INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED11
15 - 18 AUGUST 2011, TECHNICAL UNIVERSITY OF DENMARK

DESIGNING PATENT PORTFOLIO FOR DISRUPTIVE INNOVATION – A NEW METHODOLOGY BASED ON C-K THEORY

Yacine Felk [1,2], Pascal Le Masson [1], Benoit Weil[1], Patrick Cogez[2], Armand Hatchuel[1]
(1) CGS - center for management science, Mines Paristech, France
(2) Technology R&D, STMicroelectronics, Crolles, France

ABSTRACT

In this paper we explore a key element of knowledge intensive innovation, the issue of patent generation. Whereas patent is often considered as a 'by-product' (output) of design activity, we focus on the situation of disruptive innovation, where recent studies in management of innovation have shown that patent is particularly crucial. Only few methods are based on patent modelling, they rely most of all on problem solving design reasoning. Nevertheless, these are not adapted to disruptive innovation where both creativity and problem solving are mandatory. Looking at this situation as an issue of portfolio design provides a useful heuristic for management insights of a "design for patentability" approach. Our contribution is defined in two parts, first a patent model and second, a process of patent generation. We propose to model patent information as an (Action, Knowledge, Effect) triplet. In disruptive situations, all three elements (A, K, E) are unknown. Based on this modelling, we show through an illustrative case how a team in charge of disruptive innovation exploration proposed several (A, K, E) triplets. This work suggests a method "C-K Invent" derived from C-K design theory.

Keywords: Patent, C-K theory, Industrial Property, Disruptive technology, Design Teams

1 INTRODUCTION

Throughout the history of technology-based enterprise, patents have played a key role in technology diffusion. For industries based on intensive and rapid innovation, such as the semiconductor industry, it is generally accepted that given the rapid pace of technological change and high level of capital expenditures for product design, patents are a critical issue. For rule-based innovative design fields, where innovations are based on incremental approaches, patents can be considered as a problem-solving issue. In stark contrast, for disruptive innovative design fields, patents are considered both as knowledge production issue and as creative process.

There is a lacuna in the literature with regards to disruptive technology, and for this reason we decided to explore, via a case study (and with experiments), the issue linked to patent and disruptive innovation in the semiconductor industry. Through modeling and an empirical study we highlight two points. The first is that patent information can be interpreted as an Action (A), Effect (E), Knowledge (K) triplet. Second, the application of the (A, E, K) model via empirical experimentation conducted in the semiconductor industry, we show how a design team in charge of a disruptive innovative design field was able to provide a method for structuring the process of patent portfolio proposition.

In the following, section 1 will review the existing literature on patent evaluation and IP design strategies, which suggest several research questions regarding patent proposition in disruptive innovation situations. In section 2, we present the research setting and our methodology. The patent information modeling and experimental case is presented in section 3 following on from this, we turn to the analysis and discussion before drawing out conclusions on our findings and possible next steps.

2 LITERATURE REVIEW

2.1 Patent Evaluation: where do patents come from? What are they for?

A patent is a document, issued by a governmental authority such as the National Institute for Industrial Property in France (INPI) or the European Patent Office (EPO) which gives a set of exclusive rights to an inventor or their assignee for a limited period of time in exchange for a public disclosure of an invention. The grant is issued to the inventor of this device or process after an examination that focuses on both the novelty of the claimed item, its inventive steps and its potential utility. Articles 52 and 53 of the European Patent Convention (EPC) [1] stipulate that an invention must be "novel, non-obvious, and have utility". Novelty refers to the fact that you can't patent something that is already known (or has been published). "Non-obvious" means that the invention could not have been conceived by someone "having ordinary skill in the art" without undue experimentation. "Utility" says that an invention must perform some function, be operable, and must be beneficial to society. The right embedded in the patent can be assigned by the inventor to somebody else, usually to his employer, a corporation, and/or sold to or licensed for use by somebody else. This right can be enforced only by the potential threat of or an actual suit in the courts. The stated purpose of the patent system is to encourage invention and technical progress both by providing a temporary monopoly for the inventor and by forcing the early disclosure of the information necessary for the production of this item or the operation of the new process.

The literature emphasizes on the value of the rights afforded by patents. Patents are often considered as an option where *patent thickets* [2] allow the ability to maintain an option within a particular area of technological exploitation. Patent thickets can be used for several industrial or commercial purposes [3] such as invention protection, blocking or sleeping patents or licensing and cross-licensing. Given the importance of patents, and their licensing, to innovation in several firms in the area of information technology, the semiconductor industry can be shown to have adopted an aggressive licensing strategy sicne the 1980s. For example, IBM's revenues from patent licensing increased from $646Million to $1.5Billion in a five-year period (between 1995 and 2000) [4]. Moreover patent information allows conclusions about a firm's patent activity [5] and the quality of its patent portfolio. Literature has often suggested several metrics for patent evaluation, particularly for measuring the quality of a patent or a group of patents [5]: ratio between granted and filed patents, international scope [6], technological scope [7], and citation frequency [8].

