SHAPE MEMORY ALLOYS: PATENTS IN BRAZIL

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Abstract. *Shape memory alloys are metallic materials that have the capability to recover its original shape eliminating residual deformations when submitted to adequate thermal processes. This behavior is related to phase transformation induced by stress or temperature. Several alloys present this behavior, however only the alloys that are capable to recover large amount of deformations have commercial interest, as nickel-titanium (NiTi) and copper base alloys (CuZnAl and CuAlNi). These alloys have been used in many knowledge areas with applications in bioengineering, automotive and aerospace industry, for example. The purpose of this paper is to present the results of a preliminary, exploratory and quantitative documental research in Derwent Innovations Índex (DII) and in the patent database of INPI – National Institute of Industrial Property, based on deposits of patent about shape memory alloys. In this research it was possible to identify: the evolution of the number of patents; in which areas are being done the deposits; which countries and companies are using the patent system; and the title of the inventions deposited in Brazil. Complementing the work, it was made a study to check if Brazilian researchers – with publications indexed in ISI/Web of Science database – have deposited patents in INPI. The information obtained with the proposed methodology can be used to support management decisions in R&D.*

Keywords*: shape memory alloys, new materials, patent, technical information.*

1. INTRODUCTION

Technical information contained in patent documents can be used to stimulate further innovation and provides a potentially rich information resource for researches. Despite that inventions described in the patent documents, in many cases, aren't described nowhere else, this literature isn't generally used by the academic sector.

Through of technical information contained in patent documents it's possible to know what is occurring in a particular technological area, what are the subjects where research is being done, what are the technological trends, what are the emerging research lines, which are the players in a technical field, which are the leading research teams, etc. Furthermore, patent documents as a source of technical information present some advantages as most current and up-to-date, uniform structure makes reading easier, well organized due to classification system, quick and easy access (internet) and low cost (Rackette, 2006).

From reasons above described, it's important to stimulate the scientists and researches to make use of patent system to obtain technical information.

The purpose of this paper is to present the results of a documental research in Derwent Innovations Índex (DII) and in the patent database of INPI – National Institute of Industrial Property, based on deposits of patent about shape memory alloys. Shape memory alloys are metallic materials that has the capability to recover its original shape eliminating the residual deformations when submitted to adequate thermal processes. This behavior is related to phase transformation that could be induced by stress or temperature. Several alloys present this behavior, however only the alloys that are capable to recover large amount of deformations have commercial interest, as nickel-titanium (NiTi) and the copper base alloys (CuZnAl and CuAlNi). These alloys have been used in many knowledge areas with applications in bioengineering, automotive and aerospace industry, for example.

In this exploratory and quantitative research it was possible to identify: the evolution of the number of patents; in which areas are being done the deposits; which countries and companies are using the patent system; and the title of the inventions deposited in Brazil. Complementing the work, a study was developed to check if Brazilian researchers – with publications indexed in ISI/Web of Science database – have deposited patents in INPI.

2. TECHNICAL INFORMATION CONTAINED IN PATENT DOCUMENTS

The system of industrial property has two main functions that are the "exclusivity function" and the "information function". To obtain the patent and to have "an exclusive right on a special knowledge and by doing so limits the possibilities of access to this special technology for other enterprises", the inventor is obligated to disclose the information about his invention for public access (WIPO, 2007a).

The structure of a patent document comprises three key sections: the cover page; the specification/disclosure (description); and the claim or claims. The cover page provides bibliographic data as title of the invention, patent number, date of issue, inventors, assignee (owner of patent rights), international classification (IPC) of the patent's subject matter to assist in searching, data on earlier applications which may give earlier priority dates to some or all the claims, date and number of the application for the patent, classifications of the areas of technology which were searched when this patent was examined, earlier patents and other earlier publications considered relevant by the patent examiner and a descriptive abstract of the invention (FAT, 2001). The second section provides a description, in most cases including drawings, "disclosing clearly the technical details of the invention concerned, normally illustrated by working examples showing how to carry out the invention into practice" and the third section – claim or claims – defines "the scope of protection for the invention under consideration; hence satisfying the legal aspect of the patent document" (Chin, 1999).

