Project SOPHIA

**PhotoVoltaic European Research Infrastructure**

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Data Beneficiary



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| **Name Beneficiary** | ISE-IWES |
| **Contact person** | Michael Köhl |
| **Postal address** | Fraunhofer ISE, PMZ/Gaus, Heidenhofstr. 2, D-79110 Freiburg |
| **E-mail** | Michael.koehl@ise.fraunhofer.de, sina.friedrichs@ise.fraunhofer.de |
| **Project Website** | www.sophia-ri.eu |



## NA03: Interoperability benchmarking, Definition of test procedures, Common database

# D3.2- General criteria for laboratory work and equipment management

## Document Information

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## Document approval

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## Document history

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| V1 | 10/08/2012 | Creation | Ivan GORDON<br>Sina FRIEDRICHS |
| V2 | 21/08/2012 | Correction | Michael KÖHL as WP leader |

## Table of contents

# 1. Executive summary

### *1.1 Description of the deliverable content and purpose*

The deliverable focused on the development of general criteria and guidelines for laboratory work and equipment management. Methods of coordination equipment management in order to optimally use the infrastructure and minimise the loss of time should be developed. This task did not only include the criteria for ensuring the quality of equipment and laboratory work, but also took into account the operating skills needed to work in relevant laboratories.

### *1.2 Deviation from objectives, corrective action*

The deliverable could be completely achieved without the need of corrective actions.

### *1.3 Technical progress*

Operational excellence requires the development of the correct organizational and logistics system, which defines the correct way to work. This is a necessary condition to achieve goals such as improved learning cycles, cycle time reduction, yield improvement, reproducibility, traceability, timely sharing of results and information, statistical analysis of results... aimed at optimal research efficiency, optimal collaboration and increased customer satisfaction.

The deliverable D3.2 presents the development of the general criteria for tools and laboratory work.

### *1.4 Impact of the results*

First we note that in deliverable D3.2 we have focused on crystalline silicon material characterization and solar cell processing as was agreed upon by the project partners active in WP3. We did not specifically look at e.g. thin-film solar cell processing or organic material characterization (topics which are also studied within Sophia) but used the expertise of the partners present concerning the management of lab work related to crystalline-Si photovoltaics. This means that the criteria defined here are valid first of all for crystalline Si processing and characterization. However, although the processing itself may be completely different for these other materials compared to crystalline silicon processing, we believe that **the way how lab work and equipment should be managed is similar for all materials studied within this project** and hence we believe that the general criteria and guidelines defined in this deliverable for crystalline Si will also be of use for the other materials and, at least can be used as a good starting point for these other materials.

We believe that for any research lab quality control and traceability of experiments and results are of the utmost importance. This is even more so for large research infrastructures which are shared and working closely together as is the case for the project partners within the Sophia project. Hence the

**general criteria and guidelines for laboratory work and equipment management** which we have been defining within the first 18 months of this project are all defined with the goal **to maximize quality control and traceability and to come to optimal operational excellence**.

### *1.5 Dissemination activities carried out, planned*

N/A

## 2. Technical sections

Operational excellence requires the development of the correct organizational and logistics system, which defines the correct way to work. This is a necessary condition to achieve goals such as improved learning cycles, cycle time reduction, yield improvement, reproducibility, traceability, timely sharing of results and information, statistical analysis of results... aimed at optimal research efficiency, optimal collaboration and increased customer satisfaction.

We have defined the following **list of requisites** (not in order of importance) as needed for each laboratory that wants to excel in operational excellence, quality control and traceability:

- A detailed list of all tools and equipment present
- For each tool, the correct way of working should be clearly documented
- Work regulations: all personnel should be aware of the correct way of working within the lab and this correct way of working should be documented and accessible to all. All personnel should be committed to these work regulations.
- An electronic system to keep track of experiments and results
- When working with operators, a manufacturing and execution (MES) system should be used to streamline the experimental process flows
- SPC (statistical process control) should be applied on all relevant tools
- Clear role descriptions should be present for all personnel
- A tool reservation system

In the following sections, all these requisites will be discussed in more detail.

