

Posudek na disertační práci

Diamantový elektroforetický mikročip chlazený Peltierovým článkem

Pan ing. Mateusz Fijalkowski předkládá k obhajobě dle mého názoru kvalitní disertační práci, která řeší vysoce aktuální problematiku mikročipové detekce.

Samotná práce není dělena klasicky na teoretický úvod, metodickou část, část experimentálních výsledků a na jejich diskusi, ale má vlastní specifické členění na Úvod (2 strany), Přehled literatury (34 stran), Cíl a teze práce (1 strana), Vlastní výzkum (25 stran). Výsledky zkoumání (33 stran), Diskuzi výsledků (6 stran), Závěry (1 strana) a dále na Literaturu, Seznam obrázků a zkratk a Přílohy. Osobně nepokládám toto specifické členění za šťastné a rád bych autora požádal o vysvětlení důvodů, které ho k tomu vedly. Práce dle mého názoru v tomto specifickém členění trpí zejména značným překryvem metodické části s částí výsledkovou, ale i teoretickou (výsledky vlastní je občas obtížné rozlišit od výsledků jak jiných laboratoří, tak zejména spolupracovníků).

V práci se vyskytuje řada jazykových nedostatků. Jistě to lze ale tolerovat vzhledem k tomu, že autor není české národnosti. Z tohoto pohledu je nepochybně obdivuhodná jazyková kvalita disertační práce, přestože se (přirozeně) autor nevyhnul řadě anokulutů, aplikace polských výrazů i jazykových chyb. Vytýkal bych je v případě českých studentů, v tomto speciálním případě naopak oceňuji jejich akceptovatelnou četnost a nebudu je proto explicitně vyjmenovávat. Pozastavím se pouze u uvádění zkratk, kterých je v práci velmi mnoho. Autor většinu z nich uvedl na straně 8 v Seznamu zkratk symbolů, seznam však není úplný (chybí třeba LPA, LDI, EC, LC, MFTHR či HRP). Dle mého názoru nebylo v mnoha případech použití zkratk nutné, neboť se termín vyskytuje pouze jedenkrát. Autor by se také při větší pečlivosti mohl vyhnout obrázkům s anglickými popisy (obr. 28, 29) či uvedení odchylek měření na dvě desetinná místa, zatímco střední hodnoty na jedno desetinné místo (Tab. 6).

Diskuze je korektní, i když bych ji jistě rád viděl delší a podrobnější. Jsem ale přesvědčen, že u samotné obhajoby bude tato část doplněna. Na autora mám následující otázky.

1. Prosím autora o rozbor vlastní práce na tématu.
2. Málo jsou v úvodní části diskutovány současné varianty odvodu tepla ve srovnatelných systémech. Prosím autora o rozbor přínosu jeho dle mého názoru velmi přínosného řešení v porovnání s jinými alternativami.
3. Byl prototyp prakticky funkčně vyzkoušen?
4. Autor neuvedl koncentraci KCL v pufru (str. 46). Bylo to úmyslně (v tom případě proč) či z nedbalosti?
5. V příloze Ramanova spektroskopie je dle mého názoru v obr. 1 a 4 mnohem výraznější pozadí než v obr. 2 a 5, což není diskutováno. Nemůže to svědčit o

- různé depozici materiálu? Proč v textu práce jsou uvedena maxima 1332 cm^{-1} , když ve zmiňovaných obrázcích se maxima pohybují mezi 1334 cm^{-1} a 1335 cm^{-1} ?
6. Prosil bych autora, aby definoval všeobecný termín „výrazně lepší“ uvedený v závěru.
 7. Co bude z výsledků práce patentováno? Jaké předpokládá autor publikační výstupy?

Přes výše zmíněné nedostatky pokládám předloženou práci za vysoce kvalitní, velmi přínosnou a nepochybně vhodnou k tomu, aby autorovi byl v případě úspěšné obhajoby udělen titul PhD.

Evžen Amler

2/5-12

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Review of PhD thesis

Eng. Mateusz Fijałkowski:

„The diamond electrophoretic microchip cooled with Peltier device”

(Diamantový elektroforetický mikročip chlazený Peltierovým článkem)

Supervisor: Prof. dr hab. Stanisław Mitura

The review is based on the version of the PhD dissertation written in Polish language. The Author has confirmed its identity with the Czech version.

