SOUTHERN FEDERAL UNIVERSITY

SMART MICROFLUIDICS 2025

International conference

Book of abstracts

Rostov-on-Don
2025

This book of abstracts contains the results of the reports presented at the 2nd international scientific conference “Smart Microfluidics 2025”. The fields covered catalytic approaches for the synthesis of functional materials, the development of microfluidic systems using the additive DLP approach for 3D printing, as well as practical approaches to the application of microfluidic technologies for the synthesis of novel functional materials in various fields of industry, chemistry and medicine.

Integration of Modeling in the Study of Capillary Valves in Microfluidic Diagnostic Chips

Agisheva A.[1], Matishova D.[1], Tyushkevich A.[2], Altynbaev L.[2], Belousova D.[2], Muchkinova E.[1], Bukatyn A.[2]

[1]LLC "Rapid Bio", [2]St. Petersburg National Research Academic University named after Zh. I. Alferov

Corresponding author e-mail: aagisheva@drd.biotech.ru

When developing microfluidic devices, researchers typically choose either modeling [1] or experimental methods [2], which leads to insufficient model validation or a lack of predictive power. This separation complicates the transition from research to production.

In our work on capillary valves, we applied a comprehensive approach that combines modeling with experimental validation. In COMSOL, the burst pressure was calculated using the Laplace equation [2–3], while experiments were carried out on 3D-printed samples with various surface modifications. Theoretical values ranged from 129 to 432 Pa, and experimental values from 175 to 325 Pa; both methods demonstrated the necessity of using hydrophobic materials for the efficient operation of capillary valves (Figure 1).

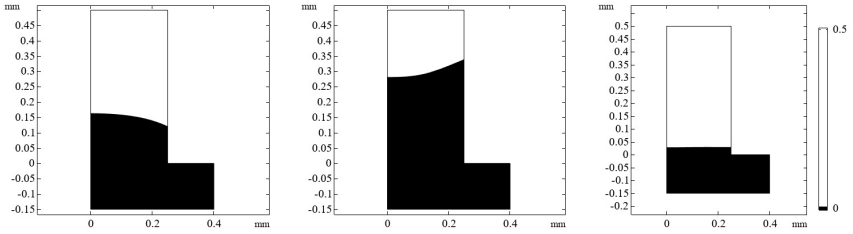


Figure 1. Phase separation in a 2D vertical cross-section: (A) contact angle 112.5°, (B) contact angle 67.5°, (C) contact angle 90°

This approach enables a more accurate description of capillary valve performance and accelerates the transition from fundamental research to reproducible prototypes and the commercialization of microfluidic chips, which may become a universal strategy for the development of next-generation point-of-care systems.

References

[1] E. Yıldırım (2017). Modeling and Analysis of a Microfluidic Capillary Valve. Politeknik Dergisi, 20(2), 487–494.

[2] S. Wang, X. Zhang, C. Ma, S. Yan, D. Inglis, S. Feng (2021). A review of capillary pressure control valves in microfluidics. Biosensors (Basel), 11, 405.

[3] T. H. G. Thio, S. Soroori, F. Ibrahim, W. Al-Faqheri, N. Soin, L. Kulinsky, M. Madou (2013). Theoretical development and critical analysis of burst frequency equations for passive valves on centrifugal microfluidic platforms. Medical & Biological Engineering & Computing, 51 (5), 525–535.

Perspectives of computer modeling in microfluidic processes

Anufriev I.E.[1], Timralieva A.A.[1], Zagrebaev A.D.[2], Skorb E.V.[1]
[1]Infochemistry Scientific Center of ITMO University, Lomonosova str. 9,
St. Petersburg 191002, Russia,
[2]The Smart Materials Research Institute, Southern Federal University,
Rostov-on-Don 344090, Russia
Corresponding author e-mail: ilya_anufriev_00@mail.ru

Microfluidic technologies open the way to the production of new materials and the observation of subtle chemical processes through precise control of synthesis conditions. One of the most important components of microfluidics is the development of the chip topology, it is the correct channel geometry that allows achieving high-quality and reproducible results. Considering all the nuances of setting up a new reaction in a chip is not an easy task, but at the same time it is quite resource intensive. To optimize the process of developing a chip topology, preliminary computer modelling is often used. It enables testing the correctness of the topology in advance, optimizing both the topology and the working conditions for synthesis. At the same time, computer modelling itself has its own difficulties and nuances. Due to the difference between a physical experiment and a computer experiment, their results can vary greatly. The task of the researcher is to bring the result of a mathematical calculation as close as possible to the real one. For this, it is necessary to know the points that most affect the result of the simulation.

We conducted a series of experiments to simulate the interaction of aqueous solutions of coloured substances in several microfluidic micromixers printed on a 3D printer. During the study, the main points were identified that make it difficult to correctly correlate the results of computer modelling with a real experiment and several solutions were proposed.

Application of Microfluidic Technologies for the Synthetic Polymeric Proppants Production

Madina Baltaeva[1], Vyacheslav Grokhovskiy[1], Denis Shatalov[1], Nikolay Nedelko[2], Danila Sumovskiy[2]
[1]SIBUR Innovations LLC, [2]Microfluidics LLC
Corresponding author's e-mail: baltaevamb@innovation.sibur.ru

Proppants play a critical role in hydraulic fracturing (HF) operations by enabling sustained hydrocarbon production. While conventional proppants—such as silica sand and sintered ceramics—remain widely used, they suffer from limitations including high specific gravity, brittleness, and incompatibility with low-viscosity fluids. In this context, synthetic polymeric proppants have emerged as promising alternatives due to their low density and tunable mechanical properties [1].

Microfluidic platforms offer a highly controlled environment for the synthesis of monodisperse polymeric microspheres, leveraging precise manipulation of multiphase flows at the microscale [2]. In this work, we demonstrate a continuous-flow microfluidic process for the fabrication of polymeric proppants. By optimizing the flow rates of monomer, stabilizer, and initiator streams, we achieve stable droplet generation with uniform size and regular detachment frequency. The smooth geometry of the microchannels promotes near-perfect sphericity, while the laminar flow regime ensures reproducible reaction conditions and minimal batch-to-batch variability.

The developed method enables continuous production of proppant granules with a narrow particle size distribution. Particle diameter can be precisely tuned micrometers by modulating reagent concentrations, microfluidics device's geometry, and flow rate ratios. Compared to conventional suspension or emulsion polymerization techniques, the microfluidic approach ensures consistent product properties, scalability, and yields polymeric proppants with high mechanical strength and resistance to harsh downhole conditions.

References

[1] K. D. Pangilinan, A. C. Leon, R. C. Advincula, Polymers for proppants used

in hydraulic fracturing, Journal of Petroleum Science and Engineering,

[2] D. Boskovic and S. Loebbecke: Polymer particles and capsules. Nanotechnol Rev 2014; 3(1): 27–38

Microfluidic platform for synthesis of micro- and nanoparticles for biomedical applications

Bukatin A.S.[1,2], Naumov E.I.[1,3], Pleshakov P.S.[1],Filatov N.A.[1,3]
[1]Alferov Saint Petersburg National Research Academic University of the RAS,
[2]Institute for Analytical Instrumentation of the RAS, [3]JSC "FLIXBIO"
Corresponding author e-mail: antbuk.fiztek@gmail.com

Microfluidics is a powerful tool for synthesis of micro- and nanoparticles with narrow size distribution.Here we present a microfluidic platform based on a custom pressure controller [1] for synthesis water-in-oil (W/O), water-oil-water (W/O/W) emulsions,hydrogel microparticles and lipid nanoparticles for screening applications,drug delivery and 3D cell cultures growth. For each application the pressure controller is accompanied by a PDMS microfluidic chip fabricated with soft lithography using a Si/SU8 mold.

