

Project KupferDigital2

Enhancing Efficiency and Sustainability of the Copper Life Cycle with Semantic Technology

Miriam Eisenbart, fem Forschungsinstitut

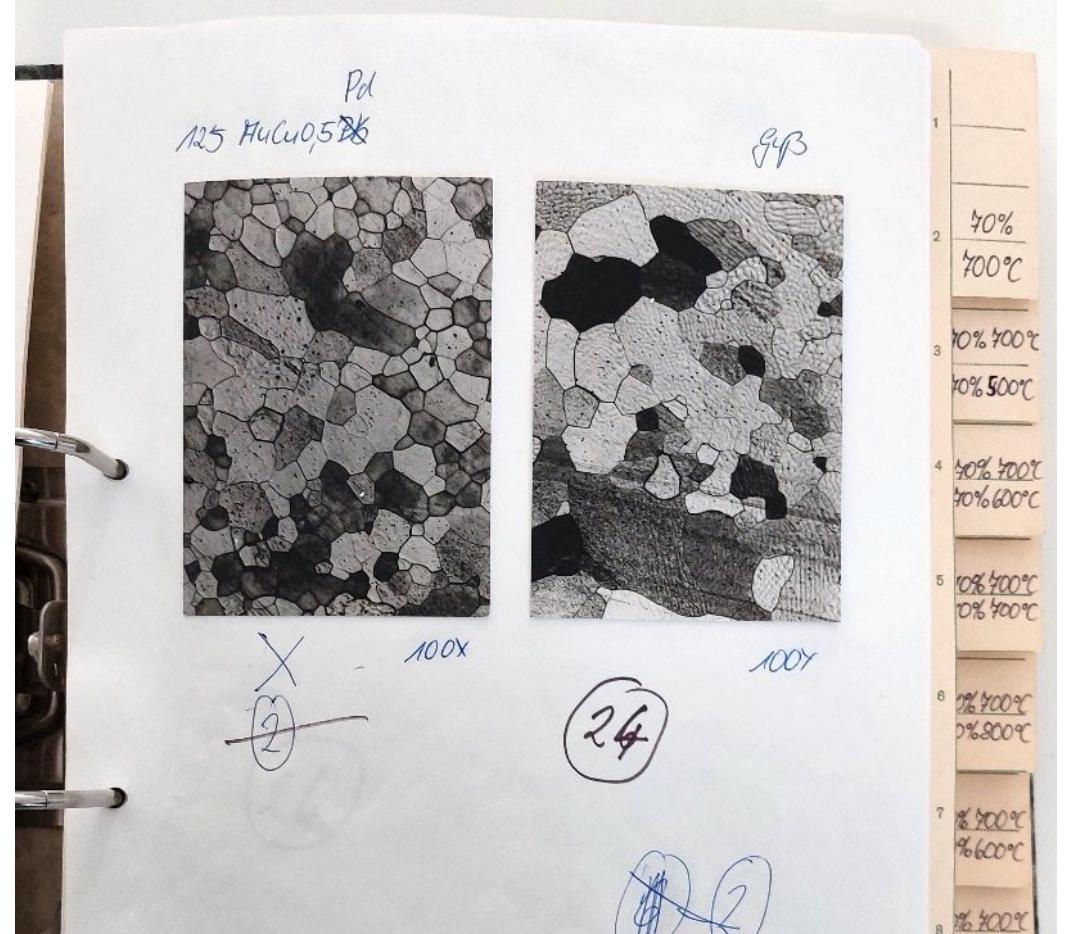
Data Week Leipzig, 12.06.2025

Alloy development data from the past

Analogous data

- Example of not-FAIR data
- Such experiments have to be repeated if
 - Important information is missing (e.g. meta data)
 - Data is not known to exist / not findable

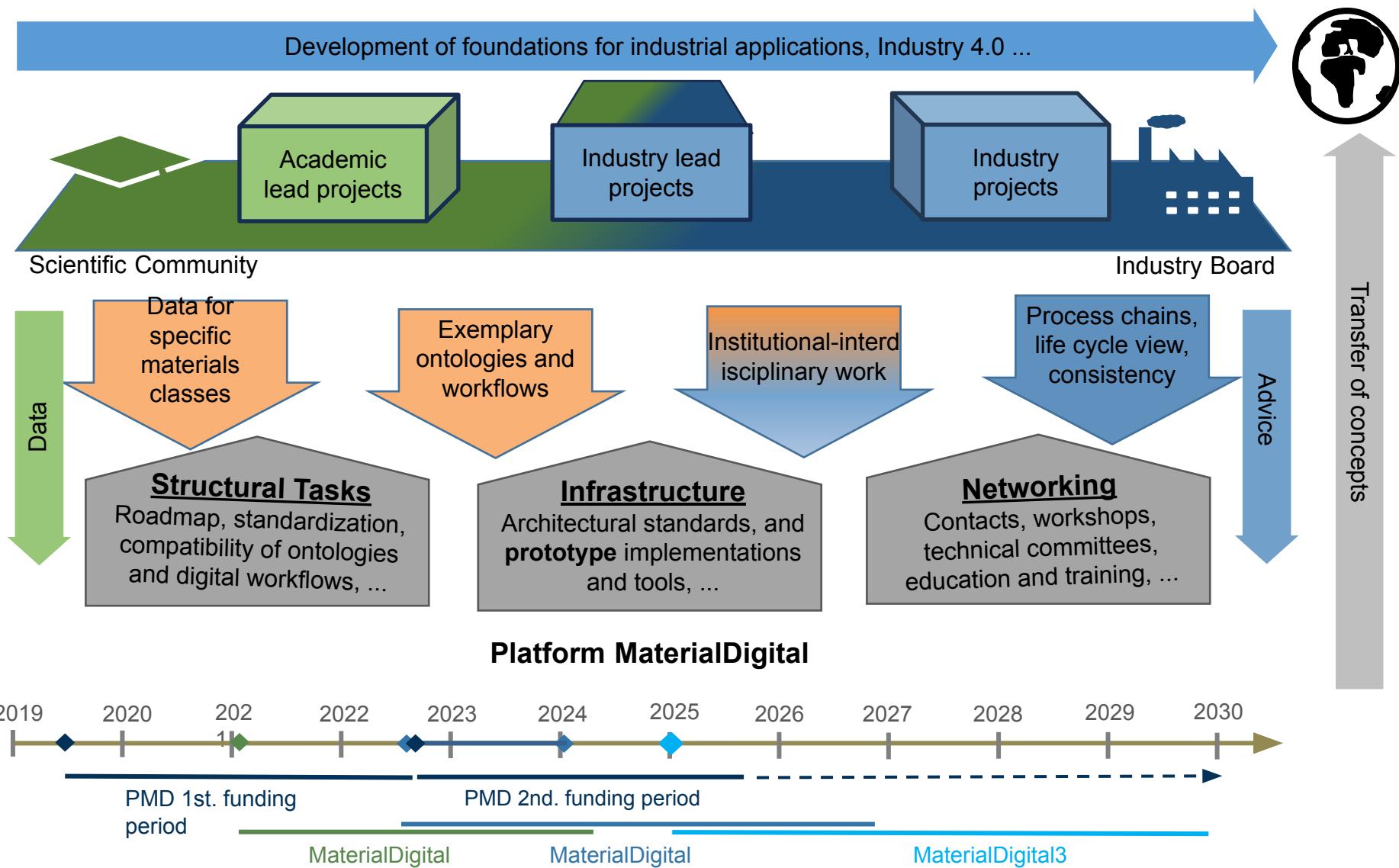
Historical data
from our archive



KupferDigital and KupferDigital2 are MaterialDigital projects from the first and third funding rounds of the MaterialDigital initiative