### *2.1 List of all tools present*

This list should be available to all personnel, preferably electronically via e.g. intranet and should contain the following information for all tools (processing, characterization, simulation, ...) that belong to the infrastructure:

- Tool name
- Place where tool is located
- Tool responsible or first point-of-contact
- Description of what tool is capable of
- List of trained users
- Current status of tool (working, in repair, ...)
- Link to where the working procedures of the tool can be found

The purpose of this list is to give information to all researchers about all tools present within the infrastructure and to help information exchange between different infrastructures (e.g. within Sophia project).

## *2.2 Working procedure for each tool*

For each tool, the correct working procedure should be written down in a so-called "tool procedure" which should be accessible to at least all people allowed to work with the tool. This working procedure has to be kept up-to-date by the tool responsible and it is the duty of all trained users to always apply the correct working procedures described in this document. Typically, the tool's working procedure should contain the following:

- Purpose of the document and to which tool it belongs
- Responsibilities: who is responsible for what regarding this tool
- Detailed description of how to use the tool: what is allowed and what not, how to start up the tool, in which state to leave the tool when finished working, ...
- A description on how to become user of the tool: which training needs to be followed, who should give the training, ...
- A list of related documents (e.g. manual of the tool, document on how to do maintenance on the tool, ...)

## *2.3 General work regulations*

Besides the work procedures for each tool, there should also be a clearly documented general work regulation that **describes how everybody that works in the infrastructure should behave**. All employees should know these general work regulations and should be committed to them.

## *2.4 Electronic system to keep track of experiments and results*

All details of each experiment should be stored into a central electronic database that is accessible to all researchers using the infrastructure. Besides the details of all process steps that were executed, also experimental results and the analysis of these results should be stored in this database. This is to ensure **traceability of results and to be able to notice links between different experiments** (e.g. a link between certain experimental results and the parameters used of a specific tool). Key features of this database system should be:

- Accessible to all users of the infrastructure based on a personalized access code.
- Every experiment, large or small, should be inserted into the database.
- Every experiment gets a reference number and has a scientist who is responsible for the experiment. The reference number is used in labeling the wafers and wafer boxes used in the experiment.
- Each experiment lists all executed steps, indicating for each step which process was executed on which system, all process parameters, who executed the process and when, any remarks of the process operator.
- Finished experiments should list the main conclusions of the experiment as drawn by the scientists involved and all experimental results (measurements, ...) should be attached.
- Lists of all tools and all baseline processes present in the infrastructure should be available and continuously updated.
- The electronic system should work as a database so that a search function can be executed, e.g. list all runs which performed a certain process on a certain tool, list all experiments in

which a certain process parameter was used, list all users who used a certain tool in a certain period, ...
- Allow different users to work on the same experiment.

Obviously a database can only be effective if its users timely and correctly give all required inputs. Hence, **the correct use of the database should be one of the crucial points in the above-mentioned general work regulations**.