Patent documents also have some specific characteristics to be used as a source of technical information. For example: patent documents have a fairly uniform format and hence are easy for reference; are usually published ahead of other forms of publication for the same inventions; cover inventions of all technical fields in the whole spectrum of technology; disclose what is new, worthwhile knowing and industrially applicable; and the technical information contained in patent documents is not secret and can be used freely for research and development purposes (FAT, 2007). It's also important to add that a large part of the technology is published only by patent documents.

From the above, the information contained in patent documents can be very useful to (WIPO, 2007a):

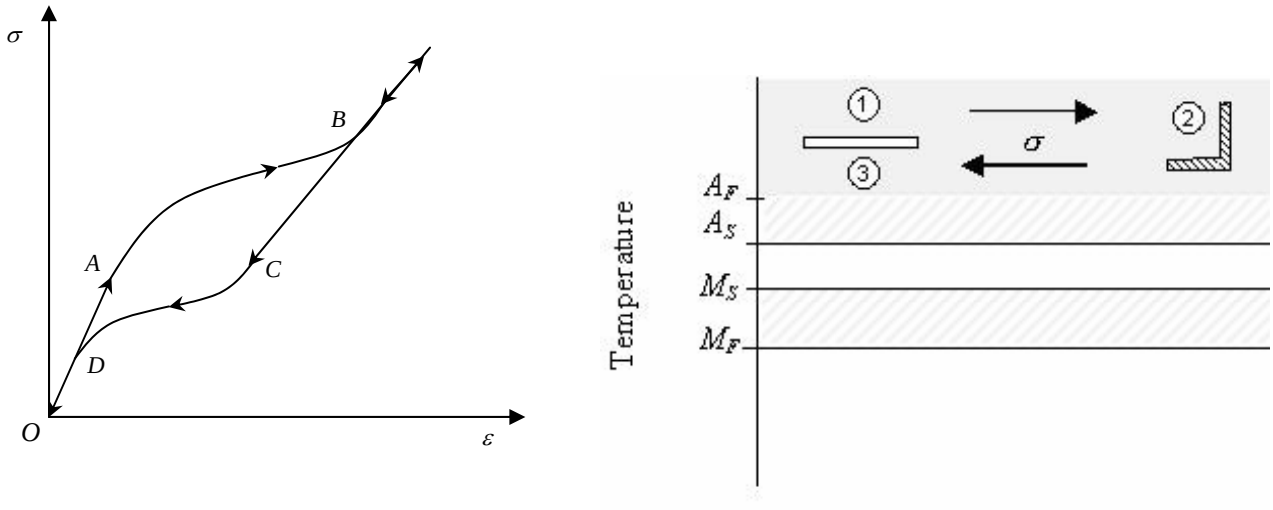
- *avoid duplication of R&D work;*
- *identify specific new ideas and technical solutions, products or processes;*
- *identify the state-of-the-art in a specific technological field in order to be aware of the latest development;*
- *assess and evaluate specific technology and to identify possible licensors;*
- *identify alternative technology and its sources;*
- *locate of sources of know-how in a specific field of technology or in a given country;*
- *improve an existing product or process;*
- *develop new technical solutions, products or processes,*
- *identify existing or prospective industrial property rights (validity, ownership, ...), particularly to avoid infringement actions;*
- *assess novelty and patentability of own developments with a view of applying for a domestic or foreign industrial property right;*
- *monitor activities of competitors both within the country and abroad; and*
- *identify a market niche or to discover new trends in technology or product development at an early stage.*

In spite of the importance of patent documents as a source of technical information, it's important to mention that there are barriers to the use of these information. These barriers are (Stembridge, 2007): the volume – more than 1,4 million patents documents were published worldwide in last year alone; the issue of language – there are patent documents that are published in non-English languages, particularly non-Roman character sets (for example: Japan, Korea and China accounted for a staggering 54 per cent of all patent documents published last year. Of these, China has the fastest growing volumes with 30 per cent more patent documents published in 2005 than in 2004); and the 'legalese' and obfuscation (patent documents can be written in complex legal language and, although it is a legal requirement to fully disclose the invention, descriptions are generally written in a way that only reveals the details that are completely necessary to fulfill this obligation).

