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TRIZ ANALYSIS OF US PATENTS IN OVONIC PHASE CHANGE MEMORY

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The initial results of US patents analysis issued in 1966-2004 for non-volatile Ovonic phase change memory in the framework of TRIZ are presented. The statistics shows that the development of non-volatile semiconductor (electrical) phase change memory occurs now at the second stage of technique evolution.

1. Introduction

The famous paper "Reversible Electrical Switching Phenomena in Disordered Structures" [1] by Stanford R. Ovshinsky was published in November 1968 and it created a new field of non-volatile phase change memory (PCM) devices. At the first time we analyze development activities in PCM in the framework of TRIZ methodology [2-5]. The prime goal of this research is to apply TRIZ to PCM development. In order to achieve it we should:

1) Figure out patent levels and heuristics already used in the field;
2) Study trends of non-volatile PCM evolution;
3) Identify problems important for PCM development and predict difficulties that this technique might face during implementation;
4) Select useful generic heuristics from TRIZ database for further memory developments;
5) Find possible solutions to these problems using TRIZ methodology.

Results of the first two tasks in this program are reported here after short introduction to TRIZ.

2. Short TRIZ Overview

TRIZ is a structured problem solving methodology that helps apply known generic heuristics to new ill-defined problems [2-5]. TRIZ author, Genrich S. Altshuller, studied patents in order to show that the same generic heuristics can be re-applied in various technical fields. Altshuller distinguished the five levels of patents between trivial legal documents (with tiny inventiveness) and truly breakthrough discoveries:

Level 1. Routine design problems solved by methods well known within the same technical field or inside a company. (About 32% of the solutions occurred at this level).
Level 2. Minor corrections (~45%) to an existing technique, by methods known within the industry.
Level 3. Fundamental improvements (~18%) to an existing technique which resolve contradictions, by methods known outside the industry.
Level 4. New generations (~4%) use a new scientific (rather than technological) principle to perform the primary functions of the technique.
Level 5. Rare scientific discoveries or pioneering inventions (less than 1%) of essentially a new technique.

The original Ovshinsky's patent US3,271,591 corresponds to the 5th level, ECD's patent US5,335,219 fits to the 4th level, and recent Nanochip's US2004/0145848 patent application matches the 3rd level, while some of recent (Ovonyx, Intel, Micron) patents belong to the levels 1 and 2. It is worth to note that these low level solutions are necessary for a technique implementation.

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TRIZ maintains that a technical problem can have few solutions at high (3-4) levels. The TRIZ methodology offers several tools for finding these solutions based on the generic heuristics usage [2-5].

After studies of numerous high-level patents, G. S. Altshuller and other TRIZ experts identified and codified a common set of inventive heuristics used across numerous technical fields from mechanical to software engineering. More than 100 such heuristics are recognized now [5], while inventors in a particular field (including PCM) often use intuitively less than 10% of them. Many PCM inventors continuously employed the same approach for solution of the problem they faced. It points to the existence of strong psychological bias of thinking inside the box for most of these developers. TRIZ helps to overcome such limits [2,3].

Improvement of one of the technique parameters often leads to deterioration of others or the same in different mode. The basic concept of TRIZ is the recognition and resolution of a **contradiction**. A contradiction arises from mutually exclusive demands that may be placed on the same or related (sub)system of a technique. The contradictions are the hidden root(s) of the technical problems and their resolution leads the technique toward an **ideal system** along different trends of the **evolution.**

As a technique evolves during a life cycle of birth, childhood, growth, maturity, and decline it should become better, i.e. its performance follows so-called S-curve (see the figure 1) [2,4]. Usually during a technique evolution its ability to satisfy human needs (e.g., faster and bigger memory) increases while its cost and power consumption decreases, i.e., the technique becomes more ideal. The ideal system, according to the TRIZ philosophy, is a non-existent technique with all of its functions still being executed. This ideal system, analogous to the definition of limit in mathematics, is unrealizable in practice. For example, any memory chip contains many subsystems that help but do not perform the primary functions (e.g., information retention) and keep a chip away from ideal.

To understand the stage where a technique is on its evolution, TRIZ suggests to use two metrics from patent analysis, i.e. number of patents and level of invention in addition to conventional metrics of performance and profit. Figure 1 shows the observed trends and correlations in these metrics. These trends are common for various techniques [2].

