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IMPLEMENTING KNOWLEDGE MANAGEMENT IN BUSINESS PROCESSES

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ABSTRACT

Today, the microelectronic industry is faced with considerable challenges to renew its products and to make production outputs more reliable. For this reason, experiments in new manufacturing processes are essential and must take into account the vulnerability of used procedures. Knowledge produced during the execution of experiments constitutes an invaluable element of productivity. However, formalism is missing for the process and knowledge management of these successive experiments. In particular, an experiment's return of experience, an exchange between processes and a capitalization of knowledge in time to initiate a later reuse are all primary success factors to increase the experiment productivity, but are often badly understood and insufficiently supported. Knowledge Management is not integrated into the experiment process management, and a reuse of existing experiments or information centralization for a process is difficult to achieve.

Consequently, this thesis proposes a new analysis method, called PIFA (Process, Information, Functionality, Analyze), for the management of knowledge and processes. This method is composed of three levels: The **P**rocess level helps to capture the process flow (dependencies between actions), the **I**nformation level helps in capturing the information flow to improve the information sharing within a process and between processes, and the **F**unctionality level guarantees that the involved actor has an immediate surplus value and will accept the changes implemented in the introduction of a new work methodology, such as higher information capitalization. In this work, the PIFA approach was applied in the context of experiment processes at STMicroelectronics. Based on the results, an IT-Tool (EMA – Experiment Management Application) was designed in order to support the execution of these processes, capitalize produced knowledge during the execution, and initiate knowledge reuse. After a test phase, the tool was deployed in June and it is currently used by 300 employees.

Keywords: Knowledge Management, Dynamic Business Process Management, Information Retrieval, Ontology

1 INTRODUCTION AND CONTEXT

One of the specifics in the microelectronic domain is that theoretic conception ideas are immediately tested through an experiment. Therefore, an experiment request will be written, a lot of 25 wafers will be taken during its fabrication process and executed to test the new fabrication conditions. The fabrication process of a lot is structured in different operations that have to be executed to produce the final product. The request for a fabrication process experiment is called a Special Work Request (SWR).

Once the involved people have discussed and validated their ideas (in formal and informal exchanges like meetings, email, presentations, etc.), they determine the process fabrication conditions that will be tested on the machines.

No formalization of the SWR process exists. It seems that the process is a very short process with only a few actions and therefore no formalization is needed. It can be considered as **shared implicit knowledge** about the process execution.

To clarify the process, interviews were done with involved process actors to formalize the process and to understand the responsibility of each actor, as well as the work method used to execute the process.

The interviews were done with 5 engineers (SWR process owner) and each took between 30 to 60 minutes.
The analysis showed that the experiment request produces a SWR document. Based on this document, the experiment is executed with specified conditions for the operations. At each requested operation, a manipulation of the fabrication process is done. Intermediate results, such as measurements, are produced and written down in results documents. The third action is the analysis of the experiment. The result and the analysis is written down and stored within the SWR document.

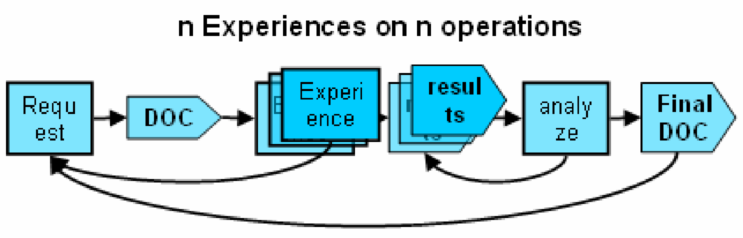

Figure 1: Special Work Request (SWR) - experiment process

1. Action: Request → document: request document, actor: DYE, R&D
2. Action: Experience → document: results documents, actor: Area, Production
3. Action: Analyze → document: final SWR document, actor: DYE, R&D