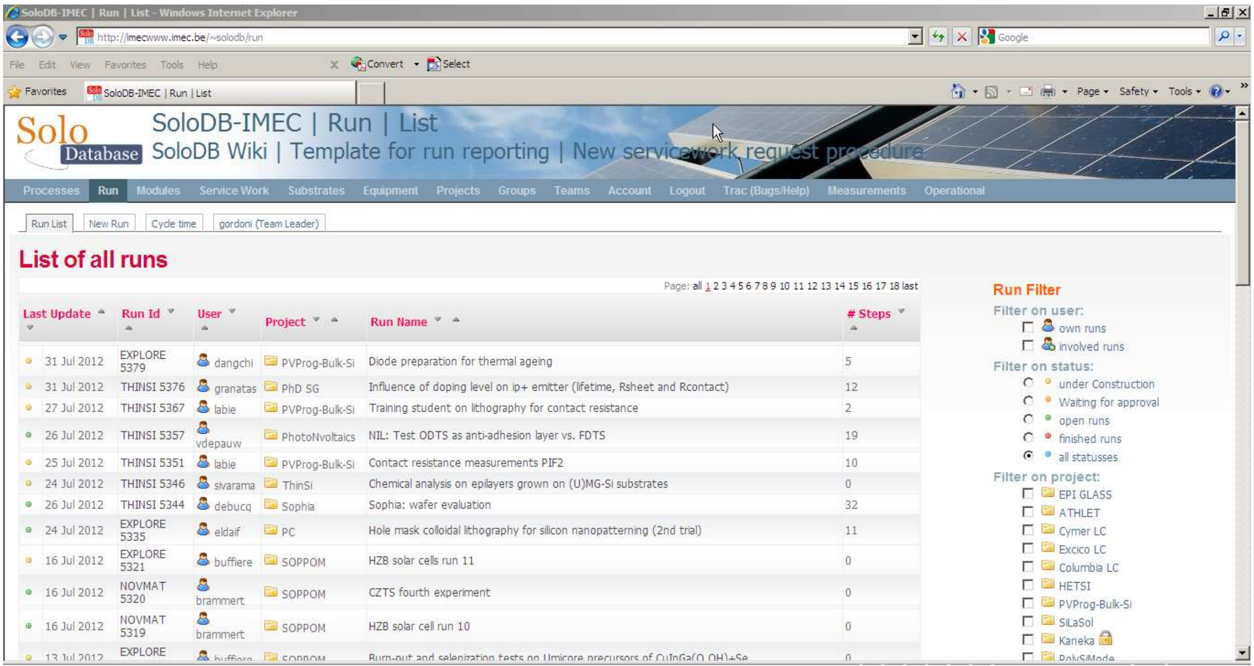


**Figure 1 : Example screen-shot of electronic database "SoloDB" used at partner IMEC.**

## *2.5 When working with operators, a manufacturing and execution (MES) system should be used to streamline the experimental process flows*

When large amounts of experiments are being run in parallel in the infrastructure and operators are being used to execute part of these experiments, the use of a "manufacturing and execution system" (MES) is recommended on top of the electronic database system. This MES and the electronic database system should preferably be one and the same system or at least linked to each other. A MES is an information technology system that manages manufacturing operations in factories and is typically also used in micro-electronics.

Such a MES enables scientists to define experiments and then have all or part of the experimental process steps executed by operators in an automated way. The MES will typically include the following features:

- Management of process definitions. This may include storage, version control and exchange with other systems of process information, recipes and best-known practices.
- Management of resources. This may include registration, exchange and analysis of resource information, aiming to prepare and execute experiments with resources of the right capabilities and availability.

- Scheduling the various experiments running in parallel, taking into account defined priorities (e.g. some experiments may have higher priority than others).
- Dispatching processing orders to operators. The operators get information from the MES about which process steps they need to execute during their shift. The MES also allows operations to be done in shifts and guarantees a smooth transition in work from one shift to the next one.
- Collection of processing data. This includes collection, storage and exchange of process data, equipment status, material lot information and production logs in either a data historian or relational database. This data allows monitoring the proper working of tools and the stability of processes.
- Process Track & Trace. Registration and retrieval of related information in order to present a complete history of lots, orders or equipment

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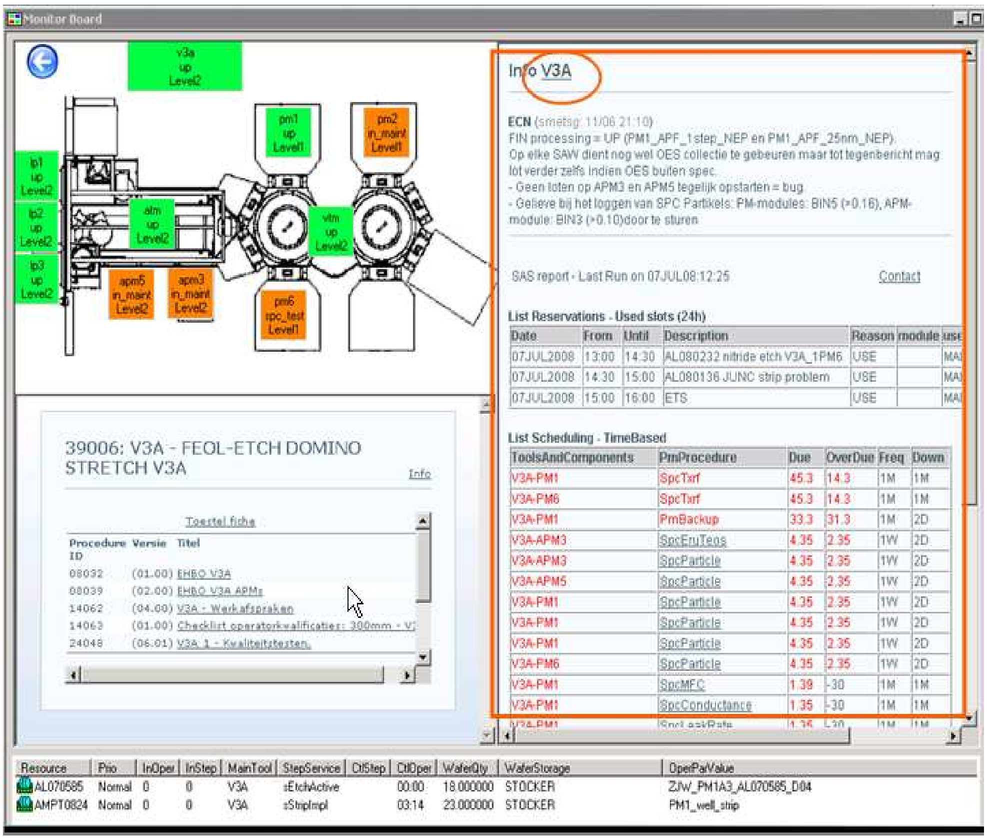