Therefore patent is considered as a 'by-product' design activity, where they are defined when products are almost designed. In that sense they can be a measure of R&D output since it can used as an indication of activities [9] that may lead to marketable technologies (and also may indicate changes to the specific rate of technological change). It is generally accepted that patents contain important information for technology management, which enables a precise competitor analysis [10]. This information is particularly interesting for the evaluation of a firm's innovative potential and mapping of technological trajectories [11] [12]. All these metrics suggest that patents are the outcome of a design activity but this is mostly equated to a metric of R&D activity output. In these cases, patents allow the innovator the ability to acquire value by protecting an already completed design activity (such as from the results of technology research results or from prototyping). If we look more into the details of the processes through which patents are created, there are classical bottom-up approaches (where patents are R&D results) or top-down approaches (where patents are considered as an objective assigned to researchers and scientist).

Nevertheless there is a third situation where there is a need to protect expected value from an emerging technological field. In this case which could be qualified as a "disruptive innovation", strong patent portfolio are needed. Lindsay and Hopkins through an experience at Kimberly-Clark company emphasize the fact that "one aspect that has not received much attention previously is the role of intellectual assets" [13], and give some recommendations about what should be done for generating and drafting Intellectual Assets. For the case of disruptive technologies they advocate that design teams "prepare for future new and disruptive business opportunities that could be protected or strengthened by the intellectual asset generated". They insist on the organization (what they call IA groups), what should be protected (products, what to be aware of (mostly emerging technologies), and to be aware of disruptive technologies impact on IA strategy. More recently, Nissing [14] describes an approach called "strategic inventing", whereby products are designed with an emphasis on strategic positioning of intellectual property. Nevertheless any method is proposed, this "obscure approach" enables inventors to determine where significant patentable opportunities exist (based on the art and invention creation in a specific field, focusing on market differentiation that may be leveraged for competitive advantage). Therefore we can ask ourselves, what happens when patents should be granted before design activity or a research work? How to protect an emerging design field with appropriated patents? In this kind of situations patents become a design object or a purpose of design.

2.2 Designing patents: which model, which process?

Therefore, disruptive innovation situation involves patent design as an object. Therefore, if portfolio patent should be designed, what could be a model of this object? In a first step, we tried to identify research works in the field of design, so as to analyze the contributions of practitioners and academics we looked at peer reviewed journals in the discipline of engineering design (e.g: Journal of Engineering Design or Research in Engineering design). Through our literature review in this academic field we couldn't find a complete conceptualization of patent information or patent interpretation as a design object. Nonetheless we present in this section three model, the first one is a formal model of what can be a "design language" that is object oriented. The second and third one are two patent model conceptualization.

If patent is an object of design, therefore we should rely on a design theory and a model of what should be designed. According to design theory, one of the models that can be used is the FBS (Function – Behaviour – Structure) [15] [16] model. With this model designing an artifact involves a series of elementary steps which 'transform', first the desired function of the artifact (roughly its purpose) into its expected behavior (which will bring about the function); then the expected behavior into a structure (intended to enable the artifact to exhibit the expected behavior). After further steps of analyzing the structure for its actual behavior (evaluating it against the expected behavior, and possibly reformulating the expected behavior) the structure is finally transformed into a design description. Therefore, when considering disruptive innovation situations, for which patents can be prior to design activity, this suggests several questions about the language to adopt for patent description and patent modeling: what can be an equivalent of F-B-S model for patents?

Regarding patent information conceptualization, one approach proposed in the literature is TRIZ, the acronym for 'Theory of Inventive Problem Solving' which is based on contradiction solving. Based on the analysis of more than 400000 patents data, Altschuller [17] proposed that any technical problem could be generalized and abstracted by a surprising small number of generic inventive principles and patterns. TRIZ has been used in a lot of ways to describe 'reverse inventing' processes [18], explains design processes and design alternatives or product DNA [19].
Therefore TRIZ is based on the identification of (Contradiction / Solution principles) couples. In case of disruptive innovation, this model suggests several limitations. One limitation is that TRIZ proposes a problem solving method and process when problems have already been defined, which is not the case for open-ended situations where exploration and potential exploitation avenues are unknown, the situation for disruptive technologies. For disruptive technologies, this leads to the questions; what are the problems to be solved? For what kind of opportunities? TRIZ and derived methods, such as Advanced Systematic Inventive Thinking (ASIT) do not provide answers to these kind of questions,particularly so for "out-of-the-box" approaches and methods [20]. Thus, the literature has provided little contributions on patents as a design object.

We found a third model, which proposes an interpretation of patent information using design theory [21] [22]. This theoretical work dealing with patent process improvement [23] proposes to decompose patent information and to model it in three data classes: Actions, Effects, Knowledge. This work is based on research study made by Couble and Devillers [23] at CEA (the "Commissariat à l'énergie atomique et aux energies alternatives"), a French government-funded technological research organization and has been used by Sincholle [24] in his research study at THALES (which is a world leader in mission-critical information systems for defence and security, aerospace and transportation). Patent are represented as a "sentence" that describes a recipe where Actions represent the interventions made on objects and their interrelations, Effects (internal or external) are action consequences and Knowledge is the set of technical information used by the invention. Patent grant criteria can therefore be read in a new way:

- Novelty: Implies that the ‘A →E’ sentence doesn’t already exists in K.
- Invention Step: Means that the set of ‘A →E’ sentences might be included in K without expert identification.
- Embodiment: Suggests that (A, E, K) triplet must be understandable and repeatable by technical experts.