The first process analysis showed that the process has three main phases. As the experiment process is related to the production process, the process could change due to occurred problems. Therefore, the process or some actions have to be executed again as shown in the figure above. Therefore,

- following actions,
- process duration,
- the number of concerned operations and
- the number of involved employees

could change during the process execution and depend on the obtained intermediate results and on the related production process. These experiments could be considered as agile and dynamic processes that have to be adapted to local and current process environments. Nevertheless, the experiment process can be considered as linear as there is always the same action flow that will be executed; but “back loops” are possible to redo the same work with other conditions. On the other hand, the action “experiment execution” has a lot of process branches in parallel, depending on the number of concerned experiment operations, and therefore also on the number of involved persons (same action for different actors).

The illustrated SWR process explains the relation between the conception and the manufacturing part of the technology fabrication. Changes of the fabrication process could be initiated by a R&D department or a Yield Department that are in charge to improve the “stabilized” industrialized products. An area engineer will configure and prepare the machines for the experiment and the cleanroom operator will execute it.

2 ANALYSIS OF PROBLEMS, NEEDS AND CURRENT SOLUTIONS

Many different tools are used to communicate, write down the experiment request, follow-up the process flow and secure the process execution. Currently, there is no link between these applications. This causes obsolete data, and makes a follow-up very time intensive to update data collected from the different application. Often, theses updates aren’t done, so processes aren’t followed up. Related to this fact, another problem is the redundancy of information. As everyone is informed by email with an attached document about experiments coming due, the same document is used as a basis for daily work and it evolves accordingly. Therefore, different versions of documents exist and circulate

between the involved persons. The project owner is in charge of analyzing the different versions and trying to extract a current valid version.
As there is no coherent information flow or implemented process flow between the employees, judgments are made by each actor and failures or problems are often only recognized at the end of a process. However, a lot of functions could be improved and supported via better IT functions.

3 GOALS OF THIS WORK

The goal of an exchange method in this context is to improve the knowledge sharing around experiments and/or problems that might otherwise not be shared with other experiment teams within the same company. Normally this information is not shared, since the experiment are independent and the information does not have a high importance compared to the daily information flow, manufacturing problems and crisis management.
This information category is more qualitative than quantitative. Only the positive results concerning a modification in the manufacturing process are communicated. This work concentrates on this informational aspect.

4 LITERATURE ACQUISITION

4.1 Knowledge Management Concepts and Definitions

Organizations increasingly focus on Knowledge Management. However, different definitions and interpretations of Knowledge Management exist. In this work, we define "Knowledge as an immaterial object that is a temporally stabilized comprehension resulting from interpretations of information, human experience and reflections based on a set of beliefs in a specific context" based on the definition of [1]. The formalization of this immaterial object becomes information in a material form that could be reused to build up the initial knowledge. Therefore, the notion of "knowledge object" is used to refer to these characteristics. In this context, the notions of implicit and explicit knowledge are often used. Implicit knowledge resides inside humans. Explicit knowledge is the formalized implicit knowledge.
Based on the given definitions, Knowledge Management activities should help to capture and to spread the existing knowledge in order to keep the information current and to optimize the enterprise and individual performance by a reutilization. Therefore, the creation, diffusion and reuse process is a transversal activity integrated in people's daily work activities and decisions. Knowledge Management has gained in popularity in recent years, but concrete application models are still missing. Implementation approaches of Knowledge Management (KM) are often concentrated on the capitalization of produced knowledge and deliver an IT tool in order to keep knowledge in time.

However, knowledge is not a stand-alone discipline. It is produced during daily work and capitalization activities should therefore also be related to and integrated into daily work activities.

4.2 Business Process Management concepts

Organizations increasingly automate their business operations. Such business processes are typically of long duration, involve coordination across many manual and automated actions, and require access to several different databases and the installation of several application systems. A typical business process may consist of many different transactions. Coordinating the entire process correctly and efficiently places demands on the organization's IT.
"A business process is a procedure where documents, information or tasks are passed between participants according to defined sets of rules to achieve, or contribute to, an overall business goal. A business process is represented as a process with a name, version number, start and termination conditions and additional data for security, audit and control. A process consists of activities and relevant data. Each step within a process is an activity, which has a name, a type, pre- and post-conditions, scheduling constraints and a role. The role determines who will execute the activity." [2].