3. SHAPE MEMORY ALLOYS

Shape memory alloys (SMAs) have the capability to generate large strains associated to phase transformation induced by stress and/or temperature variations (Hodgson et al., 1992; Rogers, 1995). During the phase transformation process of a SMA component large loads and/or displacements can be generated in a relatively short period of time making this component an interesting mechanical actuator. Two phases are present: martensite and austenite (Zhang *et al.*, 1991). Several alloys can develop strains associated to phase transformation but only those that can develop large strains are of commercial interest, as nickel-titanium (NiTi) and copper base alloys (CuZnAl and CuAlNi). Two basic behaviors are present in SMAs: pseudoelastic and shape memory effects.

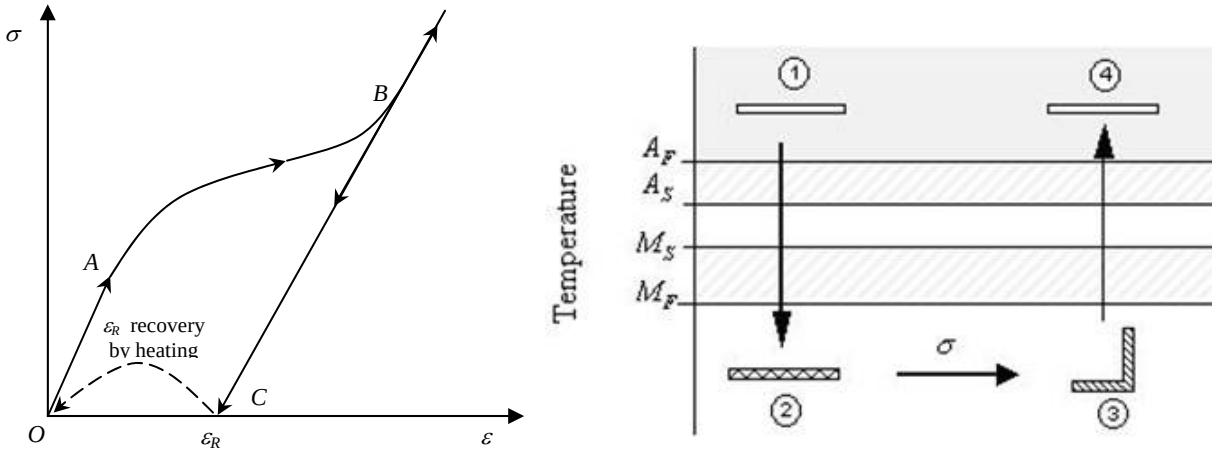
Pseudoelastic effect occurs at higher temperatures, above a critical temperature (A_F) where austenite phase is the only stable phase in a stress-free state. Figure 1*a* presents a stress-strain curve (σ x ε) for the pseudoelastic effect at a constant temperature. In the loading process, a linear behavior (*OA)* is first observed followed by a nonlinear behavior (*AB*) associated to phase transformation (austenite → martensite). After point *B* the presence of 100 % of martensitic phase reveals a linear behavior. In the unloading process a linear behavior is observed until point C is reached. After that, a nonlinear behavior (*CD*) associated to phase transformation (martensite → austenite) is observed followed by a linear behavior associated to the presence of 100% of austenite. Figure 1*b* presents a diagram that illustrates the pseudoelastic behavior. A_S and A_F are the temperatures at which the formation of austenite starts and ends, respectively. M_S and M_F are the temperatures at which the formation of martensite starts and ends, respectively.