With this (A, E, K) model, TRIZ model based on (Contradiction / Solution Principle) can be interpreted as the solution of two contradictory effect combination ($E_i x E_j$ / Actions that enable to get $E_i x E_j$). Solution Principal therefore is a combination of Actions that enable to get both these two effects ($E_i x E_j$)

2.3 Research questions

Therefore we presented the literature position regarding the patent proposal issue, In case of disruptive innovation this (plus the identified lacunae earlier in this section) suggest several research questions regarding patent generation and definition:

Q1: How to model patent information and what “object language” (representations) to use in case of disruptive innovation situation for patent design?

Q2: Based on this patent model, what could be a process that enables to generate, discuss and propose strong patent portfolios?

3 METHODOLOGY

Our methodology is an experimental approach based on a patent model. We first propose to model patent information and to conceptualize a patent as a design object. Building on this conceptualization and model, we conducted an empirical study of what is termed the “Advanced R&D” team at STMicroelectronics (the European leader of semiconductor industry). We worked with this design team in charge of exploring several new disruptive technologies for a deep and rich empirical case study. Among this team’s work we focused on a specific item called “3D-Integration” (which consists merely in stacking several semiconductor devices with new interconnections). Whereas traditional approach in semiconductor industry is based on planar technologies [25], this team is in charge of developing technological blocks enabling to stack several devices. Our aim was to analyze the process through which this design team is able to propose patents in case of disruptive innovations.

4 MODELIZATION AND INSIGHTS FROM EXPERIENCE

4.1 Modelling Patent information as a design purpose

C-K theory is a design theory that offers a formal model of creative thinking where design is a goal oriented activity, with a concept-knowledge dual expansion in case of disruptive innovation [21].. One of the application of this formalism to patent evaluation issue was proposed by Sincholle [24]. His research work consists in evaluating patent positions through design reasoning by identifying new business opportunities using what he defines as a “generative concept”. Patents content describes a solution to a technical problem, this is represented within the C-K [21] framework shown in Figure 1.

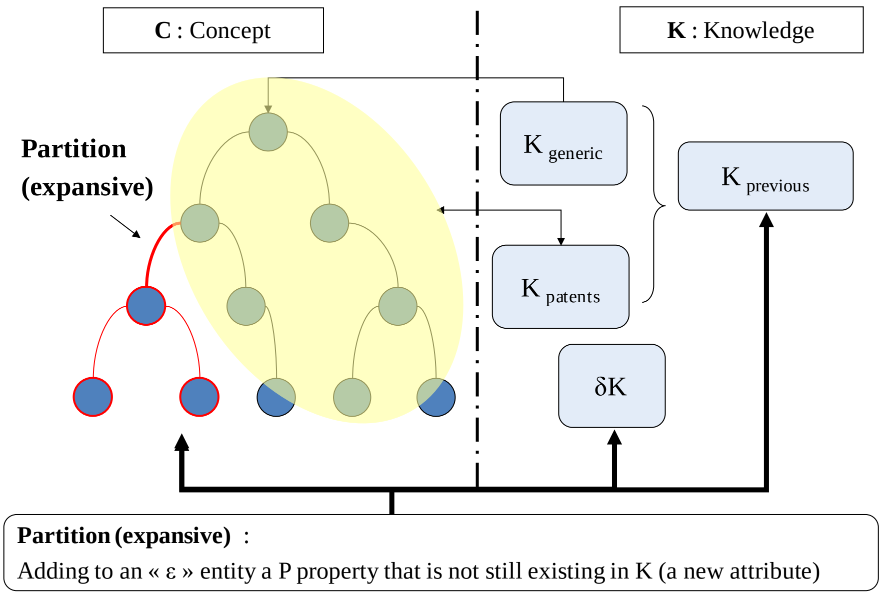

Figure 1: Inventive step within C-K theory [23]

The (A, E, K) model helps to distinguish several patent proposal situations; we present some of them in Table 1. To take an example, for the case of "Research" in the table, if the aim is to reduce the 'skin effect' (a physical phenomena that reduces interconnection conductivity) within electrical interconnection in Integrated Circuits, Action (e.g working on materials or device structure) and expected Effect (skin effect reduction) are already known. Therefore, what has to be produced is the Knowledge. For the case of "Technology" in the table, we can take the MEMS (Micro-Electro Mechanical Systems, which is the technology of very small mechanical devices driven by electricity also referred to as micro-machines) example, where the Action and the Knowledge classes are already defined (use of semiconductor substrate with etching, thin-film processes) but what has to be specified are the Effects that are explored and the functionalities aimed (e.g: accelerometer, gyroscope, etc…). One particular aspect considering disruptive innovation is that every element of the (A, E, K) triplet is unknown, which is consistent with the fact that in innovative design situations a C_0 is necessarily an expansive partition [22].