Monodisperse W/O and water-oil-water W/O/W emulsions in the range of 10 – 200 um in diameter were generated using flow focusing microfluidic chips. Encapsulating hydrogel (alginate, polyacrylamide, PEGDA, agarose) prepolymers inside the droplets hydrogel microparticles were obtained. Cultivation of living CT26 and HepG2 cells inside the alginate particles led to cell spheroids formation withcells viability >90%, which are promising to use for high throughput drug screening applications.

Using a microfluidic mixer lipid nanoparticle (DOTAP, DOPE, Cholesterol, 1:1:1 molar ratio) with average size of 80 nm and zeta potential of +36 mVwere obtained. Such nanoparticles can be used for DNA/RNA delivery in *vitro* and in *vivo*, which was shown by delivery of GFP encoded plasmid.

In this work we developed a microfluidic platform for high throughput synthesis of monodispersed emulsion, micro/nanoparticles and showed their applications for 3D cell cultures growth and DNA delivery.

References

[1] Filatov N. A. et al. Open-source pressure controller based on compact electro-pneumatic regulators for droplet microfluidics applications //IEEE Transactions on Instrumentation and Measurement. – 2022. – T. 71. – C. 1-10.

Optimal Conditions for Pt-catalyzed Microfluidic Synthesis of Iodoolefins

Bulgakov A.N.[1], Gogil'chin A.S.[2], Eid Mahmoud E.A.[1,3], Tereshchenko A.A.[1], Egil N.V.[1], Guda A.A.[1], Soldatov A.V.[1]

[1]The Smart Materials Research Institute, Southern Federal University, 344090 Rostov-on-Don, Russia,

[2]Institute of Physical Organic Chemistry and Coal Chemistry, 70 R. Luxemburg Str., Donetsk, Russia,

[3]Physics Department, Faculty of Science, Tanta University, Tanta, 31527, Egypt.

Corresponding author e-mail: albu@sfedu.ru

Microfluidic synthesis, characterized by fluid flow in tiny channels with characteristic dimensions ranging from tens to hundreds of micrometers, has emerged as a transformative approach in modern chemical engineering [1]. This approach involves manipulating small volumes of fluids in microchannels and provides several benefits including improved mass transfer, online monitoring of reaction conditions, low thermal inertia and the ability to perform high-throughput screening of reaction conditions.

The implementation of microfluidic continuous-flow methodology for iodoolefin synthesis would overcome current limitations through two principal mechanisms: first, by intensifying acetylene mass transfer to the catalytic phase via enhanced interfacial contac, and second, by enabling precise quantification of specific interfacial area within the capillary reactor.

We present a comprehensive strategy for optimizing product yields and reducing reaction times in the homogeneous catalytic synthesis of vinyl iodides using PtIV iodo complexes. Our approach integrates four key components: (a) translation of batch reactions to segmented gas-liquid flow conditions, (b) real-time droplet monitoring to track interfacial area, (c) inline phase separation for efficient product isolation, and (d) direct monitoring of acetylene conversion kinetics via in situ mass spectrometry (MS).

References

[1] Armstrong C.; Teixeira A, React. Chem. Eng. 5, 2185 – 2203 (2020).

Preparation of 2,5-dimethylpyrrole(2,5-DMP) from 2,5-dimethylfuran (2,5-DMF) via Two-Stage Microfluidic Synthesis

Grokhovskiy V.V.[1], Verpekin V.V.[1], Shatalov D.O.[2], Pokrovskiy M.V.[3], Shkultetskaya Y.M[3].
[1]SIBUR-INNOVATIONS LLC,
[2]MIREA – Russian Technological University
[3]JSC "Technopark of St. Petersburg"
Corresponding author e-mail: grokhovskiivv@innovation.sibur.ru

2,5-Dimethylpyrrole (C_6H_9N) is an important organic heterocyclic compound widely used as a key building block in organic synthesis. It is actively used in the pharmaceutical industry as a component of active pharmaceutical ingredients (APIs), including antibiotics and anti-inflammatories agents [1]; in the production of organic dyes and photosensitive materials [2]; as a protective group for amino groups in peptide synthesis; as a bioactive compound against fungi, gram-positive and gram-negative bacteria; as a ligand in catalytic systems with specific electronic properties [3].

The technology for obtaining 2,5-DMP from 2,5-DMF consists of two stages [4]: 1Acid-catalyzed hydrolysis with ring-opening of 2,5-DMF to form hexane-2,5-dione (2,5-HDO)2) Cyclization of 2,5-hexanedione with ammonia according to the Paal-Knorr mechanism. Both stages are effective at high temperatures (110-120°C) and require intensive mixing of liquids with different polarities. During batch synthesis, there are problems of heterogeneous mixing of components (for the first stage), inefficient heat and mass transfer, low diffusion rate - all this leads to high time spent on obtaining the final product.Additionally, the volumetric process leads to the formation of by-products and an increased sensitivity to oxidative degradation in non-inert synthesis conditions. All these factors affect the final yield of 2,5-DMP.

The microfluidic technology we have used makes it possible to carry out both stages in closed conditions in a flow-through mode [5]. This solution allows for the use of a different type of catalyst and eliminates the need for auxiliary solvent in the synthesis, as more critical pressure and temperature

conditions ensure sufficient intensity of reagent interaction. Furthermore, it helps to solve the chronic and fundamental problems of bulk technology and achieve high yields in both stages, for the intermediate (2,5-HDO) and the final product (2,5-DMP). In addition, the microfluidic approach significantly increases the safety of the process, substantially reduces waste generation, and the high efficiency of the use of reagents creates high prerequisites for scaling up the technology.

The flow-through microfluidic technology employed demonstrated obvious advantages over the volumetric method in a whole set of indicators. The development of this approach creates evident prerequisites for the creation of pilot and industrial plants for the production of five-membered heterocyclescompounds. Moreover, this technology offers wide opportunities for qualitative and quantitative production of a large variety of pyrrole derivatives with different sets of functional groups.

References

[1] Meir Touitou, Fabrizio Manetti, Camila Maringolo Ribeiro, Fernando RogerioPavan ,NicolòScalacci, Katarina Zrebna, Neelu Begum, Dorothy Semenya, Antima Gupta, Sanjib Bhakta, Timothy D McHugh, HanochSenderowitz, Melina Kyriazi, Daniele CastagnoloImproving the Potency of N-Aryl-2,5-dimethylpyrroles against Multidrug-Resistant and Intracellular Mycobacteria, ACS Medicinal Chemistry Letters, 2020, 11, pp 638-644

[2] Lawrence K. Low, David A Lightner, Pyrrole photo-oxidation. Unusual products from 2,5-dimethylpyrrole,Journal of the Chemical Society, Chemical Communication, issue 3, 1972

[3] Khasbiullin I. I., Wilms A. I., Kharlampidi H. E., Belov G. P. Polymerization of ethylene on the catalytic system Cr(III)-acetylacetonate/2,5-dimethylpyrrole/triethylaluminium and polymer properties, Vestnik Kazanskogo Tekhnologicheskogo Universiteta 2010, 6

[4] Anisimova N.A. Chemistry of heterocyclic compounds, Tutorial Part 1, St. Petersburg 2017, pp.43-44, 49-50

[5] Pieter Nieuwland, Ruth Segers, K. Koch, J.C.M. Hest, van, F.P.J.T. Rutjes, Fast scale-up using microreactors: Pyrrole synthesis from micro to production scale, Journal Organic Process Research&Development, 2011, pp. 783-787

Research of the process of tar dispersion during interaction with an organic solvent on microfluidic chips

Ilya Dobysh[1], Margarita Latypova[1], Maxim Gribincha[1], Yuri Kadomsky[1,2], Alexander Matiunenko[1,2], Michael Tarkhov[3], Ivan Filippov[3], Alexander Rykov[3], Evgeny Shilov[1,4], Alexey Cheremisin[1,4]

[1]LABADVANCE LLC,

[2]D. Mendeleev University of Chemical Technology of Russia,

[3]Institute of Nanotechnology of Microelectronics of the Russian Academy of Sciences,

[4]Skolkovo Institute of Science and Technology

Corresponding author e-mail: dobysh@labadvance.net

The preparation and use of tar in various industries presents several problems, including high corrosive activity, very high viscosity, difficulties in disposal. These problems increase the cost, complexity of tar processing and utilization. One possible solution is dispersion in hydrocarbon solvents, which reduces the overall viscosity of the mixture and prevents tar from sticking to the surfaces of processing vessels, facilitating many processes involved in preparing petroleum residue for processing.