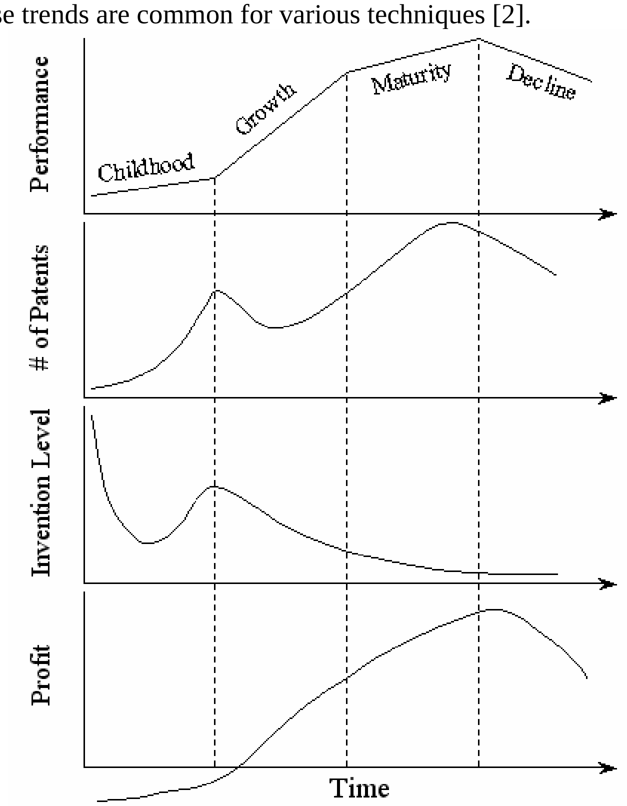


Fig. 1. Correlations of four metrics for determining the stage of technique evolution.

3. US Patents in semiconductor non-volatile phase change memory field

We have analyzed about 500 US patents issued from 1966 up to November 2004[1] for chalcogenide PCM. In this paper we report results for more than 300 patents important for non-volatile electrical memory [2]. Table 1 shows that these patents legally issued only in one country are quite representative because most of inventors and assignees have USA jurisdiction.
The level of invention is determined by analyses of the patents in the framework of TRIZ [3]. Figure 2 shows the results of the preliminary analysis. The first level patents issued recently are omitted for clarity.

Table 1. PCM patents geography. Top assignees are Energy Conversion Devices / Ovonyx, Inc.; Micron Technology, Inc. and Intel Corporation – all USA. Only 30 patents (less than 10%) were issued for 15 non-US assignees.

Country	# patents	# assignee
United States	302	27
Japan	14	7
Netherlands	4	1
Italy	3	1
Taiwan	3	1
Israel	2	1
France	1	1
United Kingdom	2	2
Republic of Korea	1	1

Comparing the figure 2 and the third graph in the figure 1 we figured out that semiconductor non-volatile PCM born in 1962-1963 just moved into the second (growth) stage of technique evolution [2,4] due to many supportive patents on the low levels. Figure 2 shows that this transition occurred around 1991-1994 after quite long childhood (1966-1990). The heuristics used for innovative developments of PCM are recovered along with various statistical results about players, problems and proposed solutions in the field. Only most important statistical results are reported in this paper.

The simple analysis of US patent numbers shows (the figure 3) that the speed for issue of PCM patents has recently increased in about 100 times. This ist also indicates the transition to the second (growth) stage of the technique evolution [2,4]. The figures 4 confirms this conclusion. The number of patent applications and the number of assignees (mostly companies participated in PCM development) also grew up from one in 1964-1974 to three in 1984-1989 to about ten at the turn of the XX century and to more than twenty in 2004. Both numbers are linearly related (figure 4c).

[1] The last date was arbitrary chosen and coinside with 36 anniversary of Ovshinsky paper [1]. We are going to add newest patents and expand database to European, Japanese, etc. patents in the future.
[2] List of the patents (#3271591 - #6822903) is available upon email request to the corresponding author (SDS).

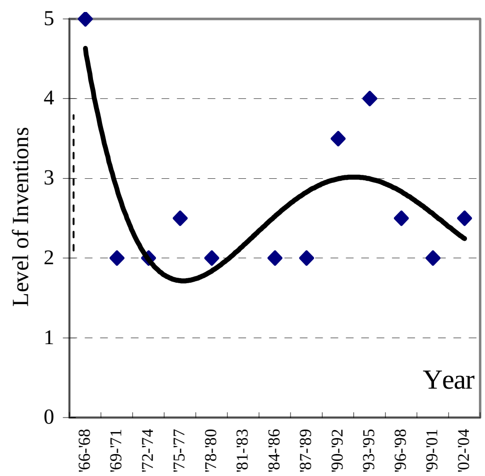


Fig. 2. Estimated highest level of inventions issued in 3-year period in chalcogenide PCM field.