Table 1: Patent ideas typology within (A, E, K) framework

	A	E	K
Research	Known	Known	Unknown
Technology	Known	Unknown	Known
Disruption	Unknown	Unknown	Unknown

4.2 Towards a C-K based method through a case-study

In this section we will illustrate how using innovation design theory (C-K Theory) and the (A, E, K) model, a design team was able to derive a methodology for patent portfolio proposition. We will show that in case of disruptive technology situations classical tools based on (*Convergence Divergence)* process would have been insufficient.

4.2.1 Usual Process for patent idea generation and evaluation

At STMicroelectronics, IP (Intellectual Property) activity is aligned with the "historical" practices, used for business and value protection and its customers. This activity covers all of STMicroelectronics' R&D activities and product business units (with a particular attention for key strategic sectors) with the goal of maintaining a portfolio patent with more than 20000 patents and 500 to 800 patents pending per year [26]. Patents are obtained in several fields such as circuit design, manufacturing processes, packaging technology and system applications.

During our case exploration, we couldn't find a systematic or repeatable process for patent idea generation and identification; nevertheless we identified several methods that are used in particular situations. Often enough, patents are considered as research or experiments result, where patent are the results of new phenomenon discovery. A second way for patent ideas generation is a serendipitial fuzzy process which happens during coffee breaks or lunches. A third way that is used is conventional brainstorming [27], and some further elaborated versions of this techniques such as C-Sketch / 6-3-5 Method [28], that are used by workgroups to solve a technical problem. Moreover, contrary to early phases of idea identification, the evaluation process is well documented and well-established. Actually each idea is evaluated through a specific process during patent committees which consists in evaluating ideas regarding several criteria including the patentability ones (novelty, inventiveness and embodiment). These committees are specific meetings where ideas are both evaluated, enhanced and perspectives for developing opportunities are identified (such as prototypes or collaborative projects).

4.2.2 What happens in case of disruptive technologies?

Advanced R&D in STMicroelectronics since 2006 is in charge of exploration of new design space such as "3D Integration" [29] which take as a disruptive technology as it introduces new types of processes. To give an example "bonding" by itself is not a new process, but at nm scale it requires considerable control of material quality and surface properties for good bonding energies, therefore new technologies have been developed such as "oxide-oxide" bonding [30] (and it is the same for "drilling" process, "etching", "alignment", etc…) [31] and new types of interconnections (called TSV for 'Through Silicon Via'). This new concept suggested several questions: what could be the applications that use this new approach? What are the technologies that should be developed? What kind of patents should be proposed? Should we consider that once a technological block is developed, all the application using this block should be patented? In section 2.3, we've shown that it it is particularly difficult to know what should be patented when both (A, K, E) are unknown? In the following we present what this design team proposed to get out of this kind of situation.

4.2.3 What approach could be expected for patent proposition?

A first attempt consisted in defining device architectures enabled by a new approach such as "3D Integration". This approach led the design team to explore what could be the different means to design a functional product (P_i) connecting components (C_i) (with functional faces) made of planar technologies. This allowed them to propose several product architectures. The main output of this first brainstorming session was the identification of several architectures enabled by "3D-Integration" approach, depending on active (or functional) face positioning (Backside or Frontside) and embodiment of interconnection through substrate called TSV (for Through Silicon Via) realised by etching or drilling processes steps
Unfortunately, this first approach didn't help to identify architecture value, but suggested several further questions: which architecture should be patented (and which not)? Based on what kind of criterion? For which value?

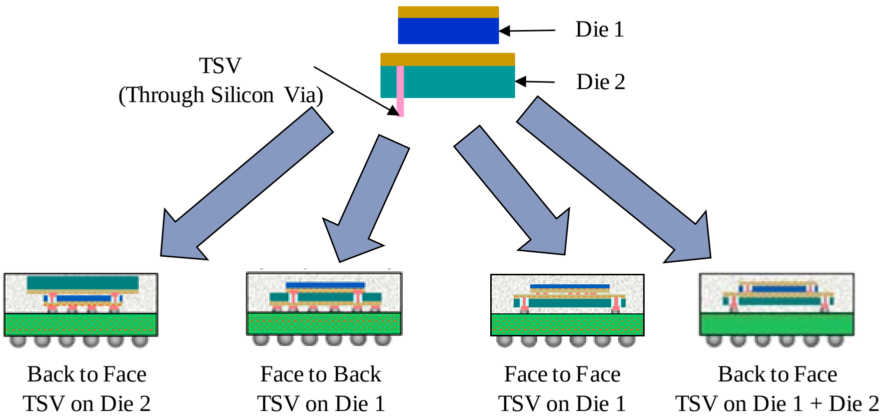

Figure 3: Device architectures as a C-K model output

In fact, we can imagine that *a priori*, any product architecture exploiting 3D Integration enabling technologies such as Through Silicon Via (TSV) should be patented (this suggests that there are plenty of potential patents). In this case, this patent strategy would be very expensive, but on the other hand if we use patent grant number as a performance metric for R&D activity, it could be very positive (whereas the design team would have no idea about application value). Moreover, if we use the (A, E, K) Model for patent interpretation, '3D Integration' is a concept where A, E and K are actually unknown. Indeed, the design team at the beginning was not able to describe A classes (should TSV be done before or after bonding?), neither E classes (what about electrical performances? What about thermal behaviour?) and K (what knowledge should be produced ? Which issue should be highlighted?). Notwithstanding this first draft underlined the necessity to uncouple two main issues, on the one hand technology assembly introduction in semiconductor processes, in the other hand the design of interconnection for electrical signals through semiconductor substrate. We will describe in next section what the research team proposed as a method in order to build a patent corpus (or patent portfolio).

