DRESDEN concept

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Extending HELIPORT for Clean Room Process Tracking at HZDR

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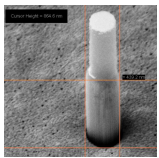
Structure

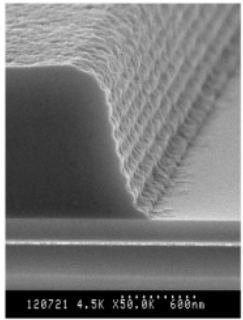
- Sample processing in Cleanroom at HZDR
- Prototype Implementation (HELIPORT)
- Outlook: Future steps and ideas

Nanofabrication in Cleanroom at HZDR

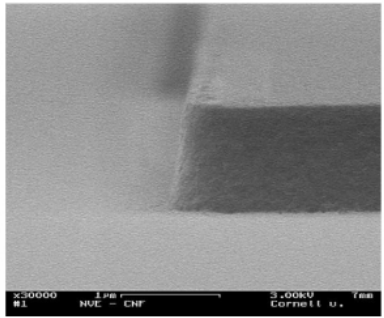
- Similar to microchip production
- Custom processes
- Written plans
- Things can break
- Equipment for each step



Photonic device [4]



Shipley 1813 no PEB

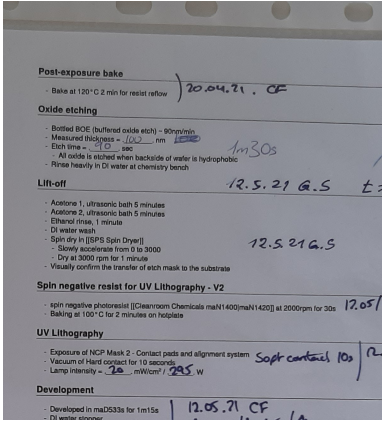


Shipley 1813 115°C 60 sec. PEB

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 = 100 nm
- Etch time = 60 sec — 1m30s
- All oxide is etched when backside of water is hydrophobic
- Rinse heavily in DI water at chemistry bench

Lift-off — 12.5.21 G.S

- 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]] — 12.5.21 G.S
  - Slowly accelerate from 0 to 3000
  - Dry at 3000 rpm for 1 minute
- Visually confirm the transfer of etch mask to the substrate

Spin negative resist for UV Lithography - V2

- spin negative photoresist [[Cleanroom Chemicals maN1400|maN1420]] at 2000rpm for 30s — 12.05
- Baking at 100°C for 2 minutes on hotplate

UV Lithography

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

Development

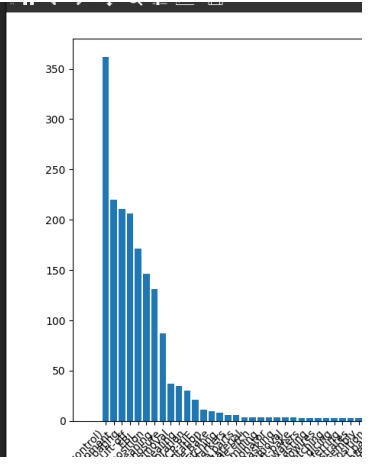
- Developed in maD533s for 1m15s — 12.05.21 CF
- DI water stopper