(*a*) (*b*)

Figure 1. Pseudoelastic effect. Stress-strain curve (a) and a diagram to illustrate the pseudoelastic effect (*b*).

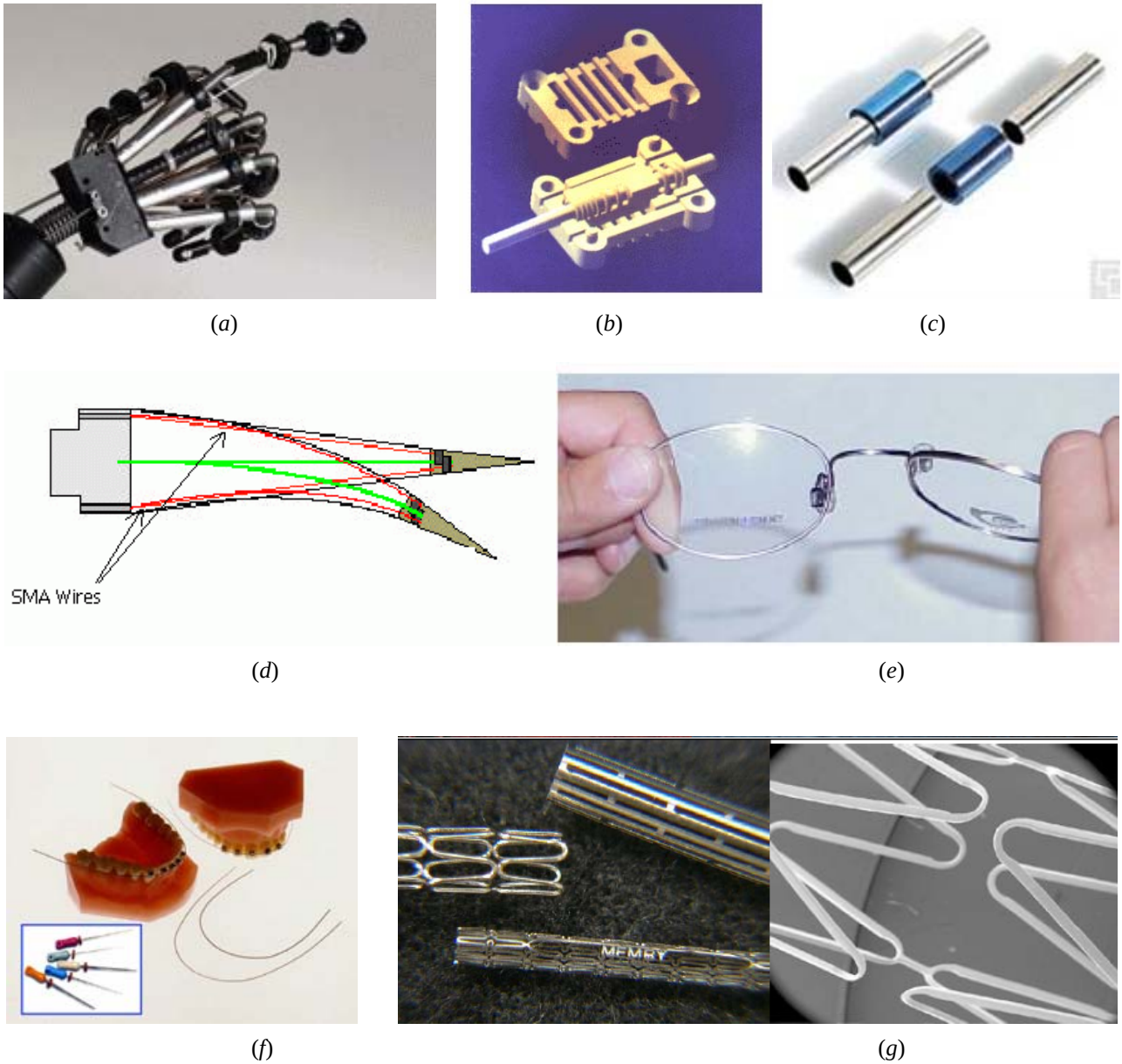
Shape memory effect occurs at lower temperatures, below a critical temperature where twined martensite phase is the only stable phase in a stress-free state (M_F). Figure 2*a* presents a stress-strain curve for the shape memory effect at a constant temperature. For this situation the nonlinear behavior in the loading process is associated to phase transformation related to the conversion from twinned to detwinned martensite. After the unloading process (*C*), some amount of residual strain remains (ε_R), meaning that the reverse transformation, from detwinned to twinned martensite, is not completed. The shape memory effect takes place by heating the alloy, which controls the transformation from detwinned martensite to austenite and promotes the residual strain recovery. Figure 2*b* presents a diagram that illustrates the shape memory effect. M_S and M_F are the temperatures at which the formation of martensite starts and ends, respectively.