4.2.4 Insights from a case-study: patents portfolio for disruptive technologies

In this section, we will describe the process followed by the research team, distinguishing three steps.

Step 1:

As described previously, the first concept based on architectures didn't help to define 3D-Integration value as every technological pieces are already defined (embodiment, technological blocks, functions). Therefore, first step consists in introducing some new words that enable to explore new design space. These proto-words help to structure Knowledge space (in a C-K model). An example of this first step was the definition of "TXV" as an interconnection between devices rather than TSV (Through Silicon Via) which is already defined as an electrical interconnection.

Table 2: A-E-K model for "TSV" and "TXV"

	TSV →	TXV
Effect	Electrical interconnection	Different flow management (electrical, thermal, mechanical)
Actions	Defined (processes, shape)	New processes, new architectures
Knowledge	Electrical behavior (R, L, C, G)	Partly unknown, (Electrical, thermal conductivity/Dissipation)

Actually TXV are sufficiently generic to consider any type of substrate and ways of interconnecting devices through this substrate. It enables to add several passive (e.g: thermal management) or active functions to the 'via' device. This new word allowed some further investigations and expansions in A, E and K. Two elements are important at this step, the first one is that by adding abstraction to already defined devices help to enrich their meaning. The second one is that the use of these "emerging words" help to build a common meaning for the concepts explored shared between designers and researchers of the Advanced R&D team.

Step 2:

Second step was to propose some concepts based on (A, K, E) model and interpretation such as: "Design TXV that have better electrical and thermal behaviour than 2D alternatives". In this kind of concept the first part describes A (Action) which consists in realizing Via (drilling, etching, etc…) through a generic substrate (X which can be Silicon or any type of substrate such as AsGa, …). The second part of the concept describes the E (Effects) that are expected from device behaviour (electrical, thermal, etc…). This definition of (A, E) first high-concepts enable to structure design space exploration and the use of C-K models for new idea identification. With these first concepts, the Advanced R&D design team organized different workshops for ideas production and knowledge production stimulation, as C-K theory is a design theory that offers a formal model of creative thinking.

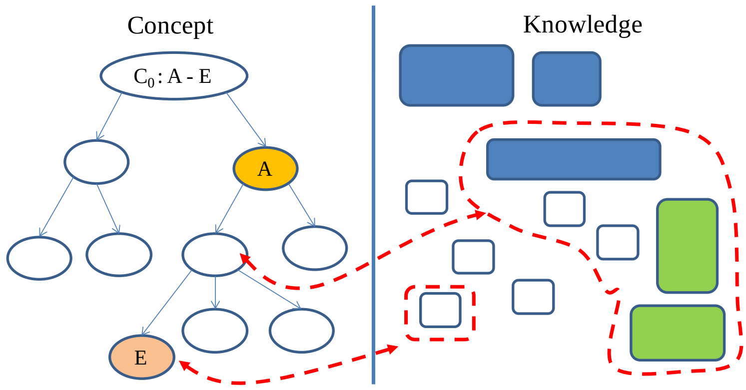

Figure 4: C-K Models based on A, K, E

Once the ideas have been identified, their classification in matrices (such as Zwicky matrices or morphological box) [32] [33] enables to visualize the design space paved and filled with ideas and potential patents.

Step 3:

As we've presented it, idea evaluation follows a specific process, based on established organisations, tools and rules. Using an A-E Matrix this enables an interpretation of the design field that has been paved and why some ideas remain at the Idea step whereas some others progress forther and are proposed as patents. We present in the Figure below an A-E matrix (similar to a Zwicky matrix) that supports a description of the design space paved (we differentiate in this matrix A-E box that represent state-of-the-art, from those which were ideas and those that remained concepts). In the table 2 below we represent the matrix regarding the alignment device issue, which is one of the key assembly technologies to be solved for 3D-Integration [34]: three items which are "Mobility", "Precision measurement" and "Localized Force" are considered for the effects (E) and for Actions several physical phenomena are taken into account. In this A-E matrix research team distinguished four types of (Ai, Ej) couples. The first one are those which remained concepts C (they couldn't propose any idea linked to this concept), second ones are the ideas I formulated. The third one are the solutions existing in the state of the art S, and last ones are ideas that became patent proposition after an evaluation

Table 3: From ideas to patents in a Morphological Matrix view

Morphological Matrix: Device Alignement issue								
		Action						
		Magnetic Field	**Electro-chemical**	**Fluidic**	**Vibration**	**Mechanic**	**Electro-static**	**Optic**
Effect	**Mobility (X, Y)**	**I6**	**I5**	**I3**	**I4**	**S2**	**C**	**C**
	Precision Measure	**P3**	**C**	**C**	**I1**	**P1**	**P2**	**E1**
	Localized Force	**P5**	**I2**	**S4**	**C**	**S3**	**P4**	**C**

C	Concept	I	Idea	S	State of the art	P	Patent

If we take as an example the alignment issue, looking closely at the (A, E) couple – (Fluidic, Mobility), form this concept (C) the design team was able to propose an idea (I) based on electro-wetting technology exploitation. This idea, presented in the figure 5 consisted in using a drop as a conveyer for several devices, enabling die placement. This idea is based on the exploitation of electro-wetting technologies. This kind of solution remained at the Idea (I3) level, because of description insufficiency of the embodiment criteria, the device sizing and drop specification (fluid type, dimensions and properties).