This study involves testing a visual analysis of the hydrocarbon feedstock dispersion process efficiency using tar as an example. This allows us to evaluate both the uniformity and size of the distributed particles, as well as the precipitation during interaction with the solvent. An optical microscope with a fluorescent lamp was used for visual observation. The test section is a microfluidic chip with a wide, tortuous structure to ensure high flow rates and prevent high filtration resistance. The dispersion process involves the combined filtration of a mixture of tar and pentane in proportions of 1/3, 1/5, and 1/8, sequentially changing from less to more solvent, through the test area. During the active phase of the experiment, the precipitation rate and particle size were assessed.

The results show a gradual accumulation of particles at the lowest solvent-to-tar ratio, followed by the formation of asphaltene agglomerates with increasing amounts of pentane, and complete clogging of the channel with precipitated particles. This observation shows the need to pay attention

to the reagent ratio parameter. In addition, a time interval was recorded during which some of the tar agglomerates were picked up by the passing mixture flow and carried out through the microchip's outlet. This phenomenon can be useful for selecting the reagent ratio that will ensure cleaning of surfaces contacting with the tar.

The presented technology for conducting a tar dispersion experiment on a microfluidic chip allows to detect asphaltene particles at the micro level, thereby allowing for precise and rapid adjustment of mixture parameters to achieve maximum process efficiency.

In-line NMR diagnostics of hydroformylation provided by segmented-flow microfluidic regime

Mahmoud E.A. Eid[1], Maria V. Nenasheva[2], Aleksei N. Bulgakov[1], Alexander V. Soldatov[1], Dudari B. Burueva[3], Elizaveta S. Kononenko[3,4], Ivan V. Skovpin[3], Igor V. Koptyug[3], Dmitry N. Gorbunov[2], Alexander A. Guda

[1]The Smart Materials Research Institute, Sladkova 178/24, 344090 Rostov-on-Don, Russia, [2]Lomonosov Moscow State University, Faculty of Chemistry, 119234, Leninskie Gory, 1, 3, Moscow, Russia, [3]International Tomography Center SB RAS, 3A Institutskaya St., Novosibirsk 630090, Russia, [4]Novosibirsk State University, 2 Pirogova St., Novosibirsk 630090, Russia

Corresponding author e-mail: eid@sfedu.ru

Hydroformylation of olefins was monitored in real time using in-line ^1H NMR spectroscopy within a microfluidic segmented-flow reactor, enabling rapid kinetic analysis without sample preparation or deuterated solvents. The microfluidic system exhibited enhanced mass transfer, achieving over 90% aldehyde yield at elevated temperature and pressure within minutes. This approach allows safe, continuous high-pressure catalytic studies with precise control and fast screening of reaction conditions. The integration of microfluidics and NMR provides a powerful platform for optimizing homogeneous catalysis and advancing industrial process development. This methodology represents a significant advancement in rapid, real-time catalytic reaction monitoring.

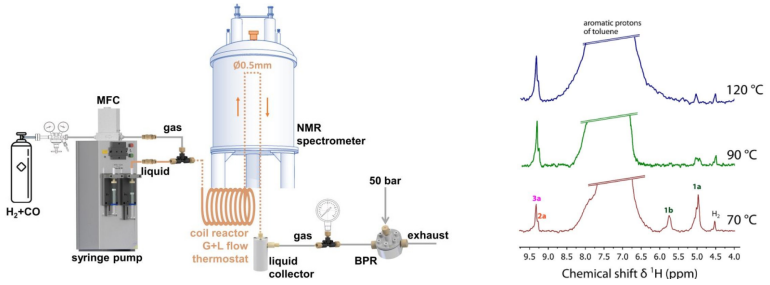


Figure 1. (a) The scheme of the microfluidic setup equipped with in-situ NMR spectrometer. (b) In-situ 1H NMR spectra

The Role of Microfluidic Technologies in Meeting the Current Needs of the Chemical Industry

Valentin Ershov[1], Danila Sumovsky[1], Nikolay Nedelko[1], Sergey Rzhevsky[1], Dmitry Snetkov[1]
[1]LTD Mikroflyudika
Corresponding Author, e-mail: office@microfluidika.ru

Microfluidics technologies have been known for a long time, but their application in the chemical industry is relatively new. Recent foreign policy changes associated with the islandization of the world are leading to a reconsideration of traditional scientific and technological development strategies and, consequently, a shift in the pool of technologies on which governments, corporations, and the academic community are focusing their efforts.

One of the most striking consequences of this approach is the increased emphasis on deep-tech technologies and the influence of the characteristics of a more limited, but more protected, market.

Microfluidic systems in the chemical industry can provide micro- and small-scale chemistry with essential chemical components, while also being cost-effective compared to traditional methods.

Industrial implementation in the form of small plants, such as GAPS and container-type plants, allows for much better utilization of the advantages of microfluidic technologies in Russia's current situation.

The authors are confident that a similar approach could also be of interest to a number of BRICS countries, such as China and India.

References

[1] RBC, Putin's Special Representative Proposes "Technological Island" Strategy

[2] National Project Passport: National Project "New Materials and Chemistry"

Modification of microfluidic chips by chemical deposition of a carbonate layer

Yury Kadomsky[1,2], Alexander Matyunenko[1,2], Maxim Gribincha[1], Ilya Dobysh[1], Margarita Latypova[1], Svetlana Naydukova[1], Michael Tarkhov[3], Ivan Filippov[3], Alexander Rykov[3], Igor Maryashev[4], Andrey Kuzmin[4], Evgeny Shilov[1,5], Alexey Cheremisin[1,5], Vitaly Kuznetsov[2]

[1]LABADVANCE LLC,

[2]D. Mendeleev University of Chemical Technology of Russia,

[3]Institute of Nanotechnology of Microelectronics of the Russian Academy of Sciences,

[4]Microscopy and Analysis Systems LLC,

[5]Skolkovo Institute of Science and Technology

Corresponding author e-mail: kadomsky@labadvance.net

Simulating carbonate reservoirs in microfluidic experiments requires reproducing not only the pore geometry, but also the basic physicochemical properties of the surface: a stable, optically compatible layer of $CaCO_3$ on the channel walls. This paper presents the testing of a previously developed method for forming such a layer directly inside silicon-glass microfluidic chips by pumping chemical agents through the chip and layer-by-layer (LbL) deposition on a pre-activated and functionalised surface [1]. After plasma cleaning, the channels are modified with an amine-containing silane, which provides nucleation centres and adhesion of inorganic deposits, and then Ca^{2+} and CO_3^{2-} solutions are sequentially passed through at controlled pH, ionic strength and contact time. The number of LbL cycles determines the thickness of the carbonate film from tens of nanometres to units of micrometres. Optimisation of flow rate and temperature conditions minimises concentration gradients and achieves high uniformity along the channel length. To suppress waterite crystallisation and preferentially obtain calcite, slightly alkaline conditions and moderate salt concentrations were used, which, in combination with the amine substrate, stabilises the desired polymorph.