"A Business Process Management System is a collection of activities organized to accomplish a business process. A task can be performed by one or more software systems, one human or a team of humans, or a combination of these. Human tasks include interacting with computers closely. A process is composed as a predefined order of tasks. Each task is assigned to a role. A role can be assigned to a group of persons or to only one person" [3].

4.3 The current Knowledge Management practices implemented in Business Processes and problematic

Different approaches already exist that combines Knowledge Management with Business Process Management. [4] already mentioned that the produced knowledge during the execution of business process represent the organizational or corporate memory. Furthermore, approaches exist to model the knowledge flow in business process. The KDML (Knowledge Description Modeling Language) [5] allows modeling the knowledge flow, need and production during processes.
However, even different approaches exist, they don't respond to the need to capitalize knowledge within processes as needed knowledge and share and distribute it as desired knowledge within different process or backwards the processes.

Therefore, the problematic could be formalized as follows:

How can the knowledge creation activities related to business process be analyzed with the goal to support and implement "real-time" knowledge capitalization into business processes?
How to implement and improve knowledge creation activities that focuses especially on keeping the produced knowledge in time and on initiating a knowledge sharing across organizational and process boundaries?

In order to respond to this problematic the PIFA approach was developed based on the discussed characteristic of knowledge and business process management and the described context of experiment processes. This approach is especially based on approaches of [6], [7].

5 THE PIFA APPROACH - AN ANALYZING METHODOLOGY

5.1 The different entities of PIFA

Our method, PIFA, has been developed in order to formalize a process and capture the related information flow and executed functions. The distinction especially allows the formalization of which information is needed and desired to execute an action. The basis of the analysis is therefore the **action** of a process, which could include different functionalities. Furthermore, the user's need is taken into account. Different model approaches already exists to manage processes by modelling, optimizing and supporting them. Technical approaches are known since years and are established as standards like Petri nets, IDEF or KDML. PIFA could also use theses approaches to determine the technical approaches. However PIFA is more concentrated on combining the human and the process part. Therefore, PIFA is approaches helping to combine the user need of information and of a process and analyses the surplus value for them to guarantee the acceptance. Therefore, PIFA describes the environment and is more concentrated on the goal and benefit of an analysis, than on the technical part. However, technical standards or existing modelling languages could be re-used for the PIFA approach.

Processes are the structured execution of actions. An action (central circle in the schema above) can be executed if all **o**pening **c**onditions (oc) are met. These conditions are distinguished as workflow conditions (W) and information conditions (I). Information could be transferred in implicit (Impl.) or explicit (Expl.) form. Once all conditions are met, the action can be executed by a person having the competence to execute the functionalities. After completing the action, the following process flow from the information flow (explicit/ implicit and sent to whom/saved in which tool) is also distinguished. These are considered as finishing conditions (fc).

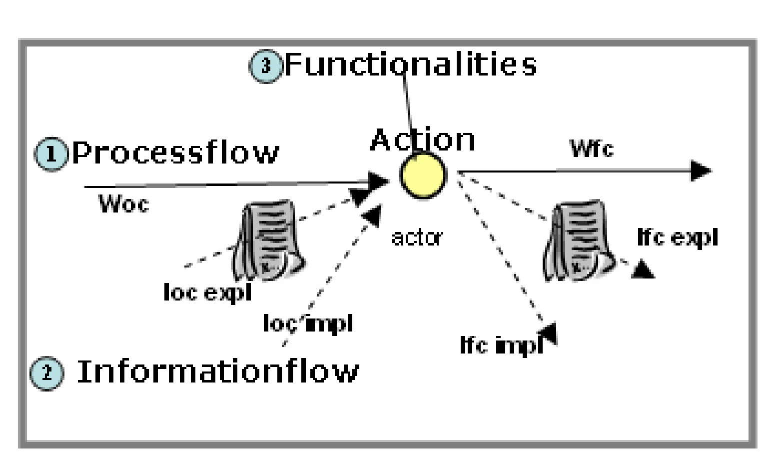

Figure 2: Principle of the PIFA analysis [6]

