A kutatás eredményeinek rövid, tényszerű összefoglalása magyarul,

Mivel a posztdok pályázatot az első év után megszakítottam, így az első évben leadott jelentésben minden elért eredmény megtalálható, azóta nem történt semmi a témában.
A polidimetil-sziloxán (PDMS) előnyös anyagi tulajdonságai miatt nagyon népszerű mikrofluidikai chipek és lab-on-a-chip eszközök gyártásában. Ennek köszönhetően számos területen nagyon elterjedt, úgy mint kémiai elválasztás, biológiai elválasztás, üzemanyag cellák, kémiai mikroreaktorok vagy éppen űreszköz hajtóművek.

A mikrofluidikai kutatásaimhoz polidimetil-sziloxánt (PDMS) választottam alapanyagul. A pályázat keretében fejlesztendő rendszer egy kémiai mikroreaktor, amely laterális méretei az 1 mm nagyságrendjébe esnek. A dizájn, reakció sebesség és hatásfok maximalizálásához végeselem szimulációkat végeztem Comsol szoftverrel, amit frissen szereztünk be ezen számolások végrehajtásához. A szimulációk alapján a a reaktor optimális geometriája kidolgozás alatt van. Az előzetes eredmények körében megemlíteném az általunk fókuszált nehézion besugárzással létrehozott mikrolencse mátrixot, ami mikrofluidikai rendszerekbe integrálható.

Az anyagmódisítási kutatések keretében kimutattam, hogy a térhálósodott PDMS mind pozitív, mint negatív rezisztként is előhívható és demonstrációként 3D mikrostruktúrákat hoztam létre velük. Eddig ismeretlen volt, hogy ezt a kémiailag igen ellenálló anyagot hogyan lehet lithográfiában rezisztként használni.

Vizsgáltuk továbbá biopolimerek degradációját ionbesugárzás hatására.

Angol – eredmények röviden

This application has been cancelled at the end of its first year, so no new results were created since then.
I have chosen polydimethilsiloxane (PDMS) as a base material for the microfluidic system to be developed. The system under development is a chemical microreactor or microstructured reactor that is a device with typical lateral dimensions below 1 mm in which chemical reactions take place.
To optimize the design, the efficiency, reaction speed and mixing of the reacting fluids, I carried out finite element simulations with the Comsol software. We have recently bought this software package exactly for the purposes of this study. By the results of these simulations, the optimal inside arrangement of the microfluidic system is still under improvement.
In the framework of a preliminary experiment we created microlens arrays by focused heavy ion irr adiation. These lenses can be integrated later in microfluidic systems.

In my materials modification research, I have found that if the structure of the polymer was modified by high fluence proton irradiations the modified PDMS could be selectively etched as either a positive or a negative tone resist with the appropriate solutions. The method of direct formation of microstructures in cured, additive-free PDMS has not been previously known. Applying the found technique on PDMS nanocomposites base materials such micro- and nanofabricated components can be fabricated that are very difficult, if not impossible, to create with other lithography methods inside microfluidic chips.

We have also investigated the modification / degradation of biologically interesting proteins such as Immunoglobulin G, Fetuin, Ribonuclease and N-glycans. The samples were irradiated with various proton doses in dry form in vacuum and also in liquid form in air.

Az elért eredmények rövid ismertetése:

Poly(dimethylsiloxane) is undoubtedly the most commonly used microfluidic material in research laboratories. It is hydrophobic, chemically resistive, cost effective and easy to use. With plasma treatment, it can easily be bonded to another PDMS layer, to a silicon or glass substrate. These are just some advantageous properties out of the many that make PDMS highly desirable in fabrication and prototyping of microfluidic chips and lab-on-a-chip devices. These devices, and thus Poly(dimethylsiloxane), have demonstrated significant potential in countless applications, such as chemical separation, separation and processing of biological cells, fuel cells, chemical microreactors or even spacecraft thrusters.

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Nagy G. U. L., Lavrentiev V., Bányász I., Szilasi S. Z., Havranek V., Vosecek V., Huszánk R., Rajta I.: Compaction of polydimethylsiloxane due to nitrogen ion irradiation and its application for creating microlens arrays, Thin Solid Films 636 (2017) 634

In the framework of materials modification, I work on two main projects. The first is connected to the microstructured fluidic system mentioned above, while the second one is biology related.

Although, poly(dimethylsiloxane) (PDMS) is a widely used m aterial in numerous applications, such as micro- or nanofabrication, the method of selective etching of the additive-free and cured polymer has not been known up to now.

The key to the application of PDMS as a resist material is the change of its chemical properties whe re it is exposed to various types of radiation. Due to irradiation, chain scissioning happens in the polymer: the main Si-O-Si chain brakes, functional groups split and the volatile products (e.g. H2, CH4 and C2H6 gases) leave the irradiated volume. As a result of these processes, PDMS shrinks at the place of irradiation and the initially elastic polymer becomes a rigid, brittle and glass-like material. Since the cured PDMS is chemically very resistant, it has been unknown how to selectively etch the modified areas. During my research, I have found that if the structure of the polymer was modified by high fluence proton irradiations the modified PDMS could be selectively etched as either a positive or a negative tone resist with the appropriate solutions. I present these results and the development methods in two papers. In the positive resist case, I determined the fluence dependence of the etch rate of the modified polymer. Since the etch rate does not change linearly with the delivered fluence but it peaks at a certain value, there must be a non-linear structural change of the PDMS in the background. For the clarification of this non-linear behaviour, a chemical investigation is in progress. I also demonstrated in both papers that by the development of the modified polymer various high aspect ratio microstructures could be formed in 7 □m – 103 □m thick polymer layers.

The method of direct formation of microstructures in cured, additive-free PDMS has not been previously known. Applying the found technique on PDMS nanocomposites base materials such micro- and nanofabricated components can be fabricated that are very difficult, if not impossible, to create with other lithography methods inside microfluidic chips.

We have also investigated the modification / degradation of biologically interesting proteins such as Immunoglobulin G, Fetuin, Ribonuclease and N-glycans. The samples were irradiated with various proton doses in dry form in vacuum and also in liquid form in air. The contained glycans were extracted from the proteins by the appropriate methods. Presently we are investigating with e.g capillary electrophoresis how the structures of the glycans change due to proton irradiation. These results may be interesting for example at long time space travels where biological species may be exposed to large doses during the flight or even at identifying the signs of life on other celestial bodies where the remnants of extraterrestrial microorganisms may receive significant doses over time.

S.Z. Szilasi, C. Cserháti, Selective etching of PDMS: etching as positive resist, submitted to Applied Surface Science, Ref. No.: APSUSC-D-17-12986

S.Z. Szilas i, L. Juhasz, Selective etching of PDMS: etching as negative resist, submitted to Applied Surface Science, Ref. No.: APSUSC-D-17-13018

The papers were uploaded to arXiv.org scientific online repository where they are freely accessible.