MATERIALDIGITAL



Project coordination: Wieland Electric



Consortium



Duration

1.2.2025 – 31.1.2028

Acknowledgement

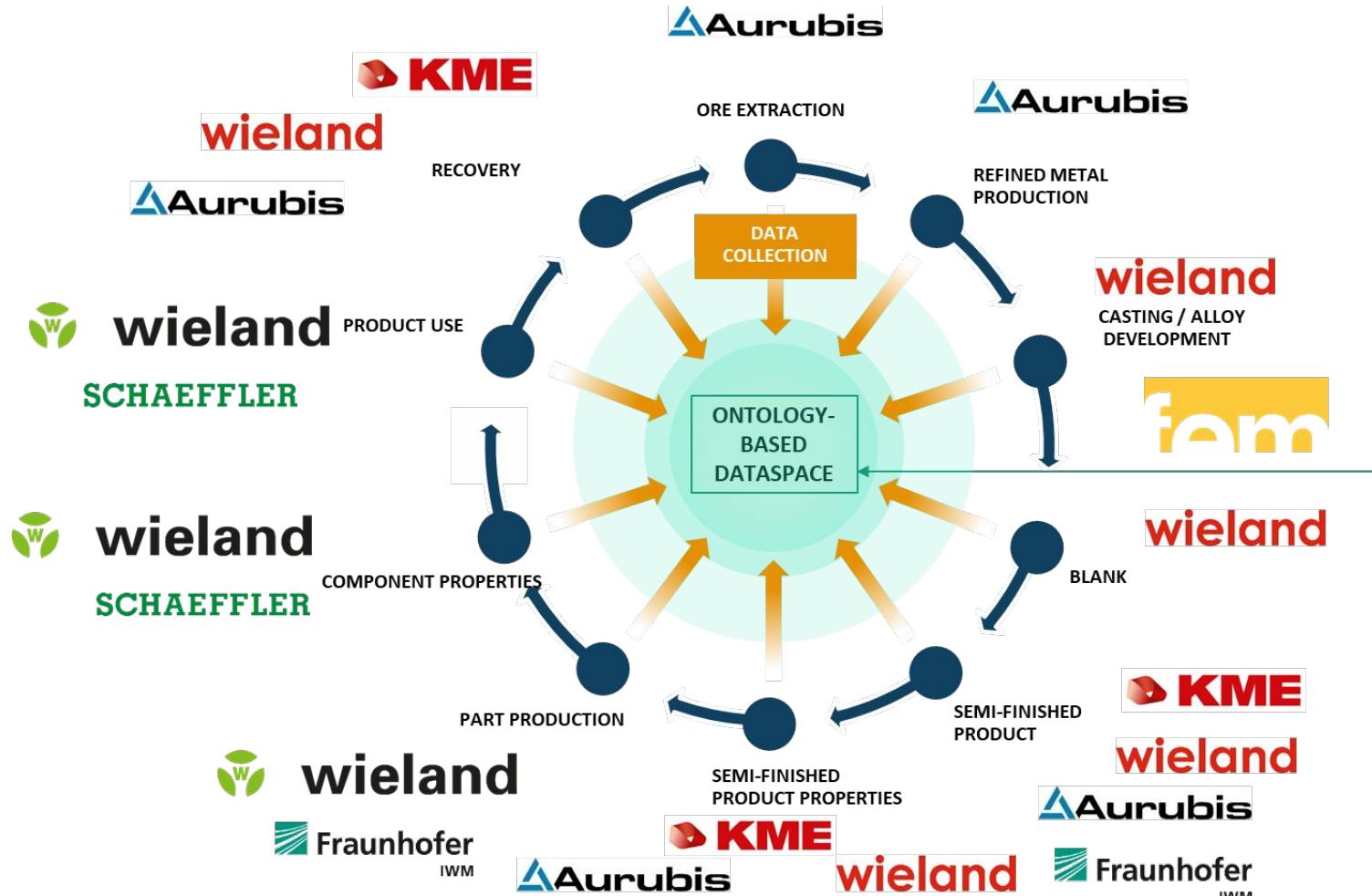
The project 13XP5230 is funded by the Federal Ministry of Education and Research as part of the MaterialDigital innovation platform.

With funding from the:

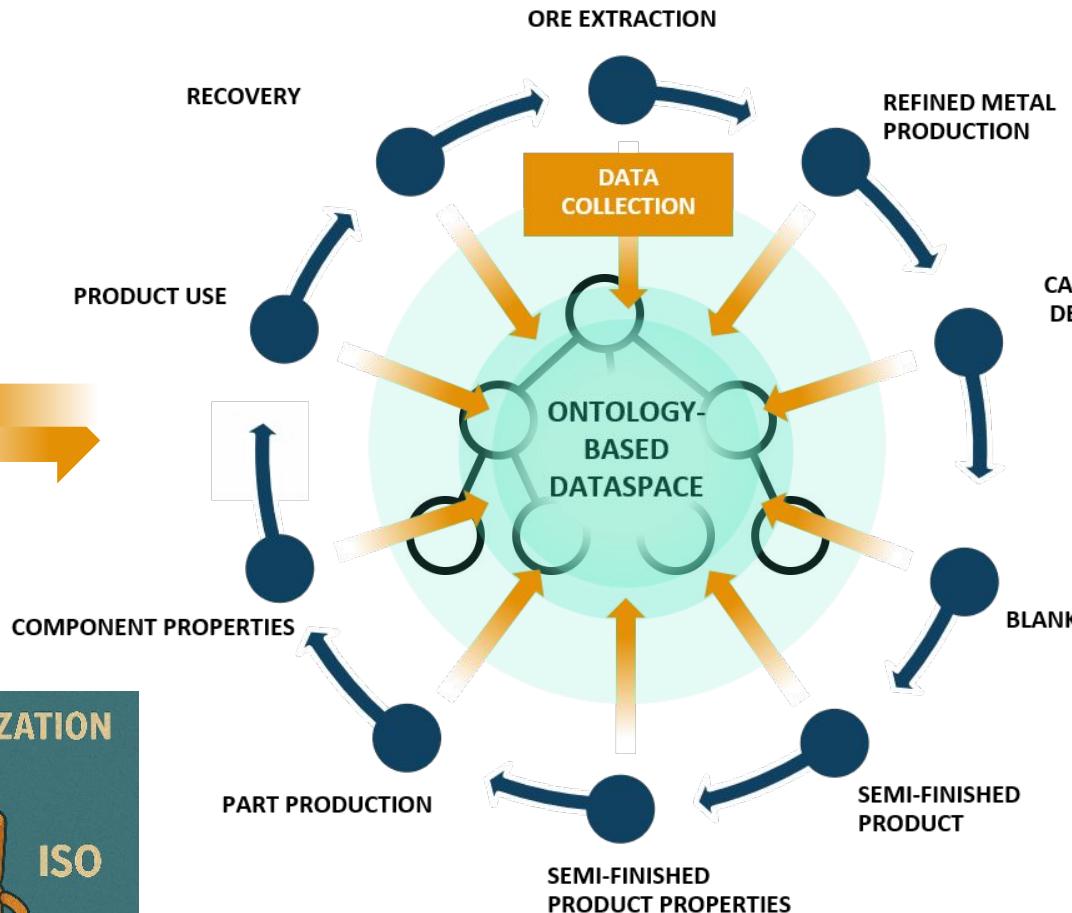


Federal Ministry
of Research, Technology
and Space

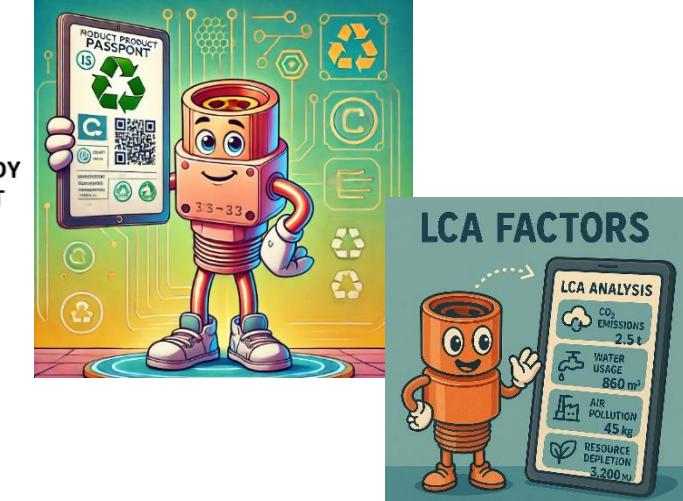
Material data space to increase the efficiency and sustainability of the copper lifecycle