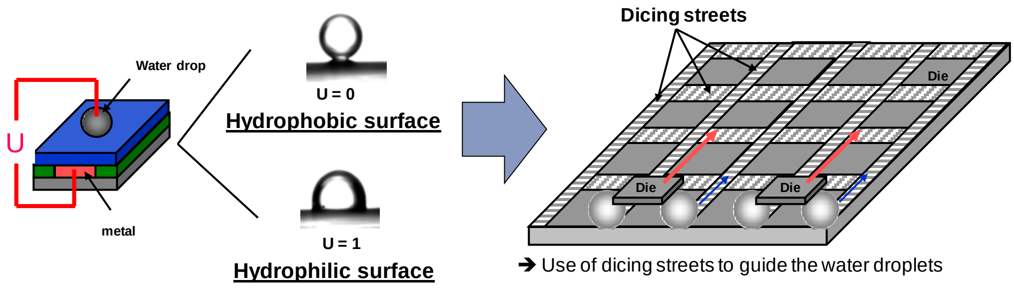

Figure 5: An idea example at Concept level (Drop use for die placement)

5 C-K INVENT: TOWARDS A METHODOLOGY FOR PATENT PROPOSAL

From this case-study in the semi-conductor industry, we outlined a methodology that enables the design of robust patent portfolios for disruptive technologies. The method "C-K Invent" is composed of two phases.

The first phase focuses on organizing and building the conceptual phase, with a first step which aims at defining (A-E) high-level concepts. These kind of "generative concepts" [24] help to enlarge the design space and identify a wide range of opportunities for a specific issue (therefore to organizing the exploration process). As we have seen, through the case study, words such as TXV are sufficiently generic to consider any type of substrate and ways of interconnecting devices through this substrate. One of the main important element of this step is the use of "emerging words" that we can qualify as a "proto-semantics" [35] that help to build a common meaning for the concepts explored shared between designers and researchers of the Advanced R&D team. These concepts facilitate the definition of specifications in terms of A (Actions) and E (Effects) expected from the designed objects. These "proto"-words have two interesting effects: the first one is that they induce commitment of each part of the design team around common objects, the second one is that it enriches their content (the main aspect to be highlighted is that with more abstraction it enables the exploration of new sides of these concepts). Thanks to these proto-words, designers are able to build a "proto"-syntax that will allow to build "A-E" sentences for patent information description.

The second step consists in structuring the exploratory design space using C-K Models, this kind of representation rediscusses design reasoning, and distinguishes the creative process from the knowledge process production. The third step consists in using morphological matrices [32] in order to clarify what are the ideas that are potential patents from design alternatives that are emerging concepts. This kind of representation enables to map out the design space that is paved by the design team in comparison with what is explored in the ecosystem (competitors, laboratories, universities, start-ups, etc…).The second phase is made of one specific step, which consists in evaluating each indentified idea through the patent committee screening process.

Table 4: TRIZ and C-K Invent methods comparison

	TRIZ	C-K Invent
Model	(Contradiction / Solution principle)	(A-E-K)
Process	$(E_i \times E_j) \rightarrow P_k$	$(E_i \times A_j) \rightarrow (\delta E, \delta A, \delta K)$
Design reasoning	Problem Solving	Expansion