1. Evaluation of originality of the problems and correctness of research propositions of the work

Microchip electrophoresis has become in recent years, a mature analytical technique. This technique grew out of the capillary electrophoresis, which is an important separation method used to separate chemical compounds with large molecules. It serves, among others, to measure the molecular mass and to analyse the chemical composition of polymers and biopolymers, e.g. proteins. The issue of improving the speed of separation and minimizing the sample volume is very important, particularly for the analysis of DNA samples in such fields as medicine or criminology. Despite notable successes in the development of this technique there are many efforts to improve it in order to further increase the resolution, accuracy and speed of analysis.

The development of new technical solutions in the field of micro devices for DNA analysis is a large task requiring the involvement of an interdisciplinary research team -- including experts in materials science, chemical analysis and molecular biology. In Poland, the pioneering researches on microchips for the DNA analysis were initiated by Dr. Eng. Anna Karczewska from the Technical University of Lodz who coordinated the work of an international team in the project "Diamond microflow devices for genomics and proteomics" (DIAMID project). Mr. Eng. Mateusz Fijałkowski, as a member of the team, was a co-author of many solutions for both the design and material selection, as well as, of techniques of manufacturing the microchip.

One of the main issues related to the increase of the speed of the electrophoretic analysis is the release of the Joule heat due to the electrical current flow through the capillary system of the microchip. The excessive heat can cause convective movements of the solution and a change of the measured signals. In extreme cases, it can cause the liquid to boil, which can lead to the equipment failure.

The main task of the author was to address the above problems. He has developed an innovative design of a microchip made of diamond material of high thermal conductivity assembled with the thermoelectric cooling module (so-called Peltier module). This technical solution would allow increasing the separation voltage and a significant reduction of time of the analysis in comparison to the previously applied solutions.

2. Evaluation of the content of the work

The thesis of Mr. Mateusz Fijałkowski has a total of 156 pages and a classical layout. The theoretical part (43 pages) is devoted to the introduction of the microchip electrophoresis and a review of the state of knowledge on materials and techniques of manufacturing of the microchips for the electrophoretic separation. The author discusses here the detailed issues related to the use of electrophoresis in DNA sequencing and genetic analysis. It should be emphasized that the review of the state of knowledge has been made in a careful and comprehensive way (145 references) and includes the latest results of research. On the background of the review the author has outlined the main objectives of the thesis.

The experimental part has 67 pages and describes the author's own research, numerical modelling, equipment design, methodology, research results and conclusions. The work contains a couple of annexes, including a list of drawings and seven appendixes with additional results and schematics of microchip components. The author has clearly formulated the main thesis of his dissertation in the third chapter. It reads: *"As a result of the application of diamond for the construction of the microchip, and of equipping the system with the Peltier module, it is possible to obtain more favourable conditions during the electrophoretic process conducted with the use of microchips."*

With such statement the Author connected the goals of the work, which in particular were: to design and construct a new type of microfluidic device made of polycrystalline diamond assembled with a cooling Peltier thermoelectric module, and to carry out the characteristics of the material properties and performance parameters of the device. Extensive studies included: the characterization of the surface morphology using scanning electron microscopy SEM and confocal optical microscopy, the investigations of the surface chemical composition by the photoelectron spectroscopy XPS and x-ray EDX microanalysis, the surface wettability study, microhardness and Young's modulus tests, phase composition analysis by Raman spectroscopy and X-ray diffraction XRD, thermal properties measurements by laser flash LFA technique and the optical properties measurements by UV-VIS and IR spectrophotometry. The experimental studies of the microchip were carried out using a high resolution thermal imaging camera.

The study covers all the major issues related to the function of the diamond material of the microchip. The selection of the research methods was fully justified (my reservation concerns the application of the microhardness tests, only). Both the applied methodology and the interpretation of the results of the investigations are fully correct.

However, despite a very extensive research the Author confined the conclusions, only to the discussion of the benefits of a high thermal conductivity of the diamond material in heat dissipation and the positive effects of using the Peltier cooling module. The author

did not pay sufficient attention to the fact, that the speed of the analysis is affected not only by the applied separation voltage, but also by the flow resistances of the fluid. These in turn are associated with the tribological, chemical and physicochemical properties of the surface of the capillaries made of diamond. However, I am convinced that despite the lack of discussion the Author is aware of the importance of these issues.

In my opinion, regardless of these and other mistakes and misinterpretations the dissertation presents an adequate level and deserves a positive opinion.