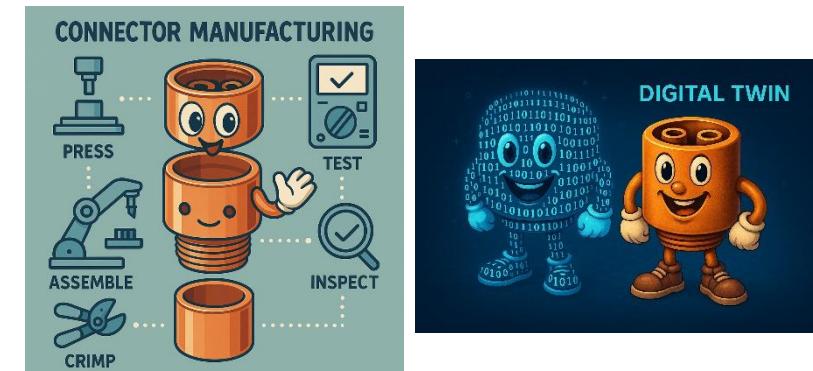
Topics in KupferDigital2



Digital Product Passport



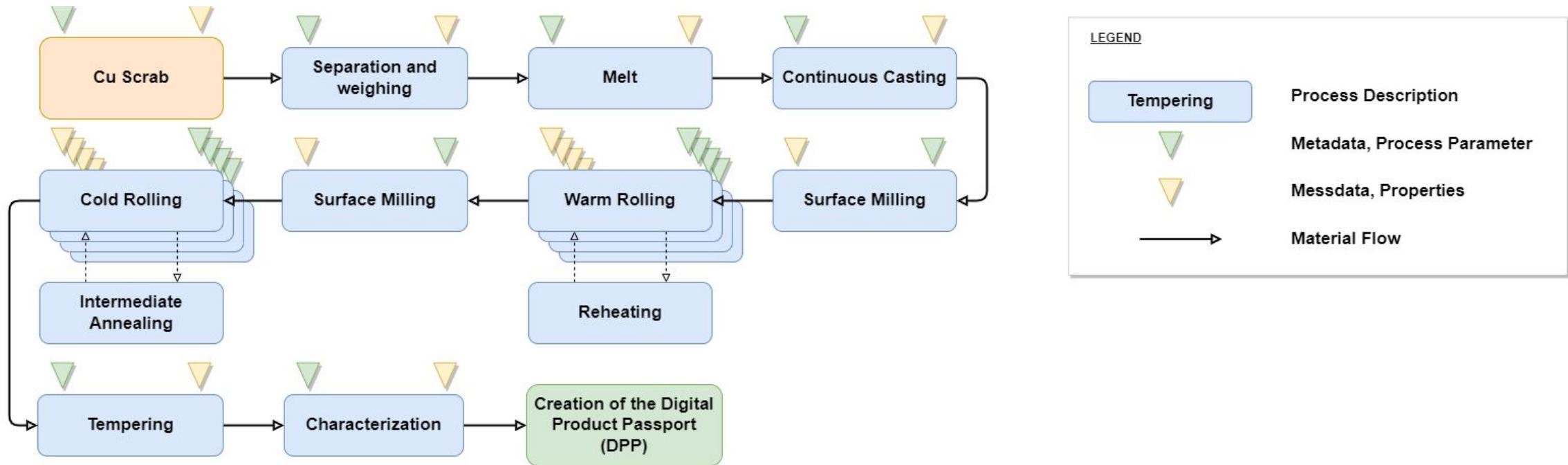
Demonstrator Process Chain



Images of the connector by ChatGPT

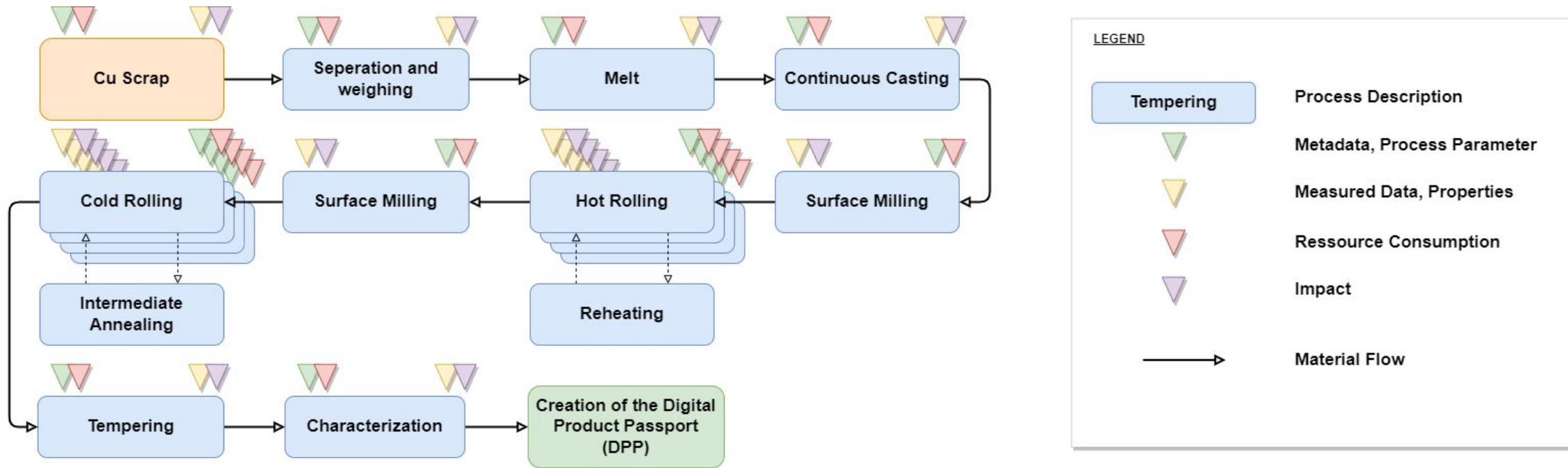
Digital representation of a manufacturing chain for a connector

Considered multiscale reference process (under laboratory conditions): 'Production of copper semi-finished products'

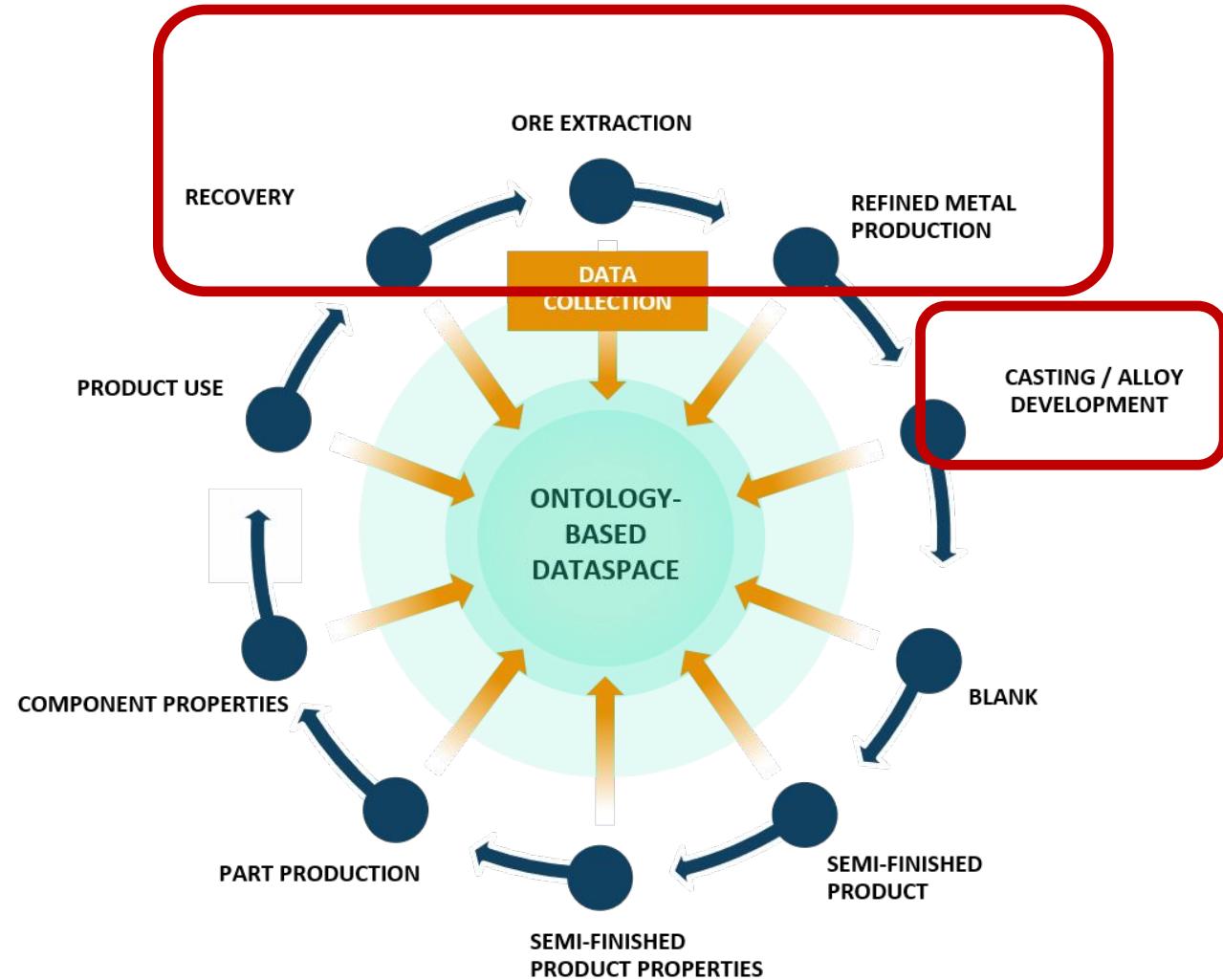


Digital representation of a manufacturing chain for a connector

Considered multiscale reference process (under laboratory conditions): 'Production of copper semi-finished products'