post-exposure bake

Automation is Difficult

Example: Find most common steps

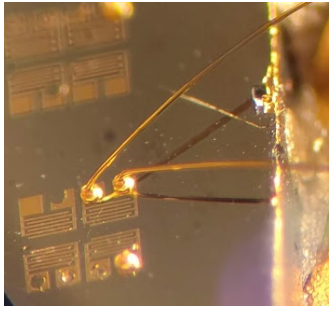
```
mappings = {
    "substrate cleaning": "cleaning",
    "sample cleaning": "cleaning",
    "piranha cleaning": "cleaning",
    "piranha sample cleaning": "cleaning",
    "development of pmma resist": "development",
    "development of hsq resist": "development",
    "developing": "development",
    "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
- ⇒ Paperless process tracking
- ELN based on MediaWiki [5]

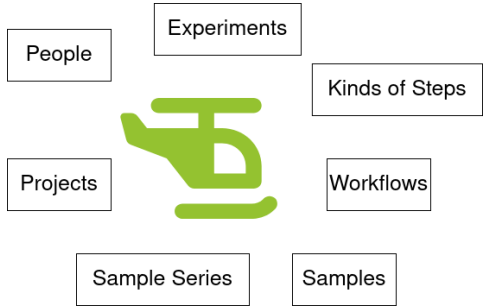


Gold Wirebonds

Piranha cleaning

Relation to HELIPORT

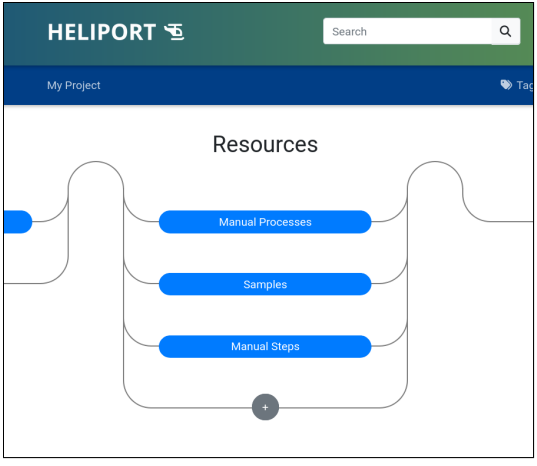
- HELIPORT is not for detailed experimental data
- A lot of high-level information relevant
- Use Digital Object concept in HELIPORT
- Interaction with other Systems



General concepts

Current State

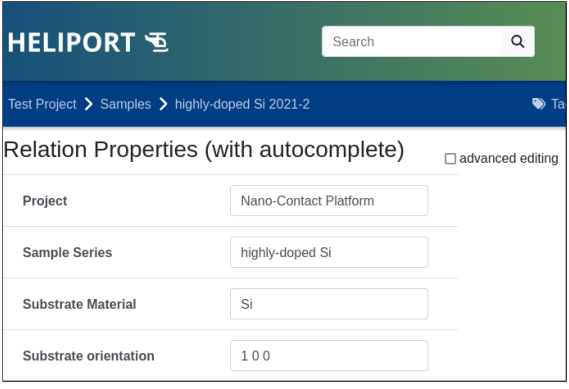
- What is needed?
- How could it be achieved?
- Look through existing Processes
- Prototype



Project graph with Samples / Workflows

Samples

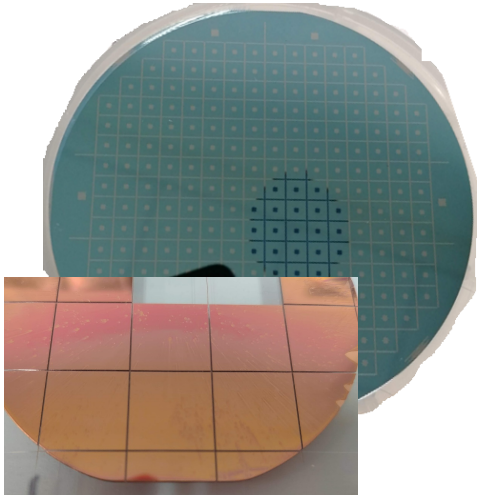
- Workflows and samples go together
- Sample as entry point for taking actions
- Different actions possible based on context e.g. currently performing workflow
- Relation workflows and samples



Sample Description

Collections of Samples

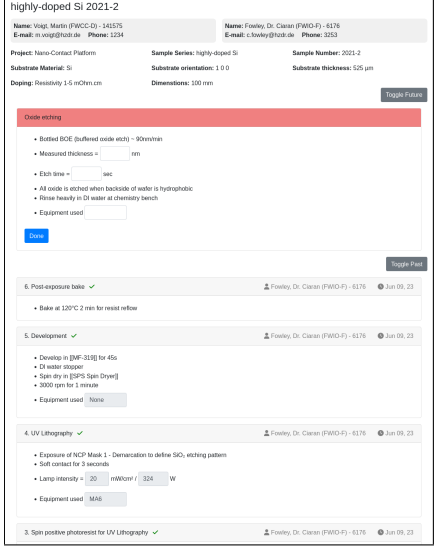