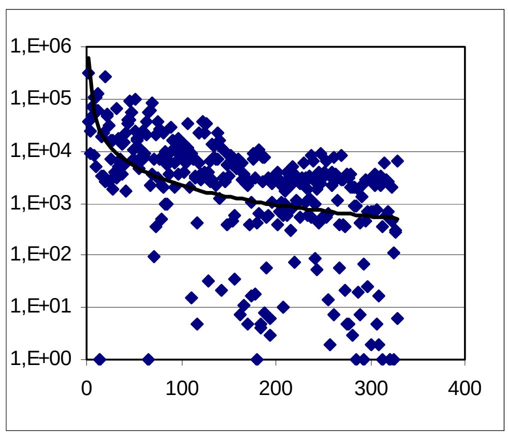


Fig. 3. Frequency of US patents issued in chalcogenide PCM field. The Y-axis shows the difference between 2 closest patent numbers in logarithmic scale (e.g., the difference between US patents 3,619,732 and 3,644,741 - which are closest to each other in the field - is about 25000). The X-axis presents linear patent order analyzed in this work from first US 3,271,591 up to the latest US 6,822,903.

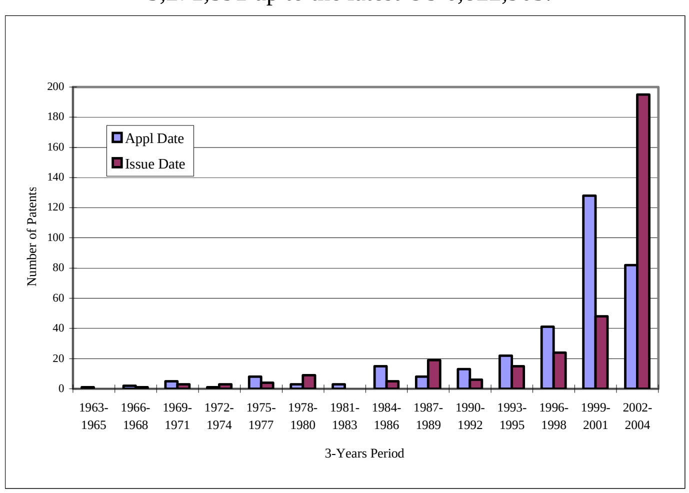


Fig. 4a. Chronological graph for number of issued US patents.

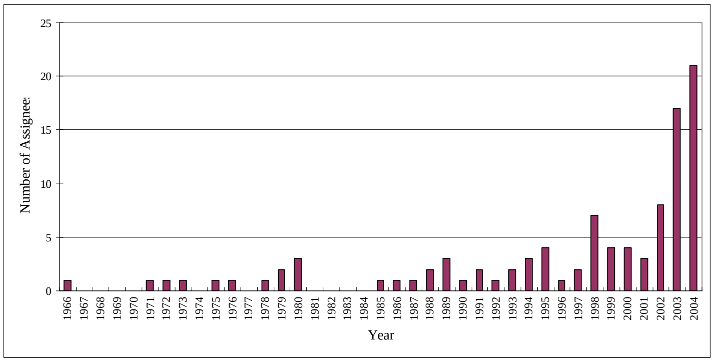


Fig. 4b. Chronological graph for assignees quantity.

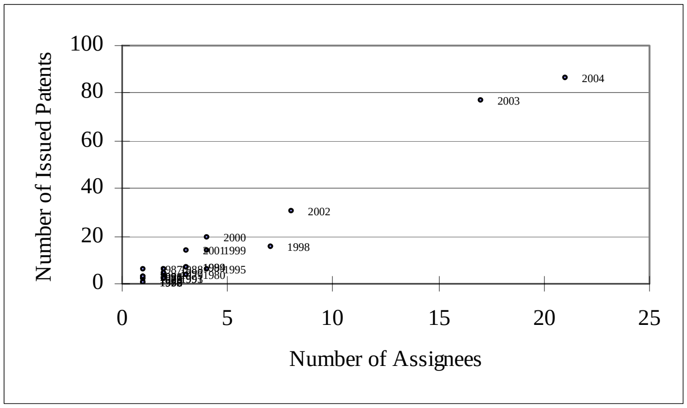


Fig. 4c. Correlation between numbers of patents and assignees.

The table 2 shows patent distribution according to the top (most frequent) classes of the International Patent Classification (IPC) for major assignees. The five most active IPC classes listed in table 2 represent about a quater of the all subclasses in this study. These 5 classes cover about 94% of all PCM patents issued in USA for the period of time under the investigation. Top ten assignees hold about 84% of patents in the field. ECD's key patents reflect wide diversity of technical knowledge of this company, while Micron's, Intel's and Ovonyx's patents show their high activities in non-volatile semiconductor PCM.