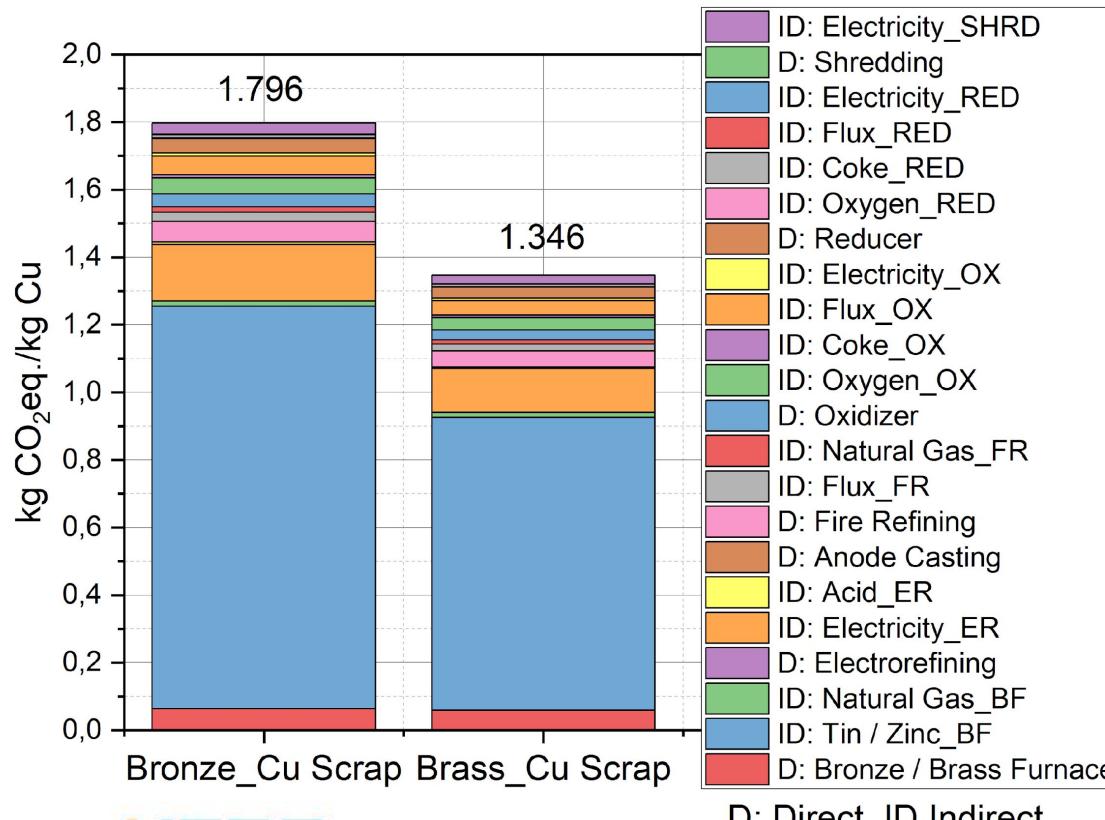
Alloy Development Data



What if we could take impacts „down the road“ already into account during alloy development?

Taking LCA Data into Account

LCA Results (Carbon Emissions)



One Result of KupferDigital was that Bronze has higher Carbon Emissions than Brass during Production

Bronze: CuSn12 (wt.%)

Brass: CuZn34 (wt.%)

Choices made early in the lifecycle matter

Data from:

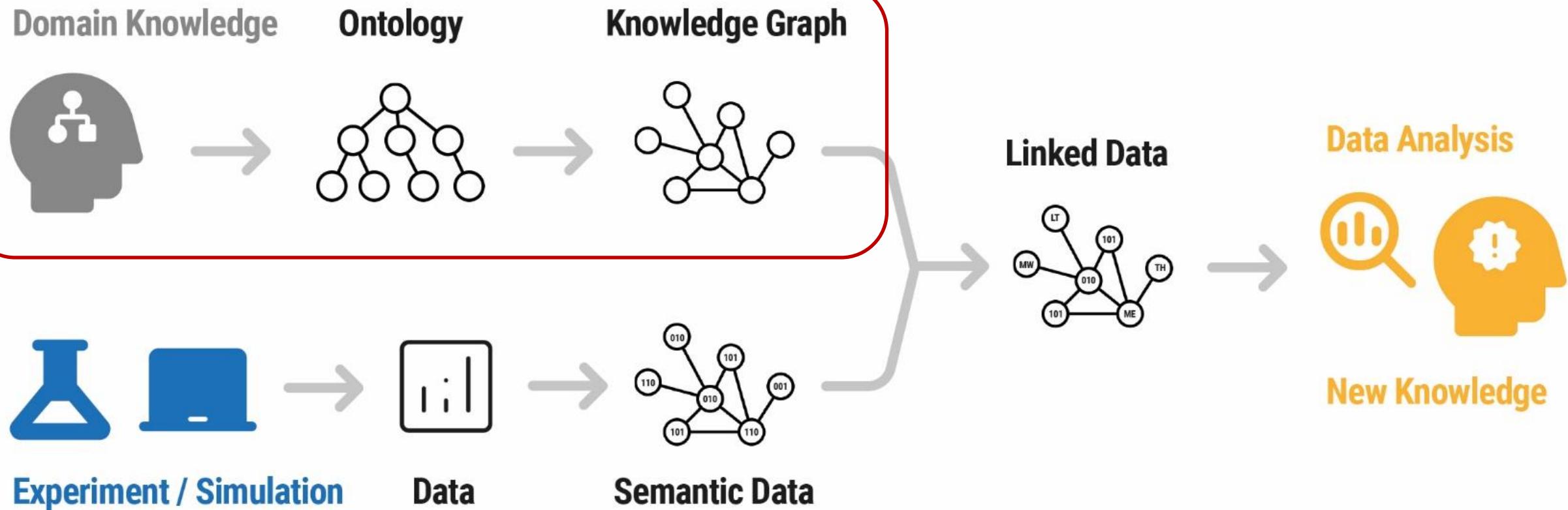
Sajjad, M., Van Den Boogaart, K.G., Steinmeier, L., Parvez, A.M., 2024. Environmental Impact Assessment of Copper-Alloy Production Using Process Simulation and Semantic Modeling. *Adv Eng Mater* 2401702. <https://doi.org/10.1002/adem.202401702>

