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ANALYSIS OF STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS (SWOT) AND PREREQUISITE TREE (PT) FOR SELECTED TECHNOLOGIES OF COATING AND LAYER PRODUCTION

ANALIZA MOCNYCH I SŁABYCH STRON, SZANS I ZAGROŻEŃ (SWOT) ORAZ DRZEWO OSIĄGANIA CELÓW (PT) DLA WYBRANYCH TECHNOLOGII WYTWARZANIA POWŁOK I WARSTW

SWOT (identification of strengths, weaknesses, opportunities and threats) analysis and prerequisite tree (PT) are very important methods in planning of certain technology development. These methods are often used during the realization of the "Foresight" – type projects, aimed at enhancing social and economic development of a country.

This work presents a SWOT analysis carried out for two selected technologies of the coating and layer deposition: Pulsed Laser Deposition (PLD) and Electrochemical Deposition (ED) from aqueous solutions. On the basis of prerequisite tree, the major barriers – according to the authors – that hinder the development and improvement of technology are presented. Potential methods of overcoming them are also proposed.

Keywords: SWOT analysis, prerequisite tree, "Foresight" – type projects, layer and coating deposition technologies, Pulsed Laser Deposition, Electrochemical Deposition

W planowaniu tendencji rozwoju technologii ważną rolę odgrywają metody badawcze (analiza SWOT – analiza mocnych i słabych stron, szans i zagrożeń oraz drzewo osiągania celów – prerequisite tree) stosowane przy realizacji projektów typu "Foresight" mających na celu socjoekonomiczny rozwój kraju. W pracy zaprezentowano analizę SWOT przeprowadzoną dla dwóch wybranych technologii wytwarzania warstw i powłok: osadzanie laserem impulsowym (PLD) oraz elektrochemicznego osadzania z roztworów wodnych (ED). Na podstawie drzewa osiągania celów wskazano główne, zdaniem autorów, bariery utrudniające rozwój i doskonalenie rozważanych technologii, a także zaproponowano potencjalne sposoby ich pokonania.

1. Introduction

The SWOT analysis and the prerequisite tree are an integral part of analyses carried out within the framework of "Foresight" – type projects [1]. A "Foresight" project is a method of data acquisition aimed at establishing a middle- or long-term vision of social and economic development of a country (directions and priorities). The results obtained from a "Foresight" analysis inform about new development tendencies, help to identify development scenarios, allow the activities of other partners (the government, research and industrial associations, companies, various business sectors, etc.) to be harmonized and aid in identifying the financing criteria of scientific research and technological implementation. This is why the SWOT analysis and the prerequisite tree are very useful instruments for technology development planning.

In frame of the "Foresight" – type project named "ForeMat" (Development scenarios of modern technologies of metallic, ceramic and composite materials) [2] SWOT analysis and PT were carried out for several technologies that are the most promising for the national economy. We can observe quick development of materials engineering processes based on laser, ion and plasma technologies, applied both in chemical vapour deposition (CVD) and in physical vapour deposition (PVD). These technologies often differ in their approach to solve the problem of surface engineering. As a result, it is frequently difficult to indicate an unequivocal solution for an interdisciplinary research and application issue. The selection of an optimum technology for manufacturing the product is based on good knowledge of available technologies, combined with advanced material diagnostics carried out within the range between macro- and nanoscale. It is important to know the already available

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technologies and trends in their development as well as their limitations. On the other hand their application requires an economical analysis of a potential market.
The development of a certain technology – based on a good understanding of physical and chemical phenomenology of the processes of surface engineering and material diagnostics of surface layers of a chosen material – constitutes the main prerequisite for the success in applying and implementing advanced environment-friendly technologies in production. Each technology has its limitations that result from a compromise between the peculiarities of the process specifications, the substrate materials, the expected properties of coatings and thin layers and the implementation costs.

In this work, as an example, SWOT analysis and PT for two technologies: Pulsed Laser Deposition (PLD) [3] and Electrochemical Deposition (ED) from aqueous solutions [4] are presented. They are technologies of the layer and coating deposition, which are developed in the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences (IMMS PAS). They are very good example to show how to use the presented analysis instruments because both SWOT and prerequisite tree provide universal information package for many surface engineering technologies.