(*a*) (*b*)

Figure 2. Shape memory effect. Stress-strain curve (a) and a diagram to illustrate the shape memory effect (*b*).

These remarkable characteristics have been responsible for the increasing interest in different applications varying from biomedical to aerospace industry. Machado and Savi (2003) make a review on the most relevant SMA applications within orthodontics and biomedical areas. They are ideally suited to be used in engineering applications as self-actuating fasteners, thermally actuator switches, seals, connectors and clamps (van Humbeeck, 1999; La Cava *et al.*, 2000). Moreover, aerospace technology is also exploiting SMA properties in order to build self-erectable structures, stabilizing mechanisms, solar batteries, non-explosive release devices and other possibilities (Denoyer et al., 2000; Pacheco and Savi, 1997). Micromanipulators and robotics actuators have been conceived employing SMAs properties to mimic the smooth motions of human muscles (Garner et al., 2001; Webb et al., 2000; Rogers, 1995; Kibirkstis et al., 1997; Chang-jun *et al.*, 2004). Furthermore, SMAs are being used as actuators and absorbers for vibration and buckling control of flexible structures (Birman, 1997; Rogers, 1995; Campanile *et al.*, 2004; Elzey *et al.*, 2005; Shi *et al.*, 2005). Some SMAs applications covering various fields are presented in Fig. 3.



(*a*) (*b*) (*c*)

(*d*) (*e*)

(*f*) (*g*)

Figure 3. SMA applications. Robotic grip (*a*), NiTi spring actuator (*b*), connection sleeve (*c*), hinge-less shape memory alloy flap (*d*), DuraFLEX eyeglasses (*e*), orthodontic wires (*f*) and self-expanding stents (*g*).

4. METHOD

The development of the research was based on searching of the patents database of National Institute of Industrial Property - INPI and of the Derwent Innovations Índex database that are available for the Internet. INPI database gathers the requests of patents deposited in Brazil. DII is a searchable database from ISI Web of Science. DII provides access to a comprehensive database of international patent information. Derwent Innovations Index covers more than 20 million patent documents including the disclosures of inventions from more than 40 patent offices worldwide (THOMSON, 2003). The research was development until April 10th, 2007 and the search parameters are described below:

4.1. Derwent Innovations Index (DII)

- Topic Search: TS = ("Shape Memory Alloy") searches within articles titles, keywords and abstracts
- Databases = Chemical Section, Electrical and Electronic Section and Engineering Section
- Timespan = 1963 to 2007

The purpose of the search in DII was to identify the total of patents and the rankings of the assignees names and the International Patent Classification Codes. Assignees names show the companies that are investing in a specific technology, in this case, shape memory alloy. The International Patent Classification provides for a common classification for patents for invention including published patent applications, utility models and utility certificates. The International Patent Classification (IPC) is a hierarchical system in which the whole area of technology is divided into a range of sections, classes, subclasses and groups. This system is indispensable for the retrieval of patent documents in the search for establishing the novelty of an invention or determining the state of the art in a particular area of technology. The Classification is periodically revised in order to improve the system and to take account of technical development. The current, eighth, edition of the IPC entered into force on January 1st, 2006 (WIPO, 2007b). An example of IPC is showed in Table 1.