Some Results of the first project

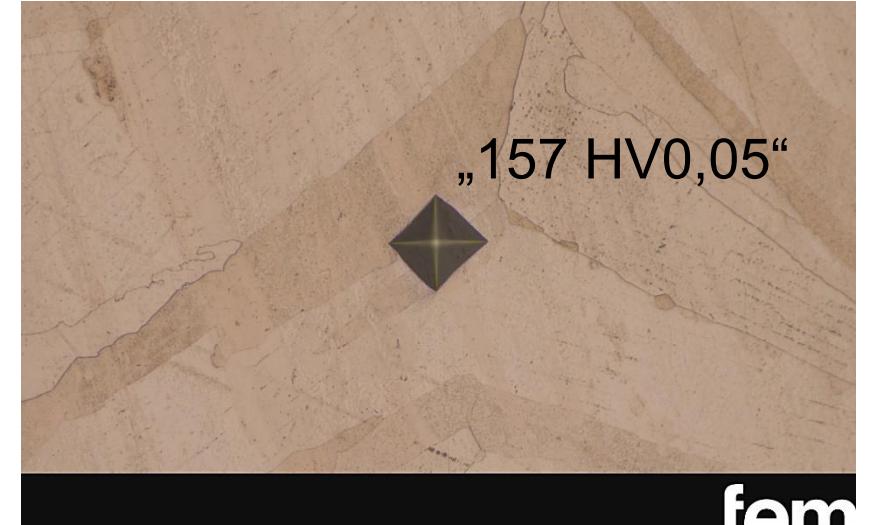


Steps during Digitalization

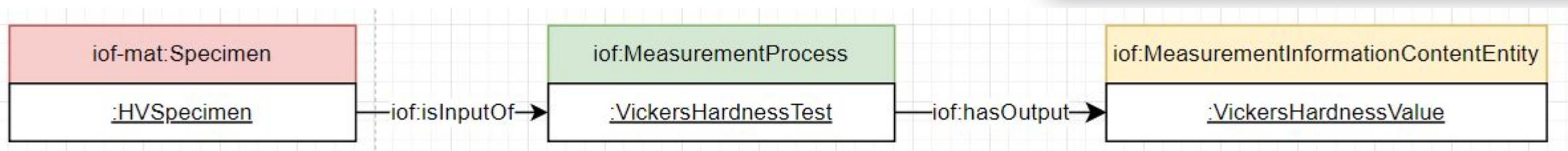
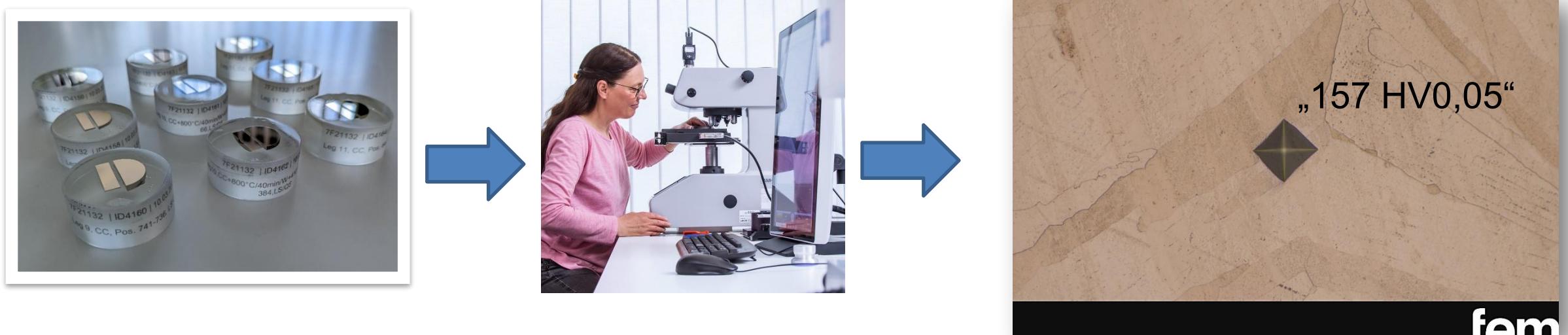
DIGITALIZATION WORKFLOW



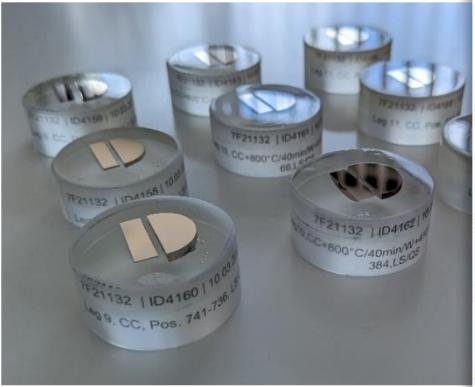
How do I make statements about my experiment?



How do I make statements about my experiment?



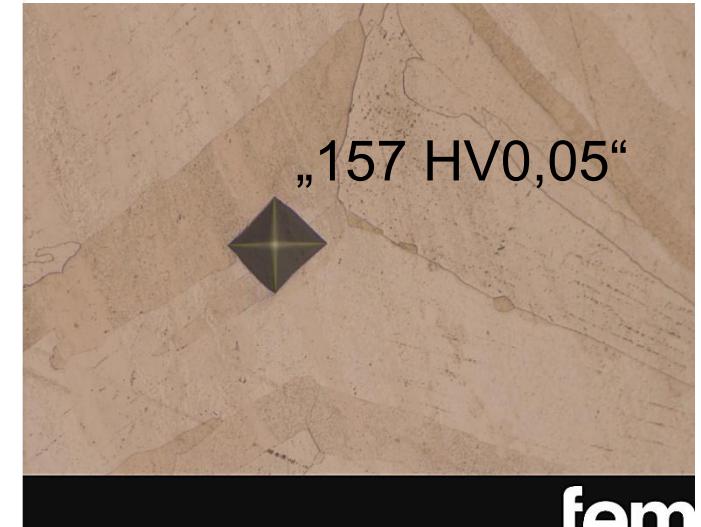
How do I make an experiment?



iof-mat:Specimen

:HVSpecimen

```
base: <https://kupferdigital.gitlab.io/process-graphs/alloy-development/index.ttl/> .  
dc: <http://purl.org/dc/elements/1.1/> .  
prefix iof: <https://spec.industrialontologies.org/ontology/core/Core/> .  
prefix iof-mat: <https://spec.industrialontologies.org/ontology/materials/Materials/> .  
prefix mod: <https://w3id.org/mod#> .  
prefix owl: <http://www.w3.org/2002/07/owl#> .  
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .  
  
dc:creator a owl:AnnotationProperty .  
  
dc:title a owl:AnnotationProperty .  
  
owl:versionInfo a owl:AnnotationProperty .  
  
base: a owl:Ontology ;  
    dc:creator "Miriam Eisenbart",  
        "Thomas Hanke" ;  
    dc:title "alloy-development" ;  
    owl:imports <https://github.com/Mat-O-Lab/MSEO/raw/main/domain/util/readable_bfo_iris.ttl>,  
        <https://raw.githubusercontent.com/iofoundry/ontology/materials/materials/Materials.rdf> ;  
    owl:versionInfo "0.0.4" ;  
    mod:createdWith <https://chowlk.linkeddata.es/> .  
  
base:HVSpecimen a owl:NamedIndividual,  
    iof-mat:Specimen ;  
    iof:isInputOf base:VickersHardnessTest .  
  
iof:hasOutput a owl:ObjectProperty ;  
    rdfs:label "has output" .  
  
iof:isInputOf a owl:ObjectProperty ;  
    rdfs:label "is input of" .  
  
base:VickersHardnessTest a owl:NamedIndividual,  
    iof:MeasurementProcess ;  
    iof:hasOutput base:VickersHardnessValue .  
  
base:VickersHardnessValue a owl:NamedIndividual,  
    iof:MeasurementInformationContentEntity .  
  
iof:MeasurementInformationContentEntity a owl:Class ;  
    rdfs:label "Measurement Information Content Entity" .  
  
iof:MeasurementProcess a owl:Class ;  
    rdfs:label "Measurement Process" .  
  
iof-mat:Specimen a owl:Class ;  
    rdfs:label "Specimen" .
```

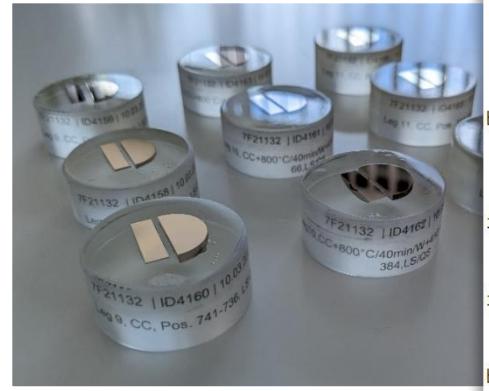


fem

MeasurementInformationContentEntity

VickersHardnessValue

How do I make an experiment?



iof-mat:Specimen

:HVSpecimen

```
base: <https://kupferdigital.gitlab.io/process-graphs/alloy-development/index.ttl> .  
dc: <http://purl.org/dc/elements/1.1/> .  
ix: <https://spec.industrialontologies.org/ontology/core/Core/> .  
prefix iof: <https://spec.industrialontologies.org/ontology/materials/Materials/> .  
prefix mod: <https://w3id.org/mod#> .  
prefix owl: <http://www.w3.org/2002/07/owl#> .  
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
```

```
dc:creator a owl:AnnotationProperty .
```

```
dc:title a owl:AnnotationProperty .
```

owl: Automated CI-Job in the KupferDigital Gitlab

```
base: a owl:Ontology ;  
dc:creator "Miriam Eisenbart",  
"Thomas Hanke" ;  
dc:title "alloy-development"  
owl:imports <https://github  
<https://raw.githubusercontent  
owl:versionInfo "0.0.4" ;  
mod:createdWith <https://ch
```

```
base:HVSpecimen a owl:NamedIndividual ;  
iof-mat:Specimen ;  
iof:isInputOf base:VickersH
```

```
iof:hasOutput a owl:ObjectProperty  
rdfs:label "has output" .
```

```
iof:isInputOf a owl:ObjectProperty  
rdfs:label "is input of" .
```

```
base:VickersHardnessTest a owl:  
iof:MeasurementProcess ,  
iof:hasOutput base:VickersHardnessValue .
```

```
base:VickersHardnessValue a owl:NamedIndividual,  
iof:MeasurementInformationContentEntity .
```