2. SWOT analysis

SWOT analysis is an effective method of identification of strengths and weaknesses of various technologies as well as of examination of opportunities and threats for a certain technology. SWOT is an acronym of Strengths, Weaknesses, Opportunities, and Threats.

S	Strengths	Strong points, advantages
W	Weaknesses	Weak points, disadvantages
O	Opportunities	Opportunities, chances, possibilities
T	Threats	Difficulties, threats

SWOT analysis is based on a classification scheme that divides all factors influencing the current and future position of a technology into four categories:
• Internal positive – strengths, i.e. advantages of a technology.
Strengths are advantages of a technology that distinguish it in a positive manner among other competitive technologies. Strengths can be attributed to a big market share, low unit costs, innovation, production quality, etc.
• Internal negative – weaknesses of a technology.
Weaknesses are consequences of limited resources and insufficient qualifications. An excessive number of weaknesses could lead to the withdrawal of a technology from a competitive market, i.e. an investment may bring loss instead of expected profits.
• External positive – opportunities.
Opportunities are phenomena and tendencies in the environment that can be used to drive development and attenuate threats.
• External negative – threats.
Threats are all the external factors that are perceived as barriers for technology development, hindrances and additional operational costs. The presence of threats has a destructive impact on the development or success of investments. Simultaneously, threats hinder from taking full advantage resulting from opportunities and strengths. The general guidelines resulting from SWOT analysis are very simple, but they are unfortunately very difficult for execution (recommendations: avoid threats, take advantage of opportunities, eliminate weaknesses, rely on strengths).

2.1. Example of SWOT analysis used to characterize selected technologies of layer and coating production

Advanced surface engineering technologies allow to modify the properties of surface by forming surface layers permanently adhering to substrates [5]. The technologies enable to obtain materials required by clients, with strictly defined physical and chemical properties.

The analyses carried out within the "ForeMat" project [2] formed the data-base ranking of several technologies that are the most promising for the national economy.

- Production of composite systems consisting of a diffusion layer/PAPVD coating (PAPVD – Plasma Assisted Physical Vapour Deposition).
- Glow-discharge thermo-chemical treatment.
- Pulsed Laser Deposition (PLD), PLD/magnetron sputtering hybrid method.
- Low pressure carburizing and nitrocarburizing.
- Gas nitriding.
- Chemical Vapour Deposition (CVD).
- Metal-Organic Physical Vapour Deposition (MOPVD).
- Ultrasonic, plasma-assisted, cold gas, detonation spraying at high temperatures.
- Electrochemical deposition of metal and alloy coatings from aqueous solutions.
- Chemical deposition of metal coatings from aqueous solutions.
- Laser ablation surface cleaning.
- Hardening of construction materials with a shock wave generated by a laser pulse.

- Micro- and nanoprocessing of organic polymers with EUV radiation (EUV – Extreme Ultraviolet).
- Gradient systems based on C, Ti and Si, formed by a hybrid method, including ion-implantation techniques.

The presented ranking of surface engineering technologies that are promising with respect to applications in national industry covers a wide spectrum of developing, already-known and improved modern technologies. The ranking of technologies may vary, depending on the assumed priorities, the possibility of their implementation in various branches of industry, as well as on the expert team that prepares it.

2.1.1. SWOT analysis for the Pulsed Laser Deposition (PLD) technology

Strengths:
- The method can use very diversified materials to produce mono- and multi-layered coatings, often characterized by unique properties.
- The method allows hard and wear-resistant coatings to be obtained in very short time (the time of the mono-layer production is in the order of microseconds).
- The method ensures considerable uniformity of nanocrystalline coating structure, compared to other physical methods of deposition from a gas phase.
- The method ensures very good stoichiometric transfer of target material to substrate.
- The PLD method combined with magnetron processes (hybrid method) allows oxide materials to be easily deposited, ensures high efficiency of deposition and good adhesion of thin layers already at room temperature.

Weaknesses:
- High cost of equipment.
- Limited ability to cover larger areas.
- Substrate heating.
- Inappropriate quality of the laser beam may result in non-stoichiometric character of the deposited layer or in the formation of undesirable solidified droplets.