Each action can be composed of the three following parts:

- The **Input:** (opening conditions for an action): All dependencies of previous actions, as well as all needed information to start its actions are identified, as well as its format and its source. The source of this information can be human or an IT tool and it is transferred in an explicit or implicit way by pushing or pulling methods.

- The **Functionalities**: Most of the needed functionalities that are part of the action are identified based on information and on business rules. For each action, a group of persons is identified who have the competence to execute the action. This group will be characterized by a name as well as the role that identifies the analyzed action with a person or a group of people.

- The **Output** represents the produced information during the execution of an action: following actions depending on the results of the actions will be identified as well as all produced information and where it is stored or sent to. Therefore, the relation between actions is formalized as well as the information flow.

This characterization is explained in more detail in the following:
Figure 3 proposes the PIFA approach in a complementary and more detailed way than figure 2.

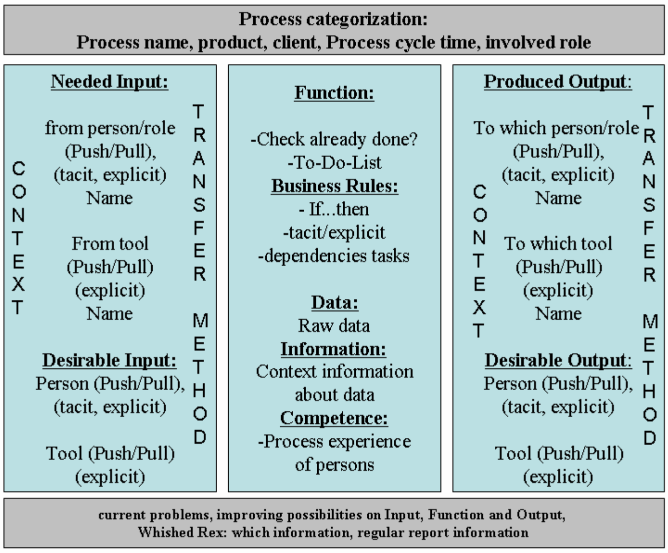

Figure 3: PIFA template – Process Information and Functionality Analysis [7]

These described parts are the heart of a process and each action. By applying PIFA, it is also important to keep in mind two additional aspects of a process and action analysis as this work is especially concentrated on the re-use of knowledge backwards the same process and between processes:

A process is unidirectional to produce a good or a service, but it might be convenient to introduce an information flow backwards the process to give a **return of experience (REX)** to all involved actors as well as to introduce a cross-over knowledge sharing between processes. Therefore, part of the analysis should be to identify all desired return of experience about a process or an action.

Additionally, the process has a certain **context** to describe itself. Each action is related to a process and has therefore a specific action and process context. A part of the context can be formalized as information – contextual information. Theses information could exist already at the initialization of the process or could be produced during the execution of the process and help to better classify the process and the action as well as support the internalization of information into knowledge.

PIFA is a help to formalize complex processes, especially organizational transversal ones. The PIFA figure (cf. figure 3) can be considered as a template to do interviews with the process actors and managers to understand and formalize the process. The idea is to follow-up different process' executions to formalize them. The goal is to capture and formalize the flowchart of the different actions and the associated produced information in real executed processes. Therefore, PIFA has three different **A**nalysis levels:

- A. The **P**rocess / action level
- B. The **I**nformation level
- C. The **F**unctionality level

For each action, the previous action, input information, and functionalities to transform input into output are analyzed. Therefore, three different levels of PIFA are established:

A. The process level:

Formalize the process flow of each analyzed process and try to build a generic process model supported via Business Process Analysis or Business Process Re-engineering approaches. The generated model should also be very flexible to support dynamic changes within process instances or in the process model. By being as flexible as possible, the process model will represent the "real world" - the real executed process - as precisely as possible.