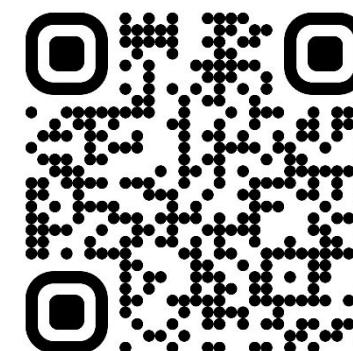
```
iof:MeasurementInformationContentEntity a owl:Class ;  
rdfs:label "Measurement Information Content Entity" .
```

```
iof:MeasurementProcess a owl:Class ;  
rdfs:label "Measurement Process" .
```

```
iof:Specimen a owl:Class ;  
rdfs:label "Specimen" .
```



```
eadable_bfo_iris.ttl>,  
Materials/Materials.rdf> ;
```



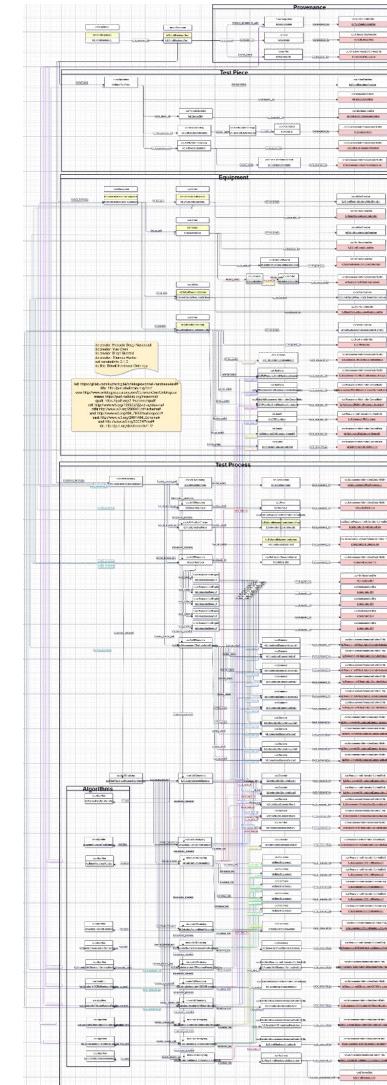
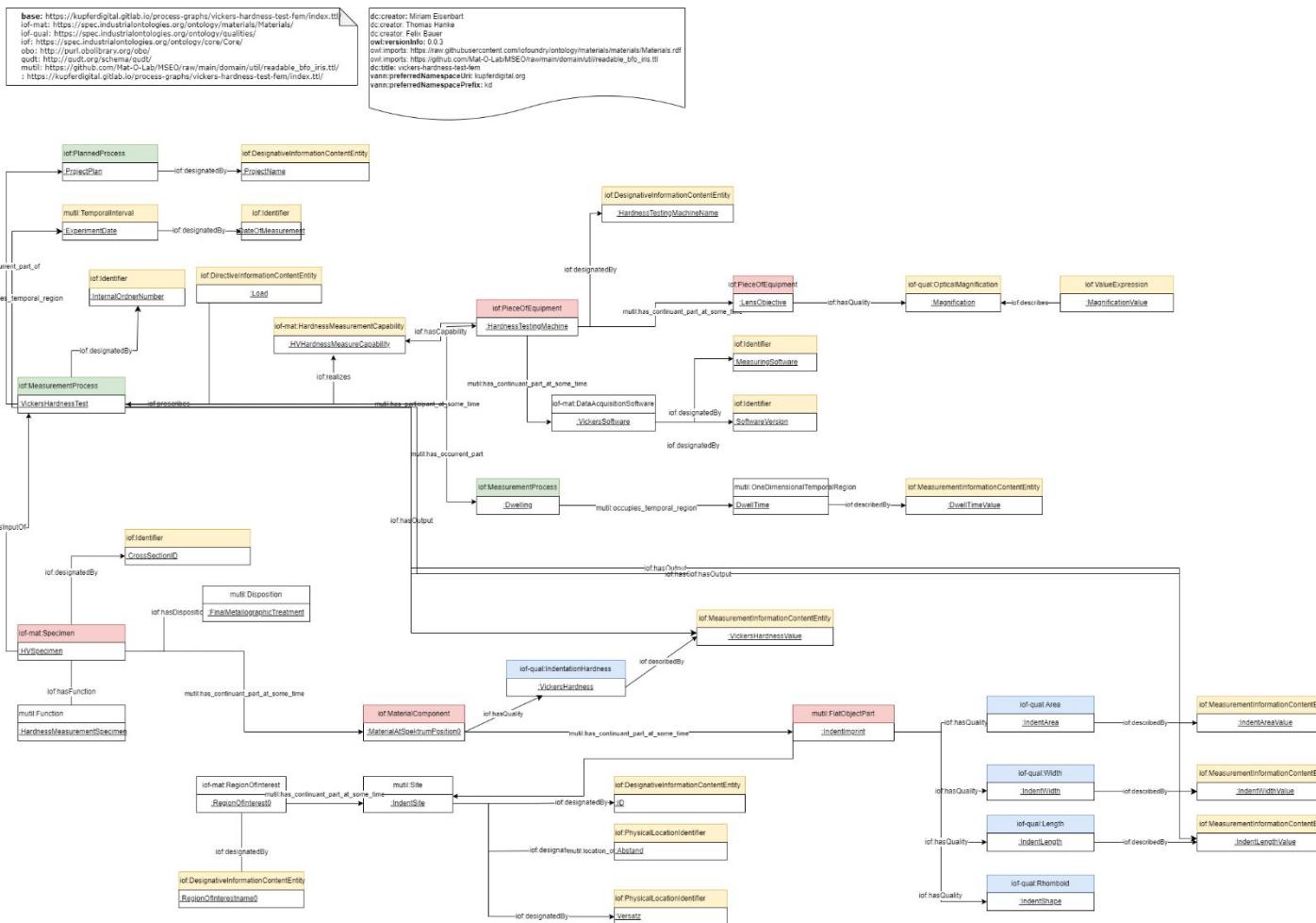
fem

MeasurementInformationContentEntity

VickersHardnessValue

Example of a full description of a hardness test

Simple representation of a grid measurement



More complex modelling of the concepts of a DIN Standard

Ontology Development

Several Top- and Mid-Level ontologies have been explored during KupferDigital

TLO: EMMO, PROVO and BFO_2020

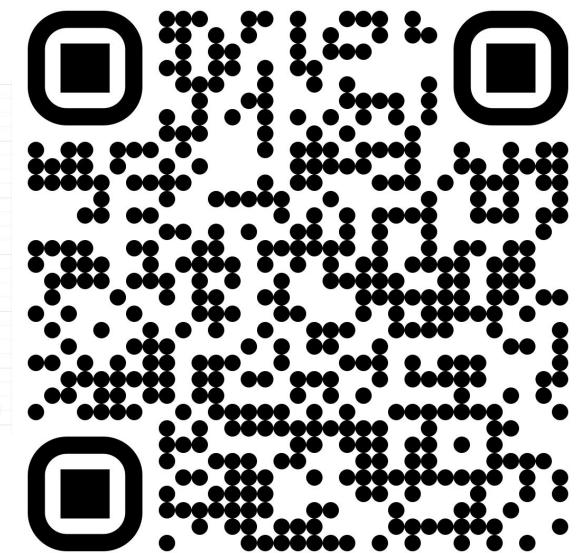
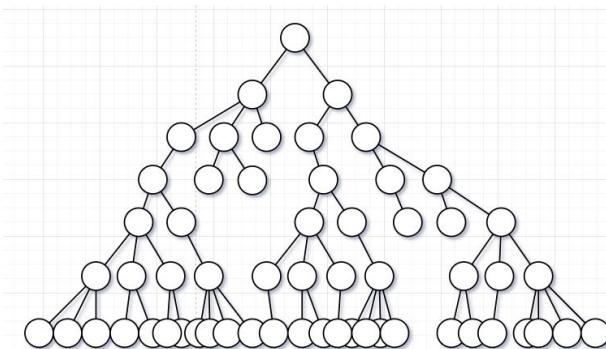
MLO: IOF core, MSEO, PMDco (V.2.0.7), CHAMEO and MT