Figure 2 : Example screen-shot of “FAB300” MES used at partner IMEC.

## 2.6 SPC (statistical process control) should be applied on all relevant tools

To ensure a proper working of all tools and the reproducibility of results and baseline processes, SPC should be applied on most, if not all, tools, including the characterization tools. SPC helps to monitor processes and detect as soon as possible if something is going wrong and needs actions, as well as aims at avoiding unnecessary actions.

Since process spread is always present in experimental results, a difference needs to be made between random causes (are intrinsic to the process itself and cannot be influenced without altering the process) leading to spread on the one hand and systematic causes (deviations on a continuous basis and which possibly do vary as a function of time, e.g. wearout, heating up of systems and tools, calibration errors,…) and specific causes (sudden (larger) changes caused by major influencing causes, e.g. broken pieces,…) on the other hand. **SPC is about detecting and correcting the systematic and special causes**.

The frequency of monitoring and the parameters that should be monitored and how to do that need to be defined for each tool individually. The resulting data should be kept in an electronic database (e.g. the database that also contains all the experiments) and be plotted into graphs where the evolution of the tool can be observed over time and in which threshold values are indicated for the measured parameters. This allows defining when the tool is “in-spec” and when not. When a tool is not in-spec, it should be an operational priority to get the tool back in spec and important experiments should be put on hold until the tool is back in spec.