Table 1: Example of International Patent Classification Application

IPC	Section	Class	Subclass	Group	Subgroup
C22C-019/03	**C** Chemistry; metallurgy	**22** Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals	**C** Alloys	**019** Alloys based on nickel or cobalt	**03** based on nickel

4.2. Patent Database of INPI

The purpose of the search in patent database of INPI was to identify the year of deposit, the priority, the International Patent Classification Code and the title of the invention of the documents of patents deposited in Brazil. The parameter of search was shape memory alloy (search for all words in abstract).

It was used the ISI/Web of Science database to check if Brazilian researches – with publications indexed in international journals – have been done patent deposits in INPI. The first step was to identify the name of Brazilian authors with papers about shape memory alloy in this database. After this, the relation of names found was checked with the relation of inventors' names of the patent documents deposited in INPI.

5. RESULTS

5.1. International results (DII)

In the Derwent Innovations Index database 5,642 results were found for the topic search TS = ("shape memory alloy"). Figure 4 shows the number of patent deposits per year from 1963 to 2007. The first patent was deposited in 1977 and the second one in 1979. Since the beginning of the 80's, the number of deposits per year maintains a rising rate until a peak occurs in 1990 and 1991, reaching more than 600 deposits per year. After that peak, the number of deposits per year returns to the previous levels maintaining a positive rising rate. The peak can be the result of a legislation change in some countries. In 2007 the data colleted until April 10th shows 68 patent documents deposited. The presented data indicate that "shape memory alloy" is a recent theme and an emerging technology.

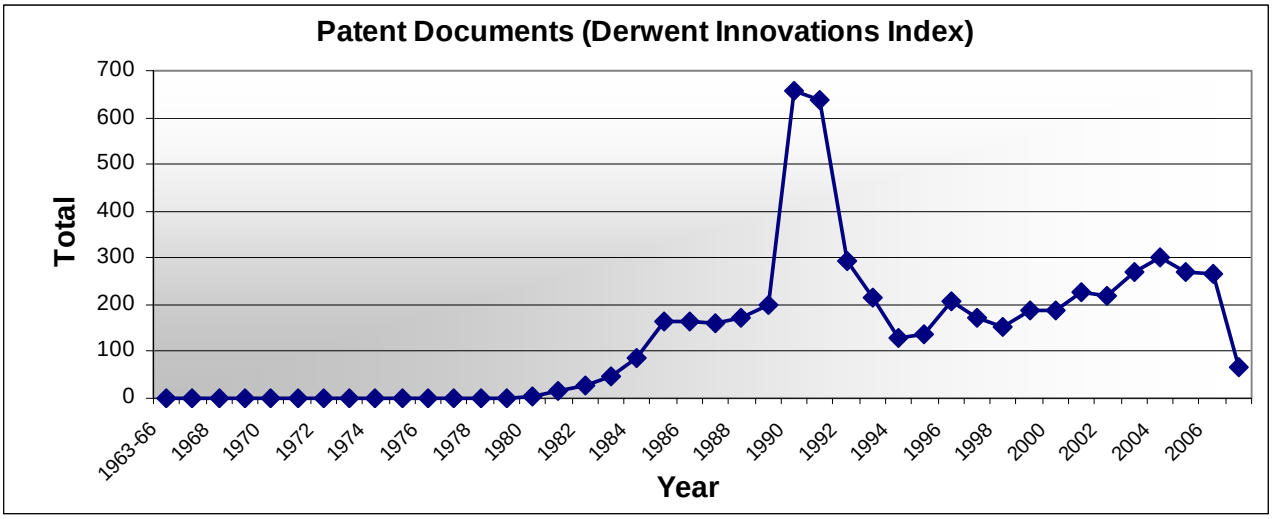


Figure 4. Total number of patents deposits per year from 1963 to 2007 in DII.