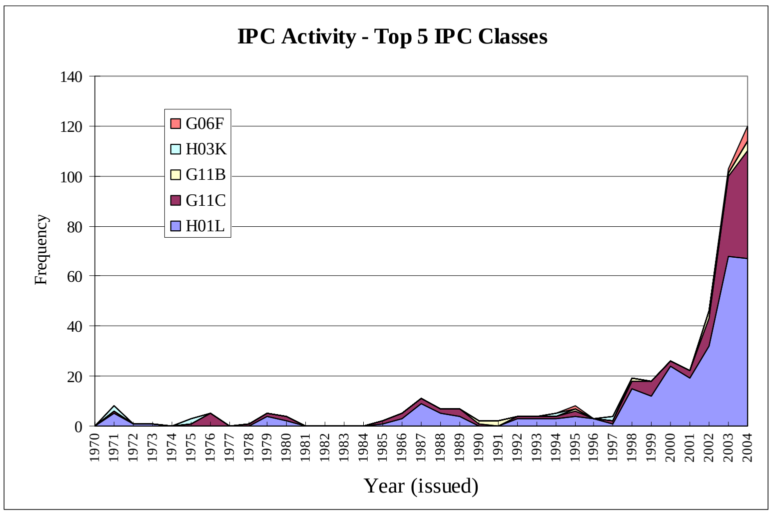
Table 2. Activities of ten major players in the field of semiconductor non-volatile PCM[3].

IPC Subclasses	H01L	G11C	G11B	G06F	H03K
Assignee					
BAE	4	0	0	0	0
ECD	35	18	0	2	4
HP	8	15	2	0	0
Hitachi	4	0	0	0	0
Intel	24	8	0	0	0
IBM	0	1	2	1	0

[3] Full names of the companies as mentioned in the assignee fields of the patents are: BAE Systems Information and Electronic Systems Integration, Inc.; Energy Conversion Devices, Inc.; Hewlett-Packard and Hewlett-Packard Development Companies.; Hitachi, Ltd.; Intel Corporation; International Business Machines Corporation; Matrix Semiconductor, Inc.; Micron Technology, Inc.; Ovonyx, Inc.; Silicon Storage Technology, Inc. in the order given in the table 3.

IPC Subclasses	H01L	G11C	G11B	G06F	H03K
Matrix	4	17	0	1	0
Micron	72	10	0	0	0
Ovonyx	23	18	0	0	0
SST	2	0	0	0	0

The figures 5 also confirm recent explosion of activities in the field and transfer of chalcogenide phase change non-volatile memory technology into the second growth stage of technique evolution.



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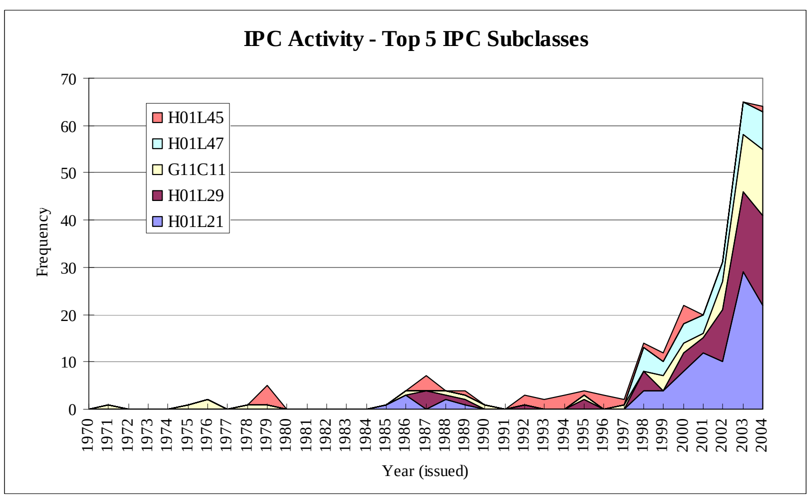

b

Fig. 5. Top IPC classes (a) and subclasses (b) distributions in time. Most activities are related to "Other Semiconductor Devices" (H01L) and "Static Information Storage" (G11C) classes.

4. Conclusion

We have analyzed few hundreds US patents selected in the field of optical and semiconductor PCM in the framework of TRIZ. Such patent analysis helps to figure out used heuristics, to prioritize technical problems, to foresee possible solutions, to identify evolution trends for PCM technique and to envisage future non-volatile memory roadmaps. The statistical results reported in this paper indicate that the semiconductor non-volatile PCM grows up presently at the second stage of the technique evolution. We figure out that only a few heuristics are used by inventors in the PCM field while several other generic TRIZ heuristics [2-5] also seem promising for this technique development.

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