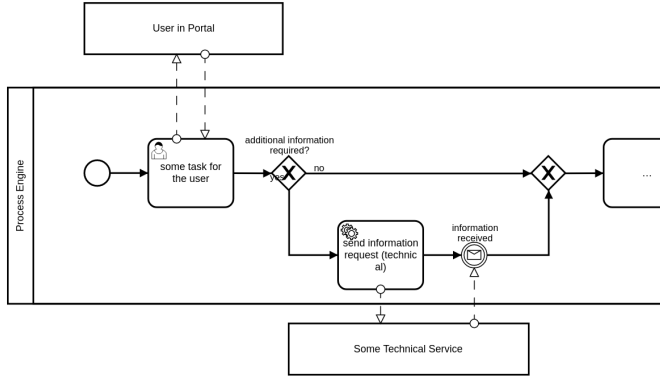
Identifier	<a href="https://z-rossendorf.de/object/51/">z-rossendorf.de/object/51/</a>
Namespace	flow

### Properties

label	CF NCP Fabrication 2021-2 Zahra 90nm	Not Public ▾
description	Si; 525µm; 100	Not Public ▾
Date Created	Mar 16, 2023	This attribute is always

# Metadata Standards - BPMN

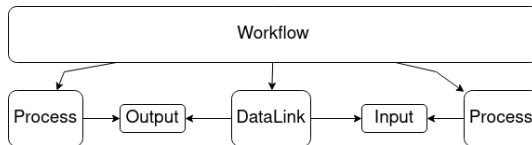
- Focus on modeling and notation
- Execution semantic
- Very expressive
- Workflow engines
  - Camunda [2]
  - python libraries [3]
- RDF ontology exists [1]



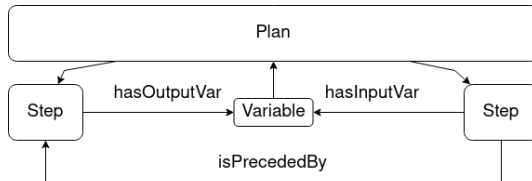
BPMN Example

# Metadata Standards - wf4ever / p-plan

- Workflow execution provenance
- Directed acyclic data flow graphs
- Subworkflows
- Specify order in p-plan



wfdesc structure



p-plan structure



## Manual workflows

- Generalize from physical steps
- Generally useful
- Enable using standard without knowing (workflow sets metadata)
- complement existing automatic workflows with manual steps

## Samples

- Generalize from cleanroom samples
- Generally useful
- Basic abstraction for integrating sample management systems

# References

- [1] Amina Annane, Nathalie Aussenac-Gilles, and Mouna Kamel. “BBO: BPMN 2.0 based ontology for business process representation”. In: *20th European Conference on Knowledge Management (ECKM 2019)*. Vol. 1. 2019, pp. 49–59.
- [2] *BPMN Examples*. CAMUNDA. URL: <https://camunda.com/bpmn/examples/>.
- [3] *BPMN-RPA*. PyPI. URL: <https://pypi.org/project/BPMN-RPA/>.
- [4] Michael Hollenbach et al. “Wafer-scale nanofabrication of telecom single-photon emitters in silicon”. In: *Nature Communications* 13.1 (2022), p. 7683.
- [5] *Semantic MediaWiki*. MediaWiki. URL: [https://www.semantic-mediawiki.org/wiki/Semantic\\_MediaWiki](https://www.semantic-mediawiki.org/wiki/Semantic_MediaWiki).