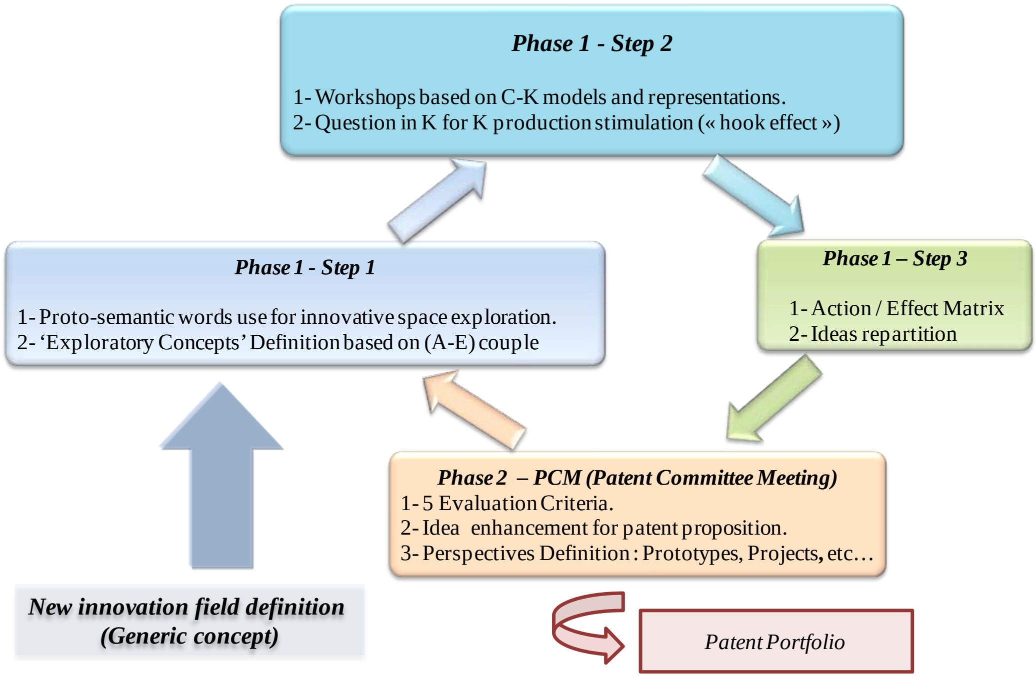

Figure 6: C-K Invent as a method in 2 Phases and 4 steps

6 RESULTS AND DISCUSSION

This paper examines the patent nature that can be proposed in case of disruptive technology. Whereas patent is often considered as a 'by-product' (output) of design activity, we focus on the situation of disruptive innovation, where recent studies in management of innovation have shown that industrial property and patent is particularly crucial. We thus provide insights of a method for a "Design for patentability" approach. One of the direct results is that thanks to this approach the Advanced R&D team was able to propose several invention disclosures in 2009 which represents more or less 10,5% of invention disclosures proposed by Technology R&D organization (which is the central R&D in charge of platform development). Moreover, feedback from this experience has been shared by the "3D & Derivatives" project manager among technical experts during specific workshops at STMicroelectronics Crolles site. The main discussions dealt with the method extension and how it could be applied to other technological fields.

What is striking with this method is that on the contrary to classical methods "C-K Invent" appears counterintuitive for three reasons:

- First, a patent is usually considered as a technical solution for a technical problem. In the meantime, the main idea developed was to begin with a technical solution (3D-Integration) in our case-study, before defining the issues addressed. Therefore one of the main incentives of this method is not to propose the solutions but to highlight the issues raised by a new concept.
- Second, the method proposes a process that is at the opposite end of the scale from "serendipity". Here, it is a collective design process which aims at organizing the exploration of innovative design space. Coming back on the design reasoning it enables to decline a long (A/E) chain that stimulates knowledge production. Using A/E matrices helps to define the design space paved and what are the (A,E) couple that still remain as concepts.
- Third, this process aims to propose robust patents portfolios, positioning each alternatives among the others. This enable to propose wide-scope patents deeply linked to concept exploration.

Table 5: Patent typology for Rule-based and disruptive innovation situations

Situation	**Rule-based Design**	**Disruptive Innovation**
Model	Object	A-E-K
Patent Information	Solving : Ki x Kj	Exploration of C0 : (A-E)
Industrial Property Strategy	Protection / Anticipation	Description Sufficiency / Design Space Paving

In conclusion, the use of C-K enables us to challenge design team member in terms of innovative design, with expansive partition proposition. This suggests several open questions for further research: What is the best way of applying this kind of methodology? Should it be internal or external to R&D teams? Is it applicable for problem solving fields? What is the best mean for this method application?

ACKNOWLEDGEMENTS

The authors thank STMicroelectronics Crolles, its Advanced R&D and "3D Integration and Derivatives" team for the insightful comments that they provided on this work and "C-K Invent" Method. This work was supported by the ANR- Agence Nationale de la Recherche – "The French National Research Agency" (under the "Programme Entreprise", project RITE 'ANR-07-ENTR-011-RITE') and CGS's design chair "Theory and Methods for Innovative Design" (TMCI).

REFERENCES

[1] EPC, *European Patent Convention*. 2007, European Patent Office.

[2] Shapiro, C., *"Navigating the Patent Thicket: Cross-Licenses, Patent, Pools, and Standard Setting,"*. Innovation Policy and the Economy, 2001. Vol. 1: p. 17 pages.

[3] PatVal-EUproject, *The value of european patents : evidence from a survey of european inventors.*, in *Final Report of the Pat-Val-EU Project*, D. Science&Technology, Editor. 2005, Contract HPV2-CT-2001-00013: Brussels. p. 60.

[4] Hall, B.H. and R.H. Ziedonis. *An Empirical Analysis of Patent Litigation in the Semiconductor Industry*. in *American Economic Association annual meeting*. 2007. Chicago.

[5] Fabry, B., et al., *Patent portfolio analysis as a useful tool for identifying R&D and business opportunities—an empirical application in the nutrition and health industry*. World Patent Information, 2005. Vol. 28: p. pp. 215 - 225.

[6] Lerner, J., *The Importance of Patent Scope: An Empirical Analysis*. The RAND Journal of Economics, 1994. Vol. 25(No. 2): p. pp. 319 - 333.

[7] Hall, B.H., A. Jaffe, and M. Trajtenberg, *Market value and patent citations: A First Look*. Economics Working Papers 2001(No. E00-277): p. University of California at Berkeley.