We illustrate in the following an example of a process analyze:

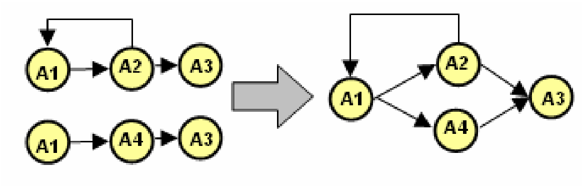

Figure 4: example of a PIFA result

The **process level output** is an optimized process model containing actions and dependencies between actions as well as opening and finishing conditions, meaning to establish different rules for the action and its associated process flow.

The PIFA-process level covers the described Input and Output parts in the previous chapter in terms of process conditions for opening and finishing actions.

B. The information level:

Formalize the information flow associated to the process. In particular, the current used type (implicit/explicit) and the used tools are analyzed to understand and formalize the current context and used infrastructure. The discovered information flows help to merge information to the right action and therefore at the right time and to the right people. The information flow should not be supported only in the direction of the process, but especially backwards through the process (a return of experience information flow) and cross-over (between) processes. Therefore, the needed and desired knowledge especially is analyzed. The knowledge produced within a process should be capitalized as needed knowledge to give an immediate surplus value to the employees and be reused as desired in the future. Therefore, the contextual information annotation of processes and its produced information is primordial. Knowledge management techniques such as ontology, annotation and semantic approaches could support this level. Especially, process domain ontology should be built. This ontology will be used for the process management to annotate the produced information within the processes. The goal is to capture the individual knowledge and diffuse it over organizational barriers in order to build up a collective knowledge (organizational memory).

The PIFA-information level covers the described Input and Output parts in the previous chapter in terms of information needed and produced within an action. Additionally, it represents the context and the return of experience parts as therefore the ontology can be build and additional process information flows could be introduced by responding to a return information flow backwards the process as well as between processes.

C. The functionality level:

Formalize the functionalities executed within an action in order to transform the input information to output information. Functionalities are formalized by interviews based on the PIFA template as well as on observations of the analyzed process actions. In discussions with the interviewees and based on the formalization of these functionalities, problems are analyzed and improvement possibilities are detected. This optimization represents additional surplus values for the companies and for the users and gives the necessary incentives and motivations to the users to accept a new work methodology. This methodology is enriched by an extended knowledge capitalization and contextual information annotation and an improved desired knowledge sharing.

A process execution has always human interactions. We consider that every employee has its habitudes and resists to changes. It is well known that we have to pay attention on the potential high barriers of acceptance. Empirical studies have already shown that users of IT systems don't enter information even if they have a personal gain in the future [7].

The **functionality level output** is an optimized process model merging functionalities to each action. These functionalities could be improved and gives a surplus value to the actor. This helps to minimize the resistance of the users to accept on the one hand a new tool and on the other hand it reduces also the resistance against knowledge capitalization.

This PIFA-functionality level covers the described functionality part in the previous chapter. It analyzes which functionalities are executed based on which business rules and with which information.

5.2 The goal of the differentiation of the three levels

PIFA can be applied on all types of processes, especially on knowledge intensive ones, as it formalizes the workflow and distinguish the associated information flow of a process.
The three levels of the PIFA-analysis guarantee to track a process model representing the real process, track the information produced and identify necessary contextual information to describe the process and formalize improvement possibilities to reduce the user resistance against changes in the current process, the work methods and the knowledge capitalization, often considered as surcharge.
PIFA can therefore help to build up a knowledge management system that combines knowledge management and workflow management activities.