3. Final evaluation of the dissertation

I express an opinion that the dissertation by Mr. Eng. Mateusz Fijałkowski includes an original scientific solution. The author has demonstrated a general knowledge of material science necessary to achieve the objectives of the research. Author's research results have important scientific value - they have been published in reputable scientific journals and were presented during several international conferences.

Reviewed here, both the trial and the scientific achievements of the graduate student fully meet the requirements of the law on scientific degrees and titles. On this ground I address the Mechanical Faculty Scientific Council of the Technical University of Liberec to admit the Mateusz Fijałkowski PhD thesis entitled "*The diamond electrophoretic microchip cooled with Peltier device*" to its public defense.

U. Wojciechowski



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Institute of Materials Science and Engineering

Associate Prof. Piotr Niedzielski, Ph.D.

Lodz, 01.04.2012 r

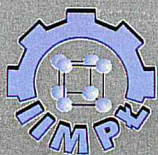
Review of PhD thesis

Ing. Mateusz Fijałkowski

**Topic: „THE DIAMOND ELEKTROPHORETIC MICROCHIP
COOLED WITH PELTIER DEVICE”**

Supervisor: Prof. Stanisław Mitura,

**Review written on the basis of the letter of the Dean of the Mechanical
Faculty of the Technical University of Liberec Doc. Ing. Miroslav Maly,
CSc. from March 22, 2012r.**



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General evaluation:

Ph.D. thesis of M.Sc. Mateusz Fijałkowski consists of 10 chapters (including: 145 references, list of figures (95) and tables (11) and annexes (7)). In total, the dissertation was written on 156 pages. References quoted in the work were chosen in a proper manner, and come mainly from the last decade of the twentieth and twenty first century. In the bibliography was demonstrated two publications co-authored by candidate for a doctor's degree.

In the reviewers opinion for the major achievements in the work can be considered:

- Creation of a virtual model using Conwenter WareTM software
- Preparation of a diamond electrophoresis chip using a replica technique (the chip was developed within the confines of the international cooperation with the Institute of Physics, Russian Academy of Science in Moscow)
- Design and implementation of a prototype of silicon lid with microports
- Characteristics of the physicochemical and structural properties of diamond chip
- Design and construction of electrophoresis apparatus along with the cooling system using Peltier cells

Dissertation completed by MSc. Mateusz Fijałkowski is very interesting and well-executed part of a worldwide laboratory research into the use and optimization of the so-called microchip system for the analysis of biological materials (such as DNA sequencing). The advantage of the these new diagnostic systems is first and foremost the acceleration (shortening) of the study and the wide possibility of automatization. Research performed by the candidate for a doctor's degree showed among others the superiority of diamond chip over the conventional devices made from glass of polymers, the possibility of application of Peltier system for efficient dissipation of heat generated during electrophoresis (Joule heat). During the implementation of research MSc. Mateusz Fijałkowski showed a large engineering experience (in the design of individual elements of the apparatus) as well as research knowledge necessary for a young scientist (the ability to plan the experiment, the use of modern research equipment and synthetic analysis of the results).

Other comments

Candidate for a doctor's degree like any other young scientist (and not only) did not avoid certain simplifications, mistakes etc. However this has more editorial

than substantive character and the comments on this topic was submitted to the PhD student in the course of direct conversation (discussion) of the work.

To the main critical remarks I would include:

- too cursory comparative analysis between the used material (diamond) and conventional materials such as glass or polymers used in production of microchips
- The study of the geometry, depending on the method show deviations from the dimensions in the range of 5-10 %. How this may affect the process of electrophoresis. Were there made a computer simulations taking into account the real data?
- What is the impact on the quality of the experiment of the fact that the chip material was not pure diamond (contaminated eg. by the materials of the silicone matrix technology)?

Final evaluation

All comments mentioned above are debatable and do not diminish the positive opinion of the reviewer about the scientific level of the dissertation.

Summarizing, it should be claimed that the dissertation from the materials science field of Mr. Mateusz Fijałkowski: „The Diamond Elektrophoretic Microchip Cooled With Peltier Device” corresponds with the terms established in the titles and degrees law.

On this ground I move to Mechanical Faculty Scientific Council of the Technical University of Liberec to allow the Mateusz Fijałkowski's PhD thesis to its public defense.

Dr hab. inż. Piotr Niedzielski, prof.PŁ