SEM was used to control the thickness and continuity of the carbonate layer. The optical transparency of the substrate is maintained due to the

thinness and uniformity of the layer, which ensures correct visualisation of fluid flow. Adhesion and mechanical stability are assessed by the critical shear stress at increasing flow rates. Resistance to washing with changes in ionic strength and pH demonstrates the suitability of the coating for long-term experimental cycles.

The proposed method has significant advantages over traditional biochemical and gas diffusion approaches. Unlike biochemical methods, which require sterile conditions and do not provide stable control of the uniformity of the formed coating, the developed approach allows for a reproducible deposition process with a high degree of uniformity. Compared to gas diffusion technologies, the implemented method provides increased adhesion strength of the deposit to the walls of microchannels and eliminates the occurrence of unfavourable concentration gradients characteristic of static mineralisation processes. The resulting carbonate surfaces make it possible to carefully control wettability, interfacial tension, and adhesion phenomena in tasks involving oil displacement simulation, reactive flow, and carbonate-dependent chemistry on the surface of microfluidic chip channels. Thus, this method of in-situ LbL precipitation of $CaCO_3$ on pre-functionalised microchip walls forms a technologically simple, scalable and optically transparent platform that provides the ability to study carbonate systems with independent control of pore space geometry and physicochemical surface properties.

References

[1] Wang, W., Chang, S., & Gizzatov, A. (2017). Toward reservoir-on-a-chip: fabricating reservoir micromodels by in situ growing calcium carbonate nanocrystals in microfluidic channels. *ACS applied materials & interfaces*, 9(34), 29380-29386.

Pore-Scale Investigation of Interfacial Tension Effects on Surfactant-Assisted Residual Oil Mobilization in Heterogeneous Porous Media

Vitaly Kazaku[1,2], Hamza Imran[1], Ade Saputra[1], Alexandr Matiunenko[2], Yury Kadomsky[2], Maria Bashinova[2], Michael Tarkhov[3], Ivan Filippov[3], Alexander Rykov[3], Evgeny Shilov[1,2], Alexey Cheremisin[1,2], Chengdong Yuan[1]

[1]Skolkovo Institute of Science and Technology,

[2]LABADVANCE LLC,

[3]Institute of Nanotechnology of Microelectronics of the Russian Academy of Sciences

Corresponding author e-mail: kazaku@labadvance.net

Understanding multiphase flow behavior at the pore scale is essential for optimizing enhanced oil recovery (EOR) strategies in complex reservoir environments. In this study, we present a pore-scale investigation of interfacial tension (IFT) effects on residual oil mobilization during surfactant flooding, using a microfluidic approach that mimics heterogeneous porous structures. Experiments were conducted with silicon–borosilicate microfluidic chips featuring regions of varying permeability to replicate realistic reservoir heterogeneity.

A 0.3% surfactant solution was prepared in brines of four salinity levels - high, medium, low, and pure brine - corresponding to IFT values of 10^{-3}, 10^{-2}, 10^{-1}, and 10 mN/m, respectively. The displacement process included sequential injections of crude oil, pure brine, and surfactant solutions with increasing salinity, while pore-scale displacement dynamics were recorded using a high-resolution optical microscope. Image analysis enabled quantification of trapped oil, flow pathways, and emulsion formation under different IFT conditions.

The results demonstrate a strong correlation between reduced IFT and enhanced displacement efficiency. Pure brine flooding primarily displaced oil from high-permeability zones, leaving significant residual oil in low-permeability regions. In contrast, surfactant flooding promoted capillary number increase and enabled oil mobilization in both high- and low-permeability areas. The lowest-IFT surfactant achieved the highest recovery

factor, confirming that interfacial tension reduction plays a dominant role in overcoming capillary trapping.

This microfluidic visualization framework provides direct experimental evidence of surfactant efficiency at the pore scale and contributes to the understanding of flow behavior in heterogeneous media. The findings support the development of optimized surfactant formulations and injection strategies for improved oil recovery in complex reservoir systems.

Application of microfluidic equipment in saponification of squalene-containing fraction

Kirillova D.D.[1], Koroleva Yu.A.[1], Shatalov D.O.[1]
[1]FSBEI HE «MIREA – Russian technological university»
Corresponding author e-mail: kirillova_d@mirea.ru

Nowadays the cardiological diseases and cancer are very sufficient issue for maintaining public health. The numerous substances are tested for the antioxidant activity to prevent the oxidative stress, which leads to the mentioned illnesses. It was discovered that squalene could be a very suitable compound for these purposes and this was approved through several investigations, which confirm its huge antioxidant, cardioprotective and anti-inflammatory properties. Squalene is contained in shark liver oil and in some plants, for instance, olives, pumpkin seeds, but the richest source of this triterpene is amaranth seeds [1].

Squalene is the part of the unsaponifiable fraction of amaranth seed oil, so it is necessary to conduct saponification process, which involves a reaction between obtained oil and an alcoholic solution of alkali. To carry out this stage a round-bottomed flask, an electric hotplate, and a water bath are usually used. During previous experiments it was stated that the optimal time is 2 hours and the temperature needed should be 60 °C.

Then it was suggested that application of the microfluidic equipment may intensify the saponification by improving the contact between alkali solution and sample of amaranth seed oil and reduce time spent on this stage.

The approach applied within the framework of the proposed theory made it possible to obtain primary data that confirm an improvement in the quality of the saponification process and can serve as a basis for further development.

References

[1] H. Soetjipto, M. Krisdayanti, N.R. Aminu. Composition of fatty acids and squalene content of wild spinach (Amaranthus dubius mart) seed oil. Makara Journal of Science, 25, 85-90 (2021).

Microfluidics encapsulation of 4-methylumbelliferone in solid lipid nanoparticles for efficient drug delivery in liver fibrosis treatment

Krikunova P.V.[1], Chubkov N.S.[2], Gritsai M.A.[2], Molodtsov D. Yu.[2], Shukla N.[2], Soldatov M.A.[2]

[1]A.V. Shubnikov Institute of Crystallography of the Kurchatov Complex Crystallography and Photonics of the NRC "Kurchatov Institute"

[2]The Smart Materials Research Institute of Southern Federal University

Corresponding author e-mail: krikunova.pv@gmail.com

4-methylumbelliferone (4-MU) is a coumarin derivative which is widely recognised as a prospective anti-cancer, anti-inflammatory and anti-fibrosis therapeutic agent for its ability to inhibit the hyaluronan expression which holds a pivotal role in these processes [1]. The administration options of 4-MU are significantly limited due to its hydrophobic nature (the partition coefficient equals 1.9) and represented by an inefficient oral or intravenous delivery, which requires the use of toxic organic solvents. The application of the core-shell system based on the solid lipid nanoparticles (SLNs) as a carrier for 4-MU delivery will minimize the toxicity and improve the therapeutic effect. A new dosage form of 4-MU could not only increase 4-MU bioavailability, but also could lead to the patent protection of a new drug [2].