- The process level constructs the process model for a workflow management tool aspect.
- The information level constructs a knowledge capitalization, sharing and retrieval model supported by ontologies for an information sharing via IT.
- The functionality level guarantees to include all necessary functionalities and giving a surplus value to facilitate the user acceptance.

Respecting these three levels improve the probability that a knowledge management system is accepted by users. Additionally, it integrates knowledge activities into daily work.

6 ABSTRACTION AND SYNTHESIS OF THE SWR PROCESS ANALYSIS BY PIFA

Even if the three levels of PIFA are formalized separately in order to analyze and apply methods of each domain (Information and Knowledge Management techniques, Business Process Management techniques, Requirement Engineering techniques), the results have to be combined into one generic model that represents the current knowledge and process activities as well as improved functionalities. Based on this model, a new work methodology extended with Knowledge Management functionalities and improved work functionalities could be deployed.
This principle was applied to the context of experiment processes at STM. In the following, the results are presented and discussed.
6 different action types were identified as in the following table:

A1 : Experiment Definition
A2 : Lot attribution for the experiment
A3 : Experiment instruction preparation for an operation
A4 : Experiment instruction preparation validation at an operation
A5 : Experiment Lot Treatment for a prepared instruction
A6 : Experiment analysis

Figure 5: Identified action types of the SWR process

These action types were identified during the observation and follow-up of 3 SWRs through the PIFA approach.

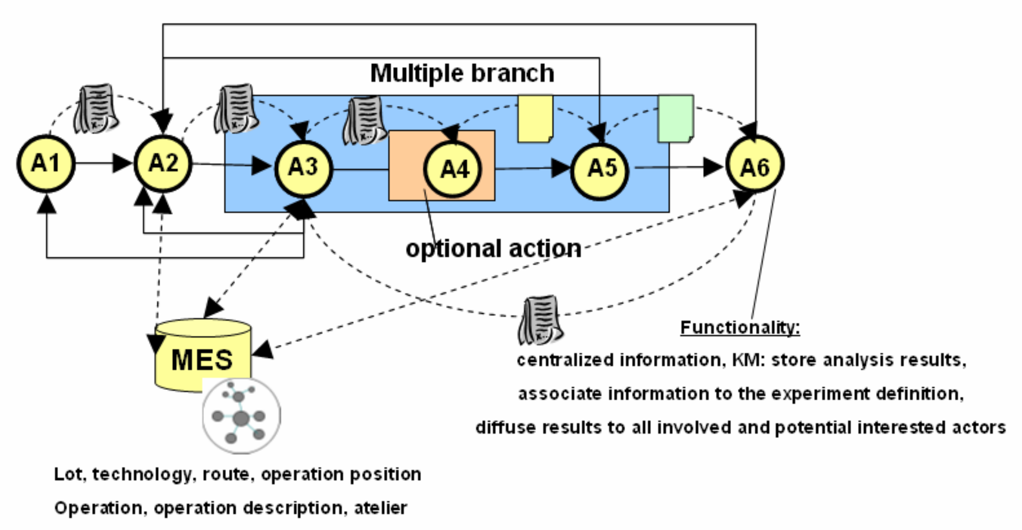

Figure 6: Integration of the three levels into one model

The deployment of a new methodology without any concrete support to motivate and initiate a change is not easy. Furthermore, the context analysis of the experiment process already showed that even existing tools could not satisfy globally the defined KM goal of knowledge capitalization related to experiment processes (especially negative results and intermediate results and comments). Therefore, a tool, called Experiment Management Application (EMA), was designed based on the established generic process model with improved functionalities, as illustrated in the figure above.
These identified specifications were analyzed and formalized, supported by the PIFA approach. The realized IT tool supporting the experiment process based on these specifications is explained in the following section.