It was found that the combination of BFO2020 in combination with IOF core and MSEO were overall best performing in the context of the project

Evaluation published here:

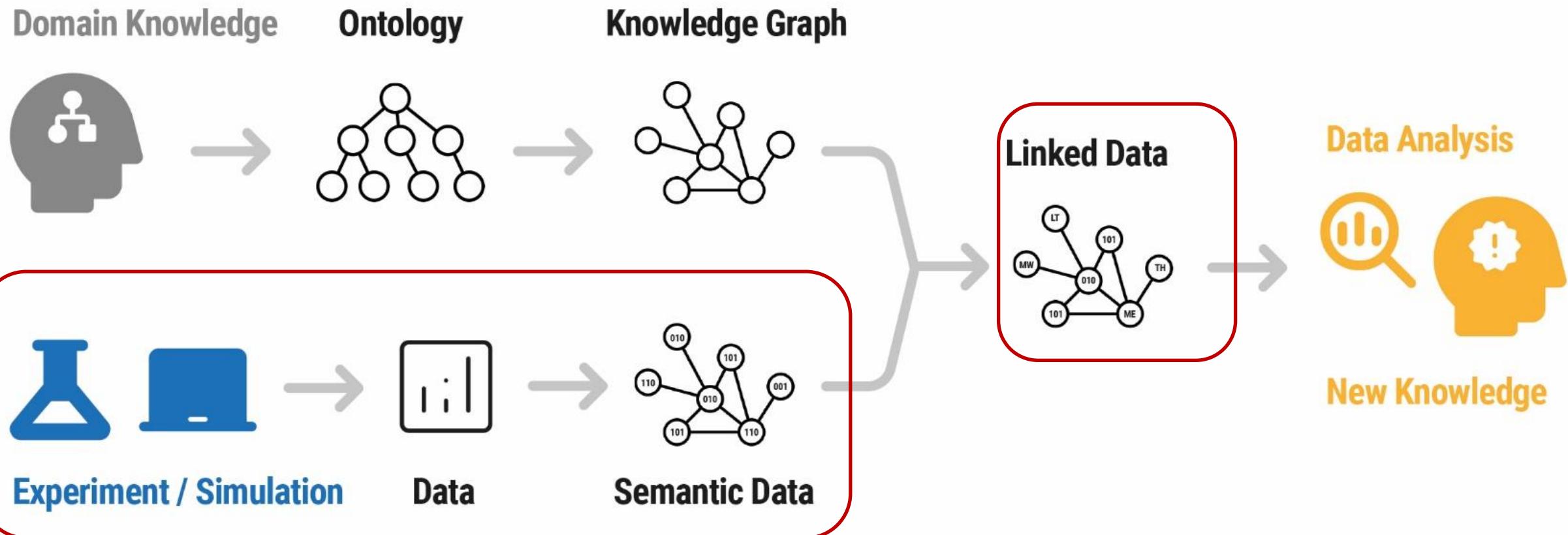
Beygi Nasrabadi, H., Norouzi, E., Sack, H., Skrotzki, B., 2024. Performance Evaluation of Upper-Level Ontologies in Developing Materials Science Ontologies and Knowledge Graphs. *Adv Eng Mater* 2401534. <https://doi.org/10.1002/adem.202401534>

Ontologies of KupferDigital can be explored here:

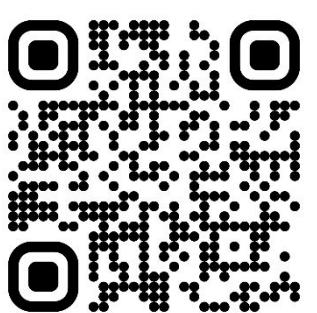


Steps during Digitalization

DIGITALIZATION WORKFLOW



Data integration



The screenshot shows a Windows File Explorer window with the following details:

- Address Bar:** Shows the path: `<> felix > kupfer...`
- Search Bar:** Contains the text: `kupferdigital durchsuchen`
- File List:** Displays 9 elements, all represented by yellow folder icons with document previews:
 - `.ipynb_checkpoints`
 - `2023.02.28_EDX_D1_raw_and_metadata_with_xy`
 - `2023.03.03_EDX_raw_and_metadata_with_xy_metadataunit`
 - `2023.03.17_EDX_raw_and_metadata_with_xy_D1_ID`
 - `data_castingmachine`
 - `data_edx`
 - `data_HV`
 - `casting-simulation`
 - `ckan_uploader.ipynb`
- Status Bar:** Shows the number of items: `9 Elemente`

Upload and update of measurement data

```
# upcaded from OSN and my Gittermessungen
import os
import time
from jupyter import paths
from kernel import import_name

database = "data/castingsmachine"
files = os.listdir(database)

for file in files:
    if file.endswith('.v1'):
        url = "http://"+URL+file
        with open(file) as f:
            contents = f.read()
        for line in contents:
            if line.startswith('%%EOF'):
                break
            if line.startswith('%%PLOT') or line.startswith('%%DATA'):
                continue
            if line.startswith('%%METADATA'):
                line = line.replace('%%METADATA,v1,"')
                frame_meta = file
                frame_meta = file.replace('%%METADATA,v1,"', '')
                package_id = file.replace('%%METADATA,v1,"', '')
                package_id = file.replace('%%METADATA,v1,"', '')
                package_id = file.replace('%%METADATA,v1,"', '')

# measuredLOCs: location
fan.action.resource.create(
    package_id=package_id,
    url=url,
    version='1.0',
    description='generated by OSN v2.6',
    destination='/metadata/experimental_data',
    name='frame_meta',
    uploaded_by='controller/(frame_meta, "r")')

# measuredLOCs
fan.action.resource.create(
    package_id=package_id,
    url=url,
    version='1.0',
    description='generated by OSN v2.6',
    destination='/measured_victims/hardened',
    name='frame_meta',
    uploaded_by='controller/(frame_meta, "r")')

time.sleep(1)
# to upload datasets
sys.argv[0].action.package.delete(
    package_id=package_id)

except KeyboardInterrupt:
    print("KeyboardInterrupt")
```