SLNs [3] were produced using a microfluidic (MF) system for the delivery of the hydrophobic compound 4-MU. The MF devices utilised in the study were designed in the computer-aided design software Fusion 360 (Autodesk, USA) and fabricated using a commercial photopolymer resin (Fun to Do Nano Clear) on a DLP 3D printer (ASIGA MAX UV, Australia). Different types of mixers were studied. The layer height for printing the MF devices was set at 25 μm. After printing, the chip was submerged into an ultrasonic bath (35 kHz, 50 W) filled with isopropanol for 60 s, followed by manual flushing of the channels with isopropanol and drying with compressed air for 2 min. Additional ultra-violet (UV) light irradiation was applied for 2 min to improve mechanical properties.

The hydrodynamic diameter of the SLNs encapsulated with 4-MU was measured using a NANO-flex dynamic light scattering (DLS) analyzer

(MicroTrac GmbH, Germany). 180 degree backscatter geometry of the experiment coupled with 3d-printed microfluidic chip enables measuring DLS data during the 4-MU encapsulation process in situ [4]. For the analysis in the "Microtrac FLEX 11.1.0.1" software, the calculation method was set to "Distribution" with the "Std:Norm" filter and "Standard" sensitivity. The data were averaged over three consecutive measurements, each with a duration of one minute.

SLNs structure, which consists of a solid lipid core coated with surfactants, is the key to ensure high colloidal stability and controlled release of the encapsulated drug. SLNs are a promising platform in nanomedicine for overcoming the poor bioavailability of hydrophobic drugs and improving their therapeutic index. Furthermore, the SLN surface can be functionalized with targeting ligands to achieve site-specific drug delivery.

The authors acknowledge the Ministry of Science and Higher Education of the Russian Federation for financial support (Agreement № 075-15-2025-509).

References

[1] N. Nagy, H. Kuipers, A. Frymoyer, H. Ishak, J. Bollyky, T. Wight, P. Bollyky (2015). 4-Methylumbelliferone Treatment and Hyaluronan Inhibition as a Therapeutic Strategy in Inflammation, Autoimmunity, and Cancer. Frontiers in immunology, 6, 123.

[2] V.V. Fedorova, A. Tsitrina, N. Halimani, Y.V. Kotelevtsev (2025). 4-Methylumbelliferone, an Inhibitor of Hyaluronan Synthase, Prevents the Development of Oncological, Inflammatory, Degenerative, and Autoimmune Diseases. Biochemistry, 90, 1–18.

[3] P. Ganesan, P. Ramalingam, G. Karthivashan, Y. T. Ko, D.-K. Choi (2018). Recent developments in solid lipid nanoparticle and surface-modified solid lipid nanoparticle delivery systems for oral delivery of phyto-bioactive compounds in various chronic diseases. International Journal of Nanomedicine, 13, 1569-1583.

[4] P. Rud, S. Chapek, P. Medvedev, O. Polozhentsev, S. Soldatov, A. Bagliy, et al. (2024) 3D printed cell for the in situ dynamic light scattering monitoring of nanoparticle size distribution in microfluidics. Microchemical Journal, 196, 109659.

From Microfluidics to Acoustofluidics: advancing materials synthesis through ultrasound integration

Kuznetsova P.[1], Molodtsov D.[1], Mukhanova E.[1]
[1]Southern federal university, Rostov-on-Don, Russia
Corresponding author e-mail: pkuznecova@sfedu.ru

The integration of ultrasound into microfluidic systems, known as acoustofluidics, offers a powerful platform for controlling particle nucleation, phase composition, and porosity in inorganic materials. This work presents a comparative study of calcium carbonate ($CaCO_3$) synthesized via microfluidic, ultrasonic, and acoustofluidic routes. The microfluidic approach promotes the rapid formation of metastable vaterite but does not support pore generation. In contrast, ultrasonic homogenization, particularly under pulsed irradiation, facilitates the transformation into single-phase calcite with improved crystallinity. The combined acoustofluidic technique demonstrates a synergistic effect, yielding highly uniform particles with tunable porosity and excellent phase purity.

XRD, FTIR, Raman, SEM, and TEM analyses revealed that acoustofluidic synthesis within a rigid 3D-printed chip (Industrial ABS resin) produces 100% calcite with a uniform porous architecture, while softer polymer chips attenuate ultrasound and limit pore formation. Porosity quantification from TEM images using the Phansalkar local thresholding method showed up to 50% pore fraction in the most rigid-chip configuration.

By combining the precise flow control of microfluidics with the energy input of ultrasound, acoustofluidics enables reproducible synthesis of nanostructured materials with controllable phase composition and porosity.

Acknowledgement

The study was carried out with financial support from the Ministry of Science and Higher Education of the Russian Federation within the framework of the state assignment in the field of scientific activity no. FENW-2023-0019.

Brain-on-a-chip. Development of a dual-barrier microphysiological system: the blood brain barrier and blood-cerebrospinal fluid barrier

Ivan A. Kushnir[1], Anton S. Averchuk[1,2], Daria D Volegova[1], Daniil A. Bystrov[1], Sofia A. Korsakova[1], Stanislav O Yurchenko[1], Alla B. Salmina[1,2]

[1]Center for Soft Matter and Physics of Fluids, Bauman Moscow State Technical University, Moscow, Russia,

[2]Russian Center of Neurology and Neurosciences, Moscow, Russia

Corresponding author e-mail: allasalmina@mail.ru

Delivering drugs to the brain across the blood-brain barrier(BBB) and blood-cerebrospinal fluid barrier(BCSFB) is a challenging task in pharmaceuticals[1]. Currently, studying the permeability of substances across these barriers is resource-intensive. Microfluidic organ-on-a-chip, mimicking the structure and function of these barriers, offer a promising platform for drug testing and fundamental research into transbarrier transport[2].

Using PDMS-based chips fabricated using soft lithography and mouse-derived primary cultures, we created a stable three-component system comprising an in vitro-formed analogue of the basement membrane and choroid plexus stroma, which provides physiological support for cell populations. Using FITC-dextrans of varying molecular weights and assessing transepithelial/endothelial resistance, we confirmed the functional integrity of both the blood-brain and blood-cerebrospinal fluid barriers. The formation of effective intercellular tight junctions was confirmed by immunocytochemistry.

The resulting system combines two key histohematological barriers in a single device for the first time, opening the possibility of more rapid drug screening for physiological conditions, as well as the creation of models of pathophysiological conditions associated with neurodegenerative diseases, such as Alzheimer's disease.

References

[1] Khare, Purva, et al., Advanced drug delivery reviews. 197, 114861, 2023.

[2] Rodrigues, R.O., Shin, SR. & Bañobre-López, M., Nanobiotechnol 22, 573, 2024.

Rapid prototyping of aptamer-based microfluidic devices for cell-based applications

K.A. Lukyanenko[1,2,3], A.S.Yakimov[3], A.A. Koshmanova[1,2], A.V. Minakov[3], A.S. Kichkailo[1,2]

[1]Krasnoyarsk State Medical University,

[2]Federal Research Center "Krasnoyarsk Science Center SB RAS",

[3]Siberian Federal University

Corresponding author e-mail: k.a.lukyanenko@yandex.ru

The conventional technology for fabricating microfluidic chips for cell and aptamer applications is soft lithography, owing to its ultra-high resolution. However, other fabrication methods, such as micro-milling and laser ablation, also enable the development of chips suitable for use with cells and aptamers.

This work presents the results of rapid prototyping of microfluidic devices for cell and aptamer studies using the micro-milling technique. Additionally, the results of fabricating a metal master mold via laser ablation are presented. Micro-milling allows for the creation of channels with a minimum width of 200 μm without microstructures, whereas laser ablation provides sufficient resolution for the reliable fabrication of complex microstructures within channels as small as 150 μm.