6.1 Example for dependencies between actions (information flow and process flow)

The following picture illustrates the described principle of separating the SWR document in different information entities and reusing it in different actions (merge information to the right actions). The experiment will be defined in the action “experiment definition” and the action form of this action is structured in information components. All concerned operations and their experiment conditions will be defined. Furthermore, the wafer used for an experiment condition can be selected. This information will be reused in different actions and complemented with recipes and equipment information as described by PIFA. Therefore, the experiment information will be divided into different information entities (one entity per operation) and the information entities can be re-used according to the user needs.

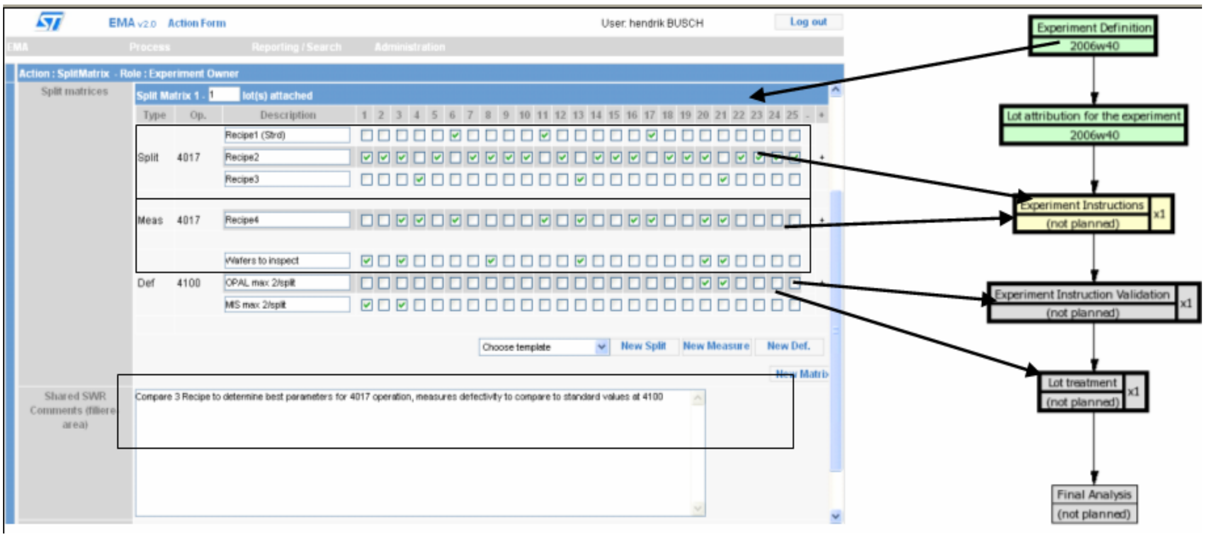

Figure 7: Information separated in entities and merge them to the right action

However, the capitalized knowledge through the execution of processes should be reused between processes. Therefore, knowledge retrieval interfaces are provided as explained in the following sections.

6.2 Knowledge Retrieval functionalities

The knowledge retrieval interfaces are necessary to introduce a cross-over knowledge sharing between processes. Therefore, two different types are provided: reporting and retrieval interfaces. In the following, an example of the 4 different interfaces is explained.

This interface allows searching in one or more categories also describing the context of the experiment, but in order to look for very precise and specific information (operation, operation description, area, actor name, recipe, and machine). As the search need can be better verbalized and more detailed and the objective is to find specific information, the result interfaces provide the experiment keywords and detail the specific searched experiment conditions such as operation number, description, area, recipes and machine.