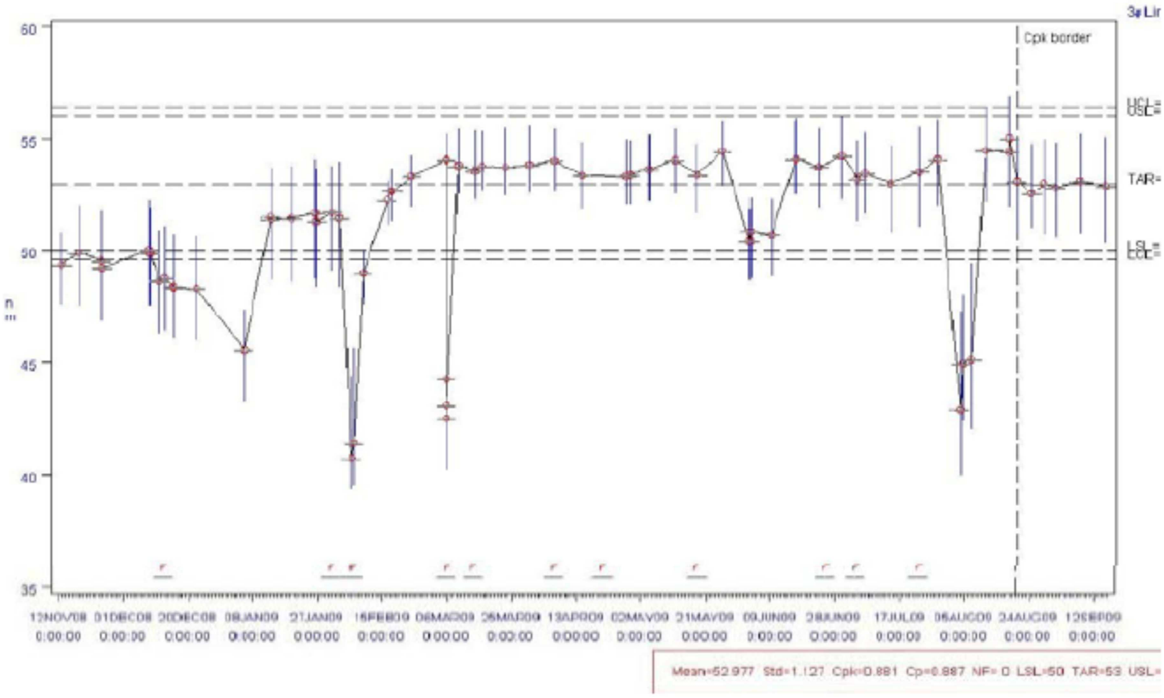


**Figure 3 : Example of an SPC graph in which a parameter is plotted as a function over time and moments where the parameter was out of spec can be easily identified.**

## *2.7 Clear role descriptions should be present for all personnel*

As part of the general work regulations, clear roles should be defined and described for all personnel. These descriptions should contain all responsibilities for each role. Each employee should be assigned one of these roles. **Role descriptions give focus for people on their specific tasks and responsibilities, and are a key element towards efficient team working**.

Some examples of possible roles include:

- Line manager: person in charge of overseeing the proper and efficient working of the infrastructure of part of the infrastructure
- Integrator: a device expert who is responsible for device integration (e.g. improving the current device architecture and processing sequence, applying new process steps developed by others into the device flow, ...)
- Basic step engineer: a scientific expert who develops and maintains processes.
- Process support engineer: someone who gives support to scientists and helps them executing technical work.
- Operator: someone who performs standard process steps and executes service work.
- Hardware responsible: a technician responsible to maintain tools.

### *2.8 A tool reservation system*

Linked to the electronic database and/or the MES, a tool reservation system should be in place. This allows operators and researchers to be sure that they will have access to a certain tool at the required time and will facilitate the efficient execution of experiments going on in parallel. The reservation tool should of course be linked to the MES and/or electronic database system described above.

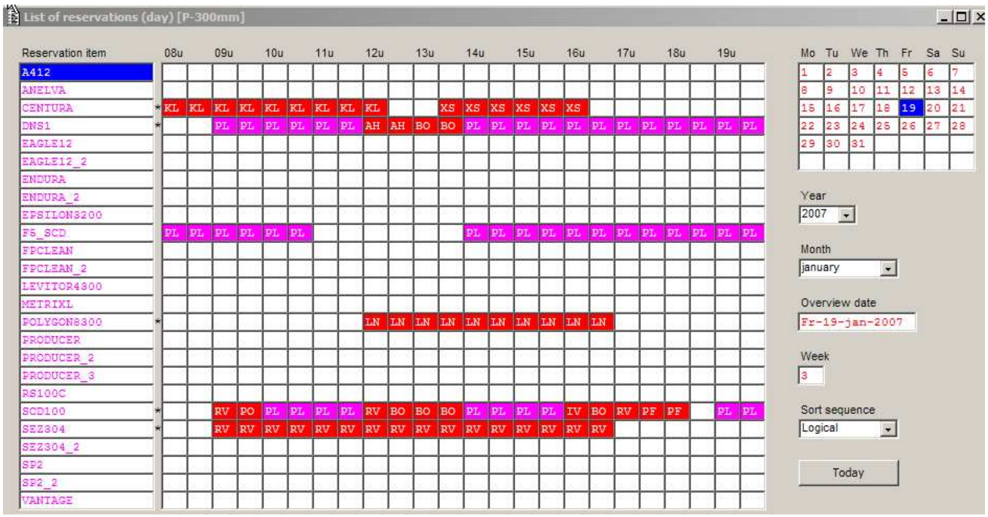


**Figure 4 : Example screen-shot of the tool reservation system used at partner IMEC.**

## 3. Conclusions

Even during the R&D and innovation process, day to day operational excellence requires the development of the correct organizational and logistics system, which defines the correct way to work. This deliverable is based upon experience existing in the micro-electronics sector, which was gradually extended on crystalline silicon wafers and silicon solar cells. This experience is useful to any other photovoltaic sectors (thin films, OPV, CPV, etc.).

Such requirements and such an organisation are a necessary condition to achieve goals such as improved learning cycles, cycle time reduction, yield improvement, reproducibility, traceability, timely sharing of results and information, statistical analysis of results... aimed at optimal research efficiency, optimal collaboration and increased customer satisfaction.

## 4. References

N/A