[8] Mariani, M. and M. Romanelli, *Stacking and picking inventions: The patenting behavior of European inventors*. Research Policy, 2007. Vol. 36: p. pp. 1128 - 1142.

[9] Griliches, Z., *Patent Statistics as Economic Indicators: A Survey*. Journal of Economic Literature, 1990. Vol. 28(No. 4): p. pp. 1661 - 1707.

[10] Ernst, H., *Patent information for strategic technology management*. World Patent Information, 2003. Vol. 25: p. pp. 233–242.

[11] Verspagen, B., *Mapping Technological Trajectories as patent citation networks: a study on the history of fuel cell research*. Advances in Complex Systems, 2007. Vol. 10(No. 1): p. pp. 93-115.

[12] D. K. R. Robinson , et al., *Forecasting Innovation Pathways (FIP) for New & Emerging Science & Technologies*. Submitted to Technological Forecasting and Social Change., (Submitted 2010)

[13] Lindsay, J. and M. Hopkins, *From experience: Disruptive Innovation and the Need for Disruptive Intellectual Asset Strategy*. Journal of Product Innovation Management, 2010. Vol. 27: p. pp. 283 - 290.

[14] Nissing, N., *Strategic Inventing, In a war of patents, choose your own battleground.* Research Technology Management, 2005. **Vol. 48**(No. 3): p. pp. 17-22.

[15] Gero, J.S., *Design Prototypes: A Knowledge Representation Schema for Design.* AI Magazine, 1990. Vol. 11(No. 4): p. pp. 26 - 36.

[16] Gero, J.S. and U. Kannengiesser, *The situated function–behaviour– structure framework.* Design Studies, 2004. 25: p. pp. 373 - 391.

[17] Altshuller, G., *Creativity As an Exact Science : The Theory of the Solution of Inventive Problem Solving*. Gordon & Breach Science Publishers. 1984, New York.

[18] Glaser, M. and B. Miecznik, *TRIZ for Reverse Inventing in Market Research: A Case Study from WITTENSTEIN AG, Identifying New Areas of Application of a Core Technology.* Creativity and Innovation Management, 2009. Vol. 18(No. 2).

[19] Dewulf, S., *Directed variation: variation of properties for new or improved function product DNA, a base for 'connect and develop'.* http://www.creax.com/mailing/2006_11/Final-ETRIA.pdf, 2006.

[20] Reich, Y., et al., *A theoretical analysis of creativity methods in engineering design: casting and improving ASIT within C-K theory* Journal of Engineering Design, 2010: p. pp. 1466-1837.

[21] Hatchuel, A. and B. Weil. *A new approach of innovative design: An introduction to C-K Theory*. in *International Conference on Engineering Design (ICED)*. 2003. Stockholm.

[22] Hatchuel, A. and B. Weil, *C-K design theory: an advanced formulation.* Research in Engineering Design, 2009. 19: p. 181-192.

[23] Couble, Y. and D. Devillers, *Une approche innovante du processus de rédaction de brevet*, in *Ecole des Mines de Paris*. 2006.

[24] Sincholle, V., *« De la gestion des brevets d'inventions au pilotage de l'innovation : Le cas d'un centre de recherche de haute technologie »*, in *Economie et Sciences Sociales*. 2009, Ecole Polytechnique: Paris. p. 265.

[25] Hoerni, J., *Method of Manufacturing Semiconductor Devices*. 1959: US patent.

[26] STMicroelectronics NV (STM), *Form 20-F, Annual and transition report of foreign private issuers pursuant to sections 13 or 15(d)*, 2010, http://investors.st.com/phoenix. zhtml?c=111941 &p=irol-reportsannual

[27] Goldenberg, J. and D. Mazursky, *Creativity in product innovation*. 2002: Cambridge university press.

[28] Bohm, M.R., J.P. Vucovich, and R.B. Stone. *Capturing creativity: using a design repository to drive concept innovation*. in *DETC 2005*. 2005. Long Beach, California.

[29] Yole Development., *3D Integration Infrastructure & Market Status*. 2010: Semicon Taiwan

[30] Di Cioccio, L., et al. *Direct bonding for wafer level 3D integration* in *ICICDT, IEEE International Conference on IC Design and Technology* 2010.

[31] Garrou, P., C. Bower, and P. Ramm, *Handbook of 3D Integration: Technology and Applications of 3D Integrated Circuits*, ed. Wiley. 2008. 798 pages.

[32] Zwicky, F. *New Methods of Thought and Procedure*. in *Contributions to the Symposium on Methodologies*. 1967. Pasadena.

[33] Zeiler, W. and P. Savanovic. *Morphology: a Tool for Design and Analysis of Design* in *International Conference on Engineering Design, ICED*. 2009. Stanford University.

[34] N.Sillon, et al. *Enabling technologies for 3D integration: From packaging miniaturization to advanced stacked ICs*. in *International Electron Devices Meeting, IEDM*. 2008. San Francisco.

[35] Wildgen, W. *La reconstruction d'une proto-sémantique et d'une proto-pragmatique des langues humaines*. in *Séminaire Des langues au langage : modèles et théories à l'épreuve des faits*. 2004. Ecole Normale Supérieure Paris.