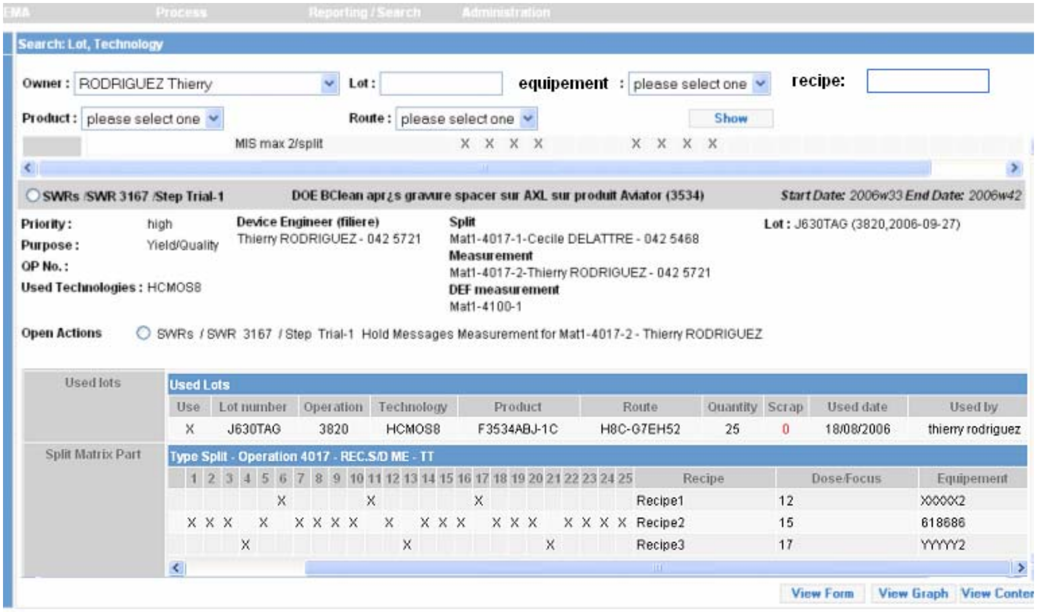

Figure 8: Experiment detail search

By searching for a recipe, lot or equipment, employee's names are displayed that already worked on existing experiments. This information retrieval could also be used to identify actors with a specific recipe, equipment or lot knowledge.

7 CONCLUSION

This work analyzed the experiment process at STMicroelectronics with the goal to capitalize produced knowledge and initiate its re-use. A lot of information redundancy was detected during a first analysis. Furthermore, scientific aspect of knowledge management, business process management and its combination was analyzed. Knowledge Management provides techniques to capitalize and diffuse knowledge. However, the domain has to deal with a user resistance against changes and capitalization as it is often considered as surcharge.

Business Process Management was initiated to automate the execution of processes. However, the human interaction and the dynamic aspects of business process became increasingly important. The integration of knowledge sharing aspects in business process management could initiate the capitalization and reuse of knowledge as well as support daily processes.

The implementation and deployment of a new work methodology can be supported by an IT tool. Therefore, the application of PIFA on the context of experiment processes allowed specifying and designing the Experiment Management Application (EMA) - a tool to support the experiment process and its associated and produced knowledge.

PIFA can be considered as an approach to detect the needed and desired knowledge flow associated with business process. Desired knowledge flow is often limited because of organizational barriers. Knowledge Management techniques such as ontologies, semantics or annotation, used for a capitalization and retrieval, could support and improve this desired knowledge flow. To integrate and deploy this desired knowledge flow, the functionalities detected by PIFA and associated with the process have to be improved to give incentives and motivate the user to accept the new work methodology by integrating KM aspects of the desired knowledge sharing.

EMA integrates the generic experiment process model in order to manage the execution of process experiment instances. The action form (user interfaces of an action) will, on the one hand, support the execution of the functionalities of an action and allow the continuation of the process by completing an action. On the other hand, knowledge capitalization methods are also provided through these action forms. These knowledge capitalization methods are based on the principle of annotation and semantic approaches supported by a domain ontology. The practical integration in EMA is based on the analyzed and formalized experiment domain ontology. The capitalized knowledge through these

processes will be used as contextual information in order to initiate a knowledge re-use by integrating an information flow backwards through and cross-over between processes.
The EMA tool, based on the scientific framework of knowledge management and business process management, supports in particular certain activities for written information content produced and associated with business processes.

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