Opportunities:
In near future, the method may be useful for industrial deposition of complex chemical compounds (e.g. high temperature superconductors, ferroelectric and optoelectronic materials).
The method allows to produce thin fullerene layers in carbon coatings, organic coatings consisting of conductive polymers, diamond-like and hydroxyapatite-type coatings.
Very thin layers of non-conductors and conductors determine a new direction in the development of multi-layered coatings that can ensure, for instance, good lubricating ability within a wide range of temperatures.
Further increase of the deposition rate is the development trend for this method.
The hybrid technology increases the versatility and competitive character of the PLD method in the context of industrial coatings.

Threats:
- Lack of close cooperation between research centres and industry.
- The development of the new technology requires high financial outlays for a long period.

2.1.2. SWOT analysis for the electrochemical deposition of metal and alloy coatings from aqueous baths

Strengths:
- The method of covering metal and plastic surfaces with alloy coatings aimed at obtaining required surface characteristics (e.g. anticorrosive, decorative, magnetic, semi-conducting features, enhanced hardness and wear resistance at high temperatures, etc.).
- The required equipment is simple and its cost is low. It is easy to automate the process. Deposition rate is high.
- It is possible to deposit layers with strictly defined thickness (from fractions to dozens of micrometers) in a continuous manner on the complex shape and large surface parts of devices.
- It is possible to produce galvanic coatings at temperatures below several tens of Celsius degrees.

Weaknesses:
- It is necessary to use conductive substrates. Coated details must be made of conductive materials.
- Substrates must be properly prepared. Coated details must be degreased, mechanically cleaned, etc.
- The baths must be durable and stable.
- In the case of large installations, it is necessary to use open tanks containing compounds that are detrimental for the health of personnel and dangerous for the environment.

Opportunities:
- The perspectives for the development and applications of the electrochemical coating deposition technology are very promising. Up to now, the possibility of coating production has been experimentally confirmed for about 300 binary and ternary alloys.

- The investment costs indispensable to start production are relatively low.
- The main industry branches, where the electrochemical deposition technology is used: automotive industry (protective and decorative coatings), jewellery industry (decorative coatings), electronic industry (technological coatings), light industry (e.g. lighting products, cabinet hardware, packaging, etc.).
- Development of new electrolytes those are harmless for the natural environment.

Threats:

- Progress in the development of the electrochemical deposition technology depends decisively on the continuation of research activities and on the establishment of a feedback between the needs of industry and the works of research centres.
- Manufacturing plants must adapt to the new legal regulations that conform with EU regulations. This applies in particular to the regulations related to environment protection and industrial health and safety.
- The obligation to reduce the amount of detrimental and carcinogenic chemical compounds will lead to additional costs to be incurred by plants implementing the electrochemical deposition processes. Enterprises will be obliged to implement alternative technologies that are often more expensive or more difficult to operate.

3. Prerequisite tree (PT)

The prerequisite tree is a research tool that allows to identify potential threats and barriers that hinder the realization of assumed objectives. The instrument also indicates the possibilities of removing barriers as it proposes particular actions to be taken.

The prerequisite tree presented in Fig. 1 contains the main barriers (according to the authors) that hinder the development and improvement of sophisticated material technologies. The barriers are related both to the specific character of a certain technology and to general conditioning factors (e.g. legal, social, economic, etc.). In accordance with the concept of prerequisite tree construction, potential actions are suggested to eliminate the main threats that can prevent the assumed objective from being obtained. In this case, the objective is: "High-quality coatings, thin layers and modified surface layers with required properties obtained by means of modern technologies in surface engineering".