The top assignee names (owner of patent rights) are NEC Corp with 194 patents deposited and Toshiba KK with 154. Table 1 shows the fourteen top assignee names. These results show which firms are investing in shape memory alloy technology.

Table 1. Ranking of Assignee Names – DII

Assignee Names	Number of patents	Assignee Names	Number of patents
NEC CORP	194	FUJITSU LTD	100
TOSHIBA KK	154	MATSUSHITA ELECTRIC WORKS LTD	92
MATSUSHITA ELEC IND CO LTD	138	SONY CORP	62
HITACHI LTD	134	CANON KK	59
FURUKAWA ELECTRIC CO LTD	125	OLYMPUS OPTICAL CO LTD	57
MITSUBISHI DENKI KK	120	DAIDO TOKUSHUKO KK	56
TOKIN CORP	113	SHARP KK	54

Table 2 presents the ranking of the IPC code of the patent documents found in DII. Table 3 shows the description of the sections, classes, subclasses, groups and subgroups of the ten principal results shown in Tab. 2.

Table 2. Ranking of IPC code - DII

IPC	Total	IPC	Total	IPC	Total	IPC	Total
C22C-019/03	463	C22F-001/00	109	A61M-025/00	64	A61B-001/00	52
F03G-007/06	259	H01H-037/32	107	H02N-010/00	61	C22C-001/00	51
C22F-001/10	168	A61M-029/00	85	C22F-001/08	60	G01K-011/00	51
A61F-002/06	121	C22K-001/00	84	A61B-017/00	54	H01L-023/50	50
C22C-014/00	118	F16K-031/70	81	C22C-038/00	54		

Table 3. Description of IPC codes present in the principal results of Table 2.

Section	Class	Subclass	Group	Subgroup
C Chemistry; metallurgy	22 Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals	C Alloys	019 Alloys based on nickel or cobalt	03 Based on nickel
			014 Alloys based on titanium	00
			038 Ferrous alloys, e.g. Steel alloys	00
			001 Making alloys	00
		F Changing the physical structure of non-ferrous metals or non-ferrous alloys	001 Changing the physical structure of non-ferrous metals or alloys by heat treatment or by hot or cold working	10 Of nickel or cobalt or alloys based thereon
				00
		K Indexing scheme associated with subclasses C21D, C22C or C22fF, relating to changing the physical characteristics of alloys	001 Changing the physical structure of alloys resulting in shape memory effect; Processes for stabilising or changing such effect; Alloys having shape memory characteristics	00*
F Mechanical engineering; lighting; heating; weapons; blasting	03 Machines or engines for liquids wind, spring, or weight motors; producing mechanical power or a reactive propulsive thrust, not otherwise provided for	G Spring, weight, inertia, or like motors; mechanical-power-producing devices or mechanisms, not otherwise provided for or using energy sources not otherwise provided for	007 Mechanical-power-producing mechanisms, not otherwise provided for or using energy sources not otherwise provided for	06 Using expansion or contraction of bodies due to heating, cooling, moistening, drying, or the like
	16 Engineering elements or units**;** general measures for producing and maintaining effective functioning of machines or installations**;** thermal insulation in general	K Valves; taps; cocks; actuating-floats; devices for venting or aerating	031 Operating means; Releasing devices	70 mechanically actuated, e.g. by a bimetallic strip
A Human necessities	61 Medical or veterinary science; hygiene	F Filters implantable into blood vessels; prostheses; devices providing patency to, or preventing collapsing of, tubular structures of the body, e.g. Stents; orthopaedic, nursing or contraceptive devices; fomentation; treatment or protection of eyes or ears; bandages, dressings or absorbent pads; first-aid kits	002 Filters implantable into blood vessels**;** Prostheses, i.e. Artificial substitutes or replacements for parts of the body**;** Appliances for connecting them with the body**;** Devices providing patency to, or preventing collapsing of, tubular structures of the body, e.g. Stents	06* Blood vessels
		M Devices for introducing media into, or onto, the body; devices for transducing body media or for taking media from the; devices for producing or ending sleep or stupor	029 Dilators with or without means for introducing media, e.g. remedies	00
H Electricity	01 Basic electric elements	H Electric switches; relays; selectors; emergency protective devices	037 Thermally-actuated switches	32 Thermally-sensitive members