- Step on collection = step on each sample
- Reduces management overhead
- Cutting can create collections



Wafers are cut

Process History

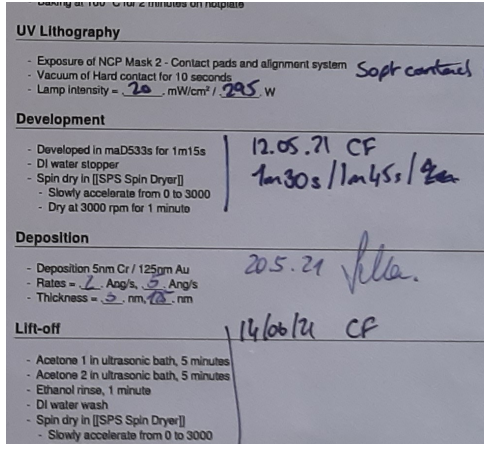
- This is the main goal
- Who did what where and when?
- What plans / steps were performed?
- What were the parameters?
- What were the measured values?



Process history

Manual Workflows

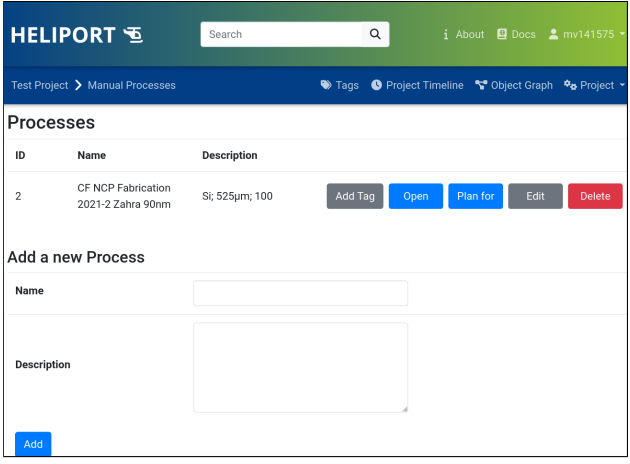
- Typically linear sequence of steps
- Basic looping and branching (user selects alternative step)
- Sub Recipes
- Merge similar consecutive steps
- Workflow with all parameters specified (template → instance → execution)



Merged Deposition Steps

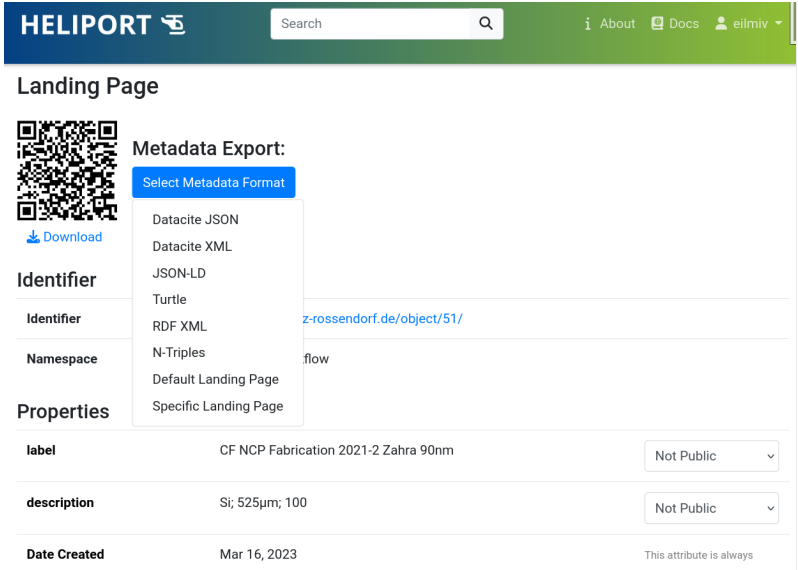
The current Prototype - Implementation

- `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



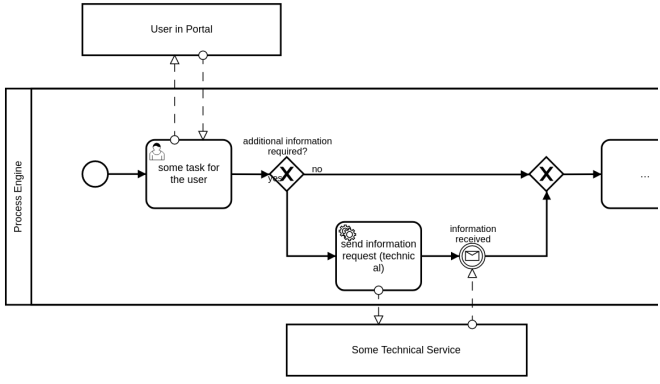
Workflow List

Metadata Export



Metadata Standards - BPMN

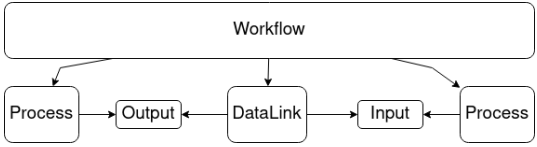
- Focus on modeling and notation
- Execution semantic
- Very expressive
- Workflow engines
  - Camunda [2]
  - python libraries [3]
- RDF ontology exists [1]



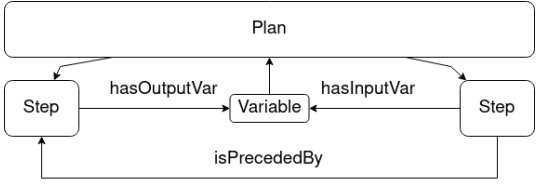
BPMN Example

Metadata Standards - wf4ever / p-plan

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



wfdesc structure



p-plan structure

Generalisation

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.