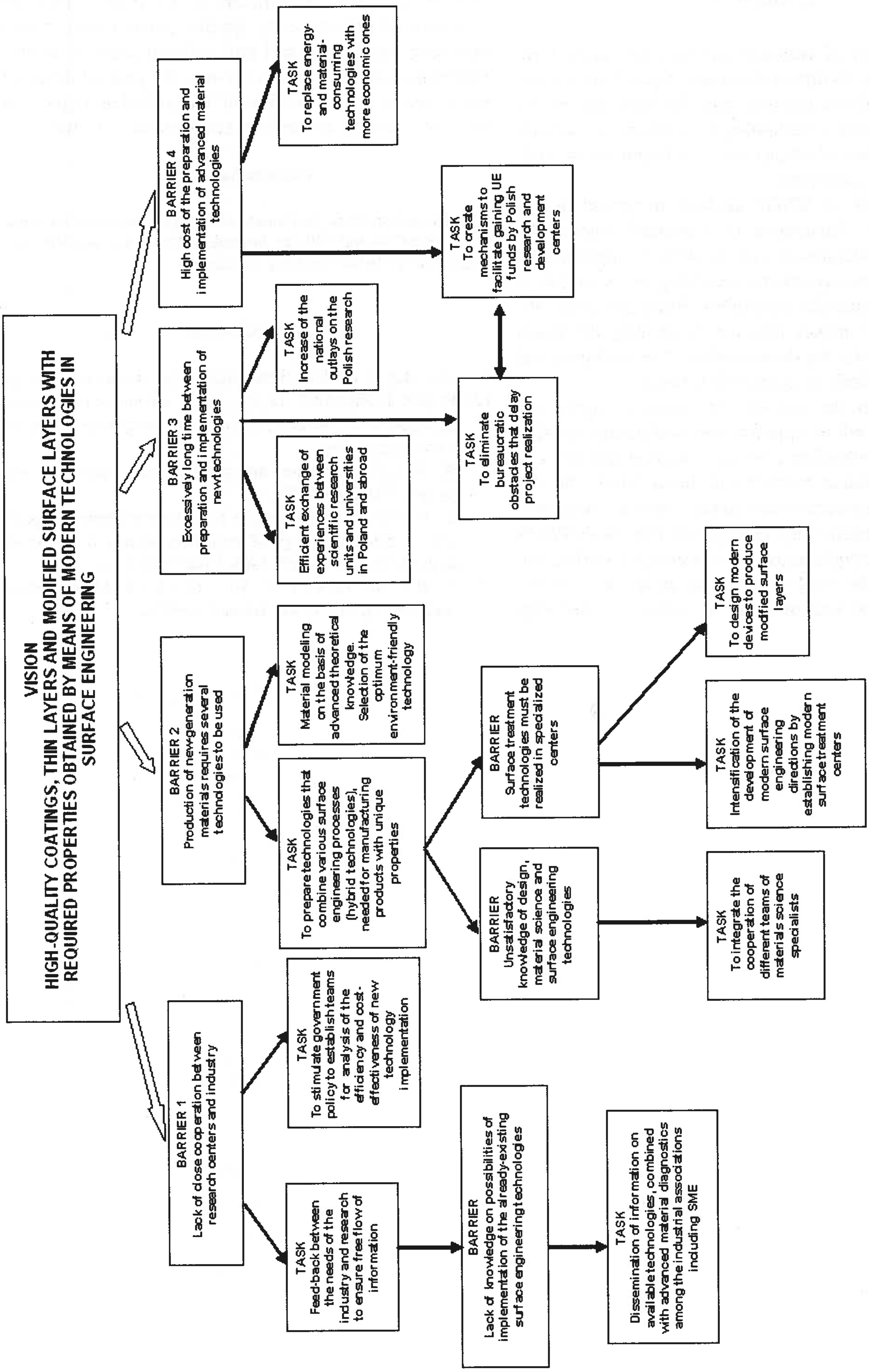

Fig. 1. Prerequisite tree (PT)

4. Summary

The diversity of available surface engineering technologies enables to obtain materials required by clients, with strictly defined physical and chemical properties. Both the considered technologies allowing to modify properties of material surface are very important in modern materials engineering.

The example of SWOT analysis presented in this work allows to characterize in a detailed manner the strengths and weaknesses and to identify opportunities and threats for the considered technologies, as well as to indicate their potential consumers. Simultaneously, the prerequisite tree makes possible to identify the major barriers that hinder the development of technologies and it indicates methods of overcoming them.

Although in the majority of cases, strengths and weaknesses as well as opportunities and threats are specific for each technology, several common features can be identified. Similar barriers and threats hinder the development of particular technologies. They are presented in Fig. 1 in the form of the prerequisite tree. Both SWOT analysis and prerequisite tree are extremely useful instruments that can be used by scientists in research on the development and improvement of surface engineering technologies. The development of a certain technology may also be influenced by specific conditioning factors operating on the regional and national scale. It is also important how the process fits into the general development trends, e.g. reduction of unfavourable impact on the environment, automation and economic factors.

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