Data transformation and data retrieval





Datasets Organizations Groups

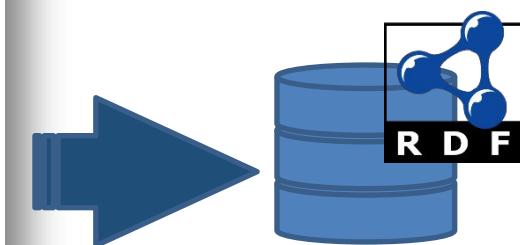
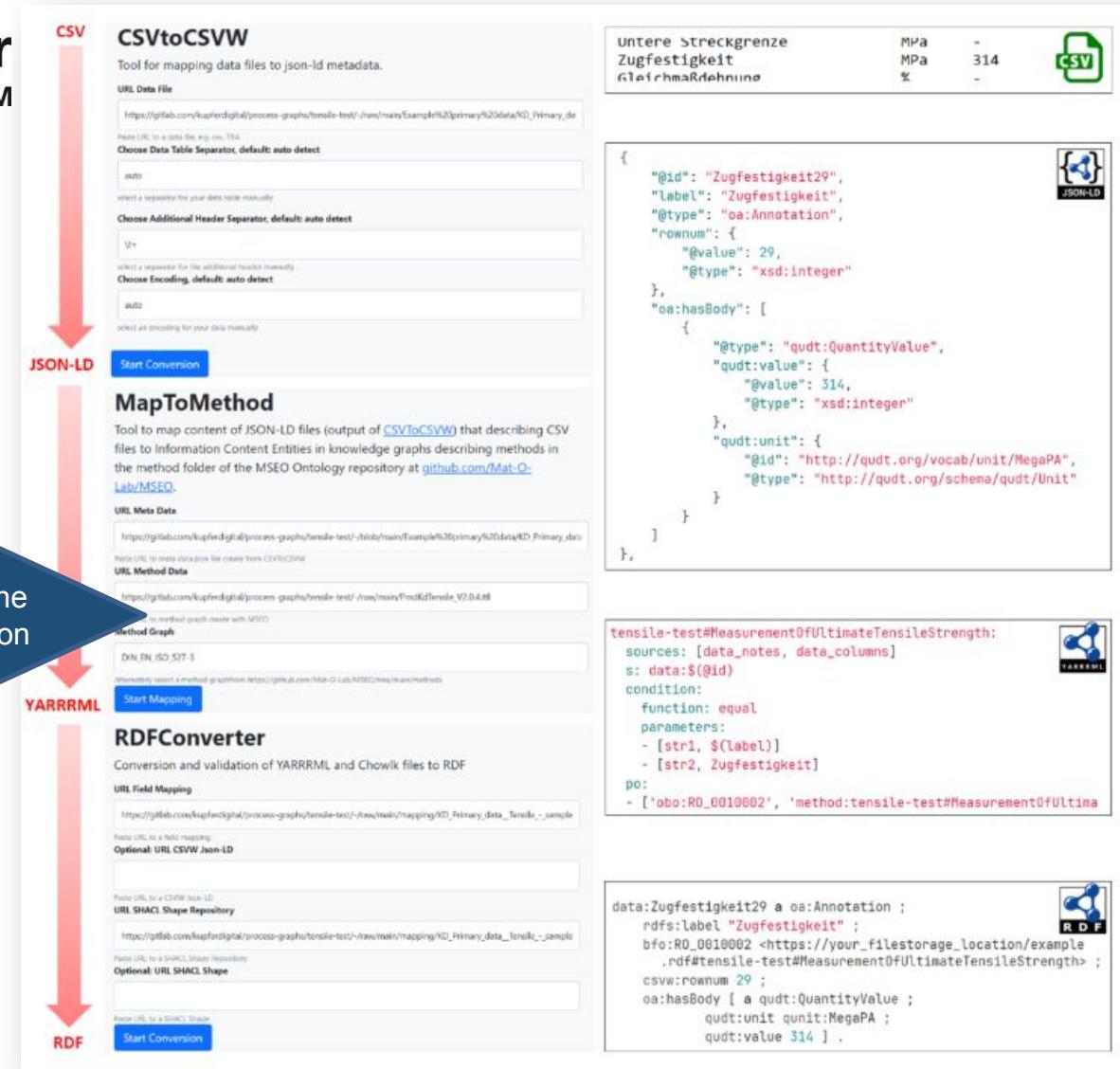
Home / Organizations / fem

fem

Das fem ist seit 1922 das weltweit einzige unabhängige Institut für Edelmetallforschung. Ziel unserer Forschung auf den Gebieten der Materialwissenschaft und Oberflächen...
read more

68 datasets found

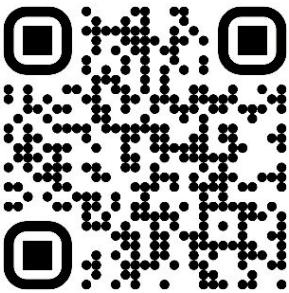
energy-dispersive-x-ray-analysis-fem-d



Semantic Data

H. B. Nasrabadi u. a., „Toward a digital materials mechanical testing lab“, *Computers in Industry*, Bd. 153, S. 104016, Dez. 2023, doi: [10.1016/j.compind.2023.104016](https://doi.org/10.1016/j.compind.2023.104016).

Platform MaterialDigital Data Portal



The screenshot shows the MaterialDigital Data Portal's main interface. At the top, there are navigation links for Datasets, Organizations, Groups, and About, along with a search bar. The main content area is titled "Datasets" and displays a list of organizations and their dataset counts. A large number "164 datasets found" is prominently displayed. Below this, sections for "KupferDigital Ontology", "StahlDigital Process Ontology", and "SmaDi-Ontology" are shown, each with a brief description and links to their respective HTML and XML files. The overall design features a light gray hexagonal background pattern.

- Organizations
 - KupferDigital - 155
 - DIGITRUBBER - 1
 - DiProMag - 1
 - GlasDigital - 1
 - KNOW-NOW - 1
 - LeBeDigital - 1
 - ODE_AM - 1
 - SensoTwin - 1
 - SmaDi - 1
 - StahlDigital - 1
- Groups
 - mappings - 1
- Tags
 - alloy development - 40
 - Tensile test - 21

Datasets are linked
Data souverenity stays at the partner

Our project partners in KupferDigital



Project partners | Project coordination: fem



Associated partners



Runtime

1.3.2021 - 30.06.2024

Acknowledgments

The 13XP5119 project was funded as part of the Innovation platform **MaterialDigital** by the Federal Ministry of Education and Research.



Bundesministerium
für Bildung
und Forschung

Our project team in KupferDigital



Birgit Skrotzki (BAM)

Hossein Beygi-Nasrabadi (BAM)

Ladji Tikana (Kupfer_)

Felix Bauer (fem)

Miriam Eisenbart (fem)

Stefan Spannbauer (fem)

Gerald van den Boogart (HZDR/HIF)

Leon Steinmeier (HZDR/HIF)

Ashak Parvez (HZDR/HIF)

Robert Klengel (IMWS)

Sandy Klengel (IMWS)

Anantha Narayanan Ramakrishnan (IMWS)

Felix Brei (InfAI)

Gordian Dziwis (InfAI)

M. Eisenbart (KupferDigital2)

Kata-Week 12.06.2024 (nfAI)



Our project team in KupferDigital2



Stefan Brehm (Wieland-Electric)

Hendrik Busch (KME Mansfeld)

Stefanie dos Santos (Aurubis)

Johannes Moeller (Schaeffler)

Dominik Boesch (Schaeffler)

Ece Topraksal (Schaeffler)

Sebastian Tramp (eccenca)

Yihan Chen (DIN)

Alexandru Todor (DIN Solutions)

Joachim Riedle (Wieland-Werke)

Ingolf Lepenies (SCALE)

Thomas Freudenmann (EDI)

Fihmi Mousa (MCS Data Labs)

Sai Chinthana (MCS Data Labs)

M. Eisenbart: KupferDigital2
Data Week 12.06.2025 MCS Data Labs



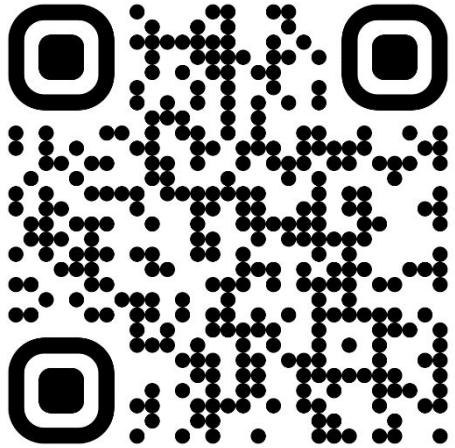
Kupfersymposium 2025

We look forward to welcoming you
to Schwäbisch Gmünd! Home of the
fem Research Institute since 1922.

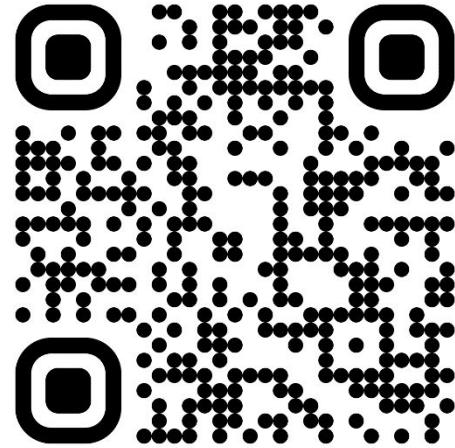
With a Digitalization Workshop tailored for Engineers and Material Experts

Some Links:

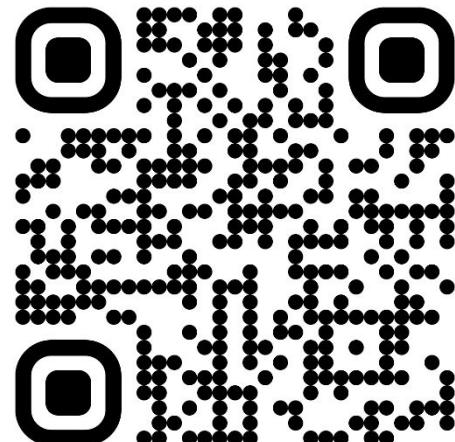
The PMD Data Portal can be found here:



Publications can be found here:



Showcases to explore can be found here:



**Thank you very much
for your attention.**



Miriam Eisenbart, fem Forschungsinstitut