(*) Previous edition

5.2. National results (INPI)

In the INPI patent database fourteen results were found from a search about the subject (shape memory alloy) developed within the articles abstracts. The first deposit of patent document happened fifteen years ago. The evolution of deposits of patent documents in INPI is showed in Tab. 4 with the respective IPC codes, priority and title of the invention.

Table 4. Evolution of deposits of patent documents in INPI.

Number	Year	IPC Code	Priority	Title of Invention (in Portuguese)
PI0602804-7	2006	A61C 5/04	Germany	Instrumento de canal de raiz tendo um revestimento abrasivo e método para a produção do mesmo
PI0405882-8	2004	A61B 17/11	USA	Dispositivo e método para anastomose intralumenal
PI0409953-2	2004	C22C 14/00 C22C 19/00	USA	Métodos de processamento de ligas de memória de forma de níquel-titânio
PI0315673-7	2003	H01M 8/24 H01M 8/10 H01M 4/86 H01M 4/90 H01M 4/96	USA	Sistema de célula combustível
PI0203726-2	2002	D06F 39/02 A47L 15/44	EPO	Distribuidor de água para uma máquina de lavar louças ou de lavar roupa suja automática, e, máquina de lavar louças ou de lavar roupa suja automática
PI0102696-8	2001	B60G 17/00	USA	Controle de característica da suspensão usando materiais de liga com memória de forma e método para o mesmo
PI0015753-8	2000	E21B 29/10	EPO	Dispositivos para vedar uma abertura através da parede de um elemento tubular de poço
PI9917232-1	1999	H01H 1/00 H01H 61/01		Processo para fabricar um computador biestável, e, computador bioestável
PI9811338-0	1998	H01M 2/34 H01H 37/32	USA	Célula eletroquímica, e, montagem interruptora de corrente para uma célula eletroquímica
PI9811982-6	1998	H01M 2/34	USA	Célula eletroquímica, e, instalação interruptora de corrente para uma célula eletroquímica
PI9713990-4*	1997	B62D 5/06 F16F 9/52	Germany	Direção auxiliar hidráulica
PI9607729-8*	1996	G02C 5/00	France	Armação de metal para óculos
PI9506976-3	1995	A61F 2/06	Israel	Sonda adaptada para colocação na uretra e dispositivo para colocação da mesma
PI9203381-4	1992	A61B 1/00	USA	Agulha e método de introdução de uma agulha curva em um campo cirúrgico

(*) Patent Letter

Complementing the work, it was made a study to check if there are Brazilian researchers – with publications indexed in ISI/Web of Science database about shape memory alloy – that have deposited patents in INPI. The result of the search showed that none of the Brazilian authors of papers indexed in that database appears as inventor in patent documents deposited in INPI.

6. CONCLUSION

This exploratory and quantitative study presents an example of the use of technical information contained in patent documents. These documents contain important data that can be used to support management decisions in R&D.

The research showed that shape memory alloys is a recent theme and an emerging technology. Also it was identified that NEC Corp, Toshiba KK, Matsushita Elec Ind Co Ltd and Hitachi Ltd are the principal assignee names of this technology and that the large number of deposits of patent is associated to alloys based on nickel.

In Brazil, there are few patent documents about shape memory alloys deposited in INPI according to the parameters of search. No one of these documents has Brazilian researches – authors of papers indexed in ISI/Web of Science database – as inventors.

It's important to be mentioned that the information of this paper is based on a preliminary search and it would be necessary to develop new searches with others topics, combinations and parameters related with shape memory alloy to retrieval of others documents in these databases and to have results more effective.

7. ACKNOWLEDGEMENTS

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