The fabricated device implements a principle for isolating MCF7 breast cancer tumor cells on the surface of the reaction chamber walls using Aptamer 2108. It is demonstrated that the immobilized tumor cells are retained by the aptamers at flow rates of up to 200 μL/min.

Commercial and Clinical Perspectives of Microfluidic Test Systems

Matishova Darina[1]
[1]Rapid Bio LLC
Corresponding author e-mail: dmatishova@drdbiotech.ru

Microfluidics-based test systems open new opportunities for clinical diagnostics by providing high analysis speed and minimizing sample and reagent volumes. A particularly promising direction is the transfer of enzyme-linked immunosorbent assay (ELISA) methods onto microfluidic platforms due to the compact integration of all stages—from sample preparation and antigen–antibody binding to signal visualization. Such solutions enable the development of compact, automated devices for rapid diagnostics of infectious diseases and biomarkers. In addition to ELISA, microfluidic systems are successfully applied for PCR diagnostics, isothermal amplifications, cell analysis, and sequencing, making them a universal foundation for lab-on-a-chip technologies. The integration of microfluidic technologies into healthcare practice contributes to the creation of accessible point-of-care solutions that improve the efficiency of early detection and disease monitoring [1]

As examples of commercial implementation, the i-STAT system by Abbott is used as a portable blood analysis device with disposable cartridges, delivering laboratory-quality results within minutes directly at the patient's side [2]. In addition, the LumiraDx platform offers an extended portfolio of point-of-care diagnostic tests [3].

References

[1] Lapizco-Encinas, B. H., & Zhang, Y. V. (2023). Microfluidic systems in clinical diagnosis. Electrophoresis, 44(1-2), 217-245.

[2] Abbott. (n.d.). *Rapid Diagnostics | Abbott Point of Care*. Retrieved [30.09.2025], from [https://www.globalpointofcare.abbott/us/en/index.html]

[3] Roche. (n.d.). *Roche Diagnostics – Home*. Retrieved [30.09.2025], from [https://diagnostics.roche.com/global/en/home.html]

Evaluation of the effect of impurities on the carbon dioxide phase transition point on a microfluidic chip

Alexander Matiunenko[1,2], Yury Kadomsky[1,2], Dmitrii Pereponov[1,4], Alexey Lipeev[1,4], Maxim Gribincha[1], Ilya Dobysh[1], Maria Bashinova[1], Michael Tarkhov[3], Ivan Filippov[3], Alexander Rykov[3], Evgeny Shilov[1,4], Alexey Cheremisin[1,4]

[1]LABADVANCE LLC,

[2]D. Mendeleev University of Chemical Technology of Russia,

[3]Institute of Nanotechnology of Microelectronics of the Russian Academy of Sciences,

[4]Skolkovo Institute of Science and Technology

Corresponding author e-mail: matiunenko@labadvance.net

Accurate knowledge of the thermodynamic properties of carbon dioxide (CO_2), especially the position of the phase line (pressure and transition temperature), is critically important for many technological processes: from supercritical fluid extraction to carbon capture and storage (CCS) technologies. The presence of even small amounts of non-condensing impurities can significantly shift the phase transition point,which leads to errors in the design and operation of equipment. Microfluidic chips provide a unique opportunity for high-precision and high-speed screening of such effects with small volumes of reagents.The purpose of this work is to quantify the effect of hydrogen (H_2) and helium (He) impurities with a concentration of 1% on the pressure of the liquid-gas phase transition of pure CO_2 in the temperature range from -10°C to +30°C using a microfluidic installation.For each system under study (pure CO_2, CO_2+H_2, CO_2+He), the pressure of the appearance/disappearance of the meniscus (phase boundary) was recorded visually (using a digital microscope) at five fixed temperatures: -10, 0, 10, 20 and 30°C. Pressure measurements were carried out using two calibrated absolute pressure sensors.Transition pressure values were obtained for pure CO_2, which are in good agreement with the literature data, which confirms the reliability of the microfluidic technique used. However, during a series of experiments on a microfluidic chip, an unexpected and significant effect of small (1%) impurities on the phase behavior of carbon dioxide was revealed. Contrary to the possible assumption that such small concentrations are insignificant, the results clearly showed

that even minor additions of hydrogen and helium contribute to a statistically significant decrease in the pressure of the liquid-gas phase transition point at all five temperature points studied (-10°C, 0°C, 10°C, 20°C, 30°C).The data obtained may indicate that the presence of light non-condensing impurities (H_2, He) disrupts the molecular interaction in the liquid phase of CO_2. A likely explanation for the observed effect is that hydrogen and helium molecules, having high volatility and low boiling point, act as "leavening agents" of the structure of liquid carbon dioxide. Their presence between the CO_2 molecules facilitates the transition from the liquid to the gaseous phase, which now requires less external pressure at the same temperature.

Design of microfluidic system for producing nanosized $ZnFe_2O_4$ powders

Mokliak M.A.[1], Volik K.K.[1], Kuznetsova P.D.[1], Gritsay M.A.[1], Mukhanova E.A.[1]
[1]The Smart Materials Research Institute, Southern Federal University,
Sladkova 178/24, 344090, Rostov-on-Don, Russia
Corresponding author e-mail: mmokliak@sfedu.ru

Zinc ferrite ($ZnFe_2O_4$) has garnered considerable attention from the researchers due to its good thermal and chemical stability, a narrow band gap, and prominent catalytic activity [1]. Numerous methods have been used to fabricate $ZnFe_2O_4$ nanomaterials. The purpose of this work was to develop a technology for the continuous flow synthesis of $ZnFe_2O_4$ powders.

$FeCl_3$, $Zn(CH_3COO)_2 \cdot 2H_2O$, NaOH were used as the starting materials. A microfluidic system consisting of two syringe pumps was used to carry out the precipitation of hydroxides. The flow rate of both solutions was set at 10 µl/s. The intermediate product was separated from the resulting mixture by centrifugation, rinsed with distilled water, and dried at 60 °C. The obtained powder was calcined in a muffle furnace at 700 °C for 2 hours.

Through X-ray diffraction analysis, it was determined that the cubic phase $ZnFe_2O_4$ prevails in the sample. The average particle size was calculated $\langle R \rangle$ = 21.4 nm. The XRF analysis indicated that the molar ratio of Zn^{2+} and Fe^{3+} in a calcined sample was n(Zn):n(Fe) = 1:2.002. The UV-Vis spectroscopy method was used for measuring band gap of the nanosized $ZnFe_2O_4$.

Thus, the proposed technique of microfluidic synthesis enables the accelerated production of $ZnFe_2O_4$ powder nanomaterials.

References

[1] F. Tabesh, S. Mallakpour, C. M. Hussain (2023). Recent advances in magnetic semiconductor $ZnFe_2O_4$ nanoceramics: History, properties, synthesis, characterization, and applications. Journal of Solid State Chemistry, 322, 123940 (2023).

Fast prototyping of microfluidic devices

D.Yu. Molodtsov[1], A.D. Zagrebaev[1], A. A. Tereshchenko[1], A. A. Guda[1], A. V. Soldatov[1]
[1]The Smart Materials Research Institute,
Southern Federal University, Sladkova 178/24,
344090, Rostov-on-Don, Russia
Corresponding author e-mail: dmolodcov@sfedu.ru

The advancement of microfluidics is fundamentally linked to the development of rapid prototyping methods that allow for quick iteration and testing. Techniques like CNC milling and laser ablation enable the direct and fast fabrication of microchannels in various substrates, drastically shortening the time from a digital design to a functional prototype. This agility is crucial for research, as it allows scientists to explore complex fluidic phenomena and develop new applications without the limitations of traditional manufacturing. Furthermore, the addition of 3D DLP printing expands these possibilities by allowing the creation of devices with complex three-dimensional architectures, such as integrated valves and mixing chambers, which are essential for sophisticated chemical and biological assays [1].

The collective impact of these accessible fabrication tools is the accelerated adoption of microfluidics across science and industry. By making device production faster and more cost-effective, these methods are key enablers for micro-tonnage production. This approach, which uses minute volumes of reagents, promises to make chemical synthesis and biological testing safer, less wasteful, and more scalable. The ability to quickly design and manufacture these intricate systems is therefore not just a technical convenience, but a cornerstone for developing more efficient and distributed manufacturing processes in fields like personalized medicine and specialty chemistry.

References

[1] Comina, German. (2021). Autonomous Lab-on-a-chip: solutions and fast prototyping tools. 10.3384/diss.diva-175544.

Application of SERS for the detection of trace amounts of maleic acid anhydride in N,N-dimethylformamide

Naidenko D.P. [1]*,Nesterov N.A.* [1]*, Tereshchenko A.A.* [1]*, Guda A.A.* [1]
[1]The Smart Materials Research Institute, Southern Federal University,
Sladkova 178/24, 344090, Rostov-on-Don, Russian Federation
Corresponding author e-mail: tereshch1@gmail.com

Surface-Enhanced Raman Scattering (SERS) is crucial for analytical chemistry due to its potential single-molecule sensitivity and real-time capability. This work aims to implement this technique for monitoring highly diluted solutions, particularly in industrially relevant catalytic processes.

Using a model system of maleic acid dissolved in N,N-Dimethylformamide (DMF), we demonstrate how different spectroscopic techniques (FTIR, UV-VIS, Raman) can detect substances at low concentrations (Fig. 1). The SERS technique using colloidal nanoparticles was applied to enhance sensitivity. The obtained results demonstrate reliable identification at trace levels, highlighting the potential of SERS for sensitive analysis in polar aprotic solvents.

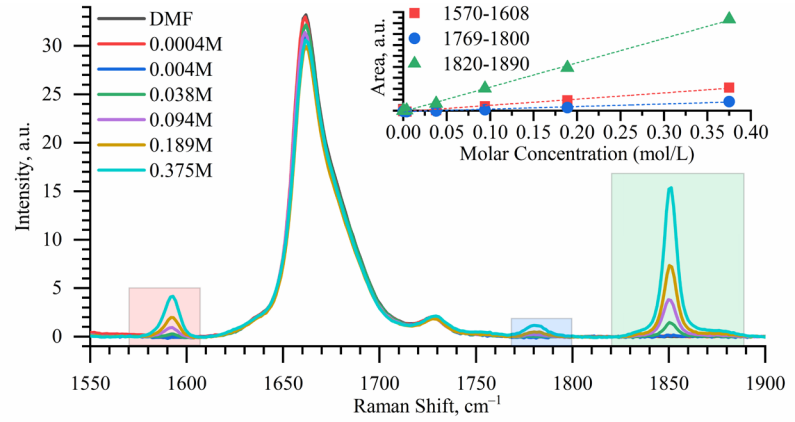
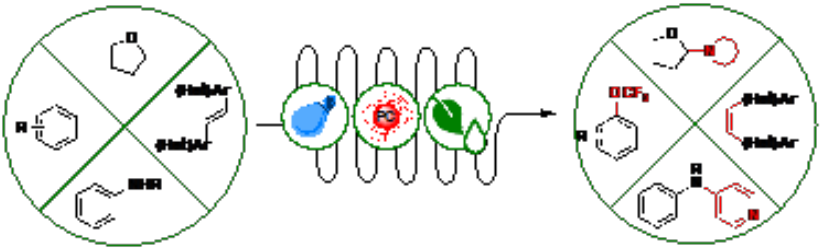


Figure 1. Raman spectra of maleic acid anhydride diluted in DMF. Peak areas are shown in the inset.

Continuous-flowtechnique as an effective method for implementation of photochemical reactions

A.V. Nyuchev[1]
[1]N.I. Lobachevsky State University of Nizhny Novgorod,
603022 Nizhny Novgorod, Gagarina av., 23.
Corresponding author e-mail: Alex.Nyuchev@ya.ru

The combination of photo chemistry and microfluidic technology makes it possible to in crease reaction yields and selectivity while reducing energy and material consumption (due to lower catalyst loadings, solvent economy in both reaction media and product purification).



Sheme1. Generals chemefor performed reactions

We have demonstrated that the application of microfluidic technology enables the intensification of decyanative amine arylation [1], trifluoromethoxylation of arenes and heteroarenes [2], C(sp^3)–heteroarylation[3], and E→Z isomerization of alkenes.

Researchwas carried out with financial support via State assignment in Research scientific laboratory of "Chemistry of natural products and their synthetic analogues" of Scientific Educational Centre "Technoplatform 2035", grant number FSWR-2024-0002.

References

[1] BoroninE.N. etal. Photochemical organocatalytic heteroarylation of anilines and secondary alicyclic amines in continuous-flow // Reaction Chemistry & Engineering. 2024. Vol. 9, № 7. P. 1877–1882.

[2] Nyuchev A. V et al. Photocatalytic trifluoromethoxylation of arenes and heteroarenes in continuous-flow // Beilstein Journal of Organic Chemistry. 2020. Vol. 16. P. 1305–1312.

[3] Wan T. et al. Decatungstate-Mediated C(sp3)–H Heteroarylation via Radical-Polar Crossover in Batch and Flow // Angewandte Chemie International Edition. 2021. Vol. 60, № 33. P. 17893–17897.

Microfluidics of multiphase Newtonian and Non-Newtonian fluids

Stanislav Patlazhan[1,2], Igor Kravchenko[2], Dmitrii Roshchin[1],
[1]Semenov Federal Research Centre for Chemical Physics RAS,
[2]Federal Research Centre for Problem of Chemical Physics and Medicinal Chemicstry RAS
Corresponding author e-mail: sapat@yandex.ru

Droplet microfluidic technologies are increasingly employed to generate monodisperse droplets for diverse applications in chemistry, physics, medicine, and biology. Such droplets serve as microreactors, drug-delivery vehicles, and platforms for studying individual biological objects. These applications require not only a fundamental understanding of droplet formation mechanisms and jetting regimes, but also insight into how the rheology of non-Newtonian liquid phases influences droplet deformation, hydrodynamic stability, and the behavior of complex fluids under various flow conditions in microchannels of different geometries. Numerical modeling, when combined with experiments, enables visualization of the underlying hydrodynamic processes and facilitates the identification of the governing physical laws.

In this talk, we present several effects related to the deformation behavior and hydrodynamic stability of Newtonian and shear-thinning droplets in microchannels with an abrupt contraction, identified through both experimental studies and numerical simulations. Specifically, we discuss: 1) the dynamics of shear-thinning and viscoelastic droplets at various capillary numbers and confinement ratios, 2) the formation and stability of composite microfibers, and 3) jet stability under confinement.

This work was supported by the Russian Science Foundation (Project No. 24-29-00411).

Microfluidic approach for PVT analysis of reservoir fluids

Dmitrii Pereponov[1,2], Maxim Gribincha[2], Alexey Lipeev[1,2], Ilya Dobysh[1], Maria Bashinova[2], Michael Tarkhov[3], Ivan Filippov[3], Alexander Rykov[3], Evgeny Shilov[1,2], Alexey Cheremisin[1,2]

[1]Skolkovo Institute of Science and Technology,
[2]LABADVANCE LLC, [3]Institute of Nanotechnology of Microelectronics of the Russian Academy of Sciences
Corresponding author e-mail: pereponov@labadvance.net

Accurate characterization of reservoir fluids is a key for successful hydrocarbon production. However, standard laboratory methods face persistent practical constraints: long test durations, large sample requirements, difficulty in detecting incipient liquid bubbles/droplets, challenges with low interfacial tension. This work presents a microfluidic approach for rapid, small-volume PVT analysis that determines (i) saturation (bubble) point of crude oil, (ii) dew point of gas-condensate mixtures, (iii) minimum miscibility pressure (MMP) for real oil–gas systems, and (iv) oil–gas IFT at reservoir conditions.

For bubble-point detection, a long serpentine microchannel is first saturated with live oil; pressure is then decreased stepwise while temperature is held constant. The saturation pressure is identified from the earliest nucleation of gas bubbles, detected via high-magnification imaging. Dew-point measurements follow the same principle but employ a vertically oriented cell saturated with a gas-condensate mixture. Condensate onset is determined from the first nucleation of a liquid droplet inside a dead-end channel, which improves detectability of very small droplets. MMP is measured on a slim-tube microfluidic analog: a channel with randomly distributed polls is filled with oil and contacted by injection gas at controlled pressures. We track the propagation of the gas front and the evolution of composition along the network; the pressure at which the displacement transitions to a nearly piston-like, continuous front is taken as the MMP. Oil–gas IFT is obtained in a conical microchannel that imposes a controlled curvature on the interface; pressure steps yield meniscus radii from which IFT is calculated via the Young–Laplace equation.

Across all measurements, the microfluidic methodologies reduce total test time, while cutting fluid requirements from hundreds of milliliters to hundreds of microliters. Moreover, microfluidic results are cross-validated against conventional laboratory methods, showing agreement within typical experimental uncertainty. Finally, microfluidic technology is established as a practical complement or even an alternative to standard experimental workflows.

Brain-on-a-chip. Finite element modeling for determining relevant physiological parameters

Pavel A. Libet[1], Leonid Y. Polynkin[1], Mikis R. Saridis[1], Egor V. Yakovlev[1], Sofia A. Korsakova[1], Alla B. Salmina[1,2], Anton S. Averchuk[1,2], Natalia A. Rozanova[1,2], Stanislav O. Yurchenko[1]*

[1]Center for Soft Matter and Physics of Fluids, Bauman Moscow State Technical University, Moscow, Russia,

[2]Brain Science Institute, Russian Center of Neurology and Neurosciences, Moscow, Russia

Corresponding author e-mail: polynkin.l.y@bmstu.ru

Microfluidic chips that mimic the structure and function of various organs represent a promising tool for studying physiological processes and pathologies [1]. Investigation of the blood–brain barrier (BBB) and the blood–cerebrospinal fluid barrier (BCSFB) is crucial for understanding the mechanisms underlying neurological diseases and for developing new therapeutic approaches [2].

We present a four-channel microfluidic model that mimics the coupled operation of the BBB and BCSFB, comprising adjacent blood, parenchymal, and CSF channels separated by semi-permeable microstructures to enable controlled studies of physiologically relevant fluid dynamics. Using CFD, we analyzed flow regimes and shear stress across the barriers [3], confirming laminar flow and realistic stress distribution.

By adjusting flow parameters, the device can reproduce both normal and pathological barrier states. The proposed system provides a realistic framework for microphysiological brain models, supporting studies of barrier coupling, drug transport, and the effects of mechanical factors on brain homeostasis [4].

References

[1] Abbott, N. Joan, et al., Acta neuropathologica, 135, 387-407, 2018.

[2] Cucullo, L., et al., BMC Neuroscience, 12, 1, 2011.

[3] Wang, X., et al., Microvascular Research, 128, 103930, 2020.

[4] Wevers, N.R., et al., Fluids and Barriers of the CNS, 15, 1, 2018.

The influence of wall roughness on fluid flow in microfluidic MEMS cell channels

Poplevka A.V.[1], Karaseov P.A.[2], Kopanichuk I.V.[3,4], Kondrateva A.S[1,2].
[1]Alferov University, St. Petersburg, Russia
[2]Peter the Great St. Petersburg Polytechnic University,
St. Petersburg, Russia
[3]Moscow Institute of Physics and Technology, Dolgoprudny, Russia
[4]AIRI, Moscow, Russia
Corresponding author e-mail: poplevkaanna@mail.ru

Microelectromechanical systems-based microfluidic devices offer broad research and technological capabilities for biomedicine and chemistry. A key factor influencing hydrodynamic characteristics is the internal surface roughness of the microchannel [1-2]. This work has demonstrated that the targeted design of roughness topology allows for flow control to enhance device efficiency. A mathematically justified classification of the main types of roughness (rectangular, sawtooth, k-step, ridge) has been proposed [3-4]. The influence of roughness geometry and the order of the root mean square roughness value on fluid flow has been investigated. It has been shown that the stepped (k-step) topology exhibits a unique effect, combining a significant increase in maximum flow velocity with a minimal change in the effective channel width and providing the most efficient interaction between the fluid and the channel wall. The obtained results enhance the understanding of microhydrodynamics and allow for the optimization of microfluidic MEMS cell performance.

References

Posmitnaya, Y.S., Kukhtevich, I.V., Evstrapov, A.A., Tupik, A.N.: The target surface treatment of materials for microfluidic chips. Nauchnoe Priborostroenie 22(4), 38–45 (2012);

Pelusi, F., Filippi, D., Derzsi, L., Pierno, M., Sbragaglia, M.: Emulsions in microfluidic channels with asymmetric boundary conditions and directional surface roughness: stress and rheology. Soft Matter 20(26), 5203–5211 (2024);

Han, S., Yang, R., Li, C., Yang, L.: The wettability and numerical model of different silicon microstructural surfaces. Applied Sciences 9(3), 566 (2019);

Gong, Y., Zhou, G.: Numerical simulation of structured surface roughness effects on flow boiling characteristics in microchannel. Chemical Engineering and Processing-Process Intensification 216, 110439 (2025)

Optimizing mixing in microdroplets and microchannels via numerical simulations

Dmitrii Roshchin[1], Stanislav Patlazhan[1,2], Igor Kravchenko[2]
[1]Semenov Federal Research Centre for Chemical Physics RAS,
[2]Federal Research Centre for Problem of Chemical Physics
and Medicinal Chemistry RAS
Corresponding author e-mail: roschin.d.e@mail.ru

Mixing is a key stage in many physicochemical processes occurring in microfluidic devices. However, the small characteristic dimensions of such systems suppress turbulence, making mixing driven by inertial effects impossible due to the inherently low Reynolds numbers. A viable alternative is passive mixing, where fluid streams intermix solely by virtue of their own kinetic energy.

In this work, the mixing efficiency of miscible liquids is investigated using direct numerical simulations. Three representative cases are considered. 1. Mixing in a T-junction microchannel under time-varying inlet pressure, with a particular focus on non-harmonic oscillations. The influence of anharmonicity on mixing rates is analyzed, and conditions providing optimal mixing are identified. 2. Mixing inside droplets co-flowing through straight microchannels with either constant or stepwise-varying cross-section. Both Newtonian and shear-thinning continuous phases are examined. It is demonstrated that the dependence of mixing time on the Peclet number is strongly affected by the rheology of the surrounding phase. 3. Chemical engineering case. The effect of internal vortices on the kinetics and molecular-weight distribution of free-radical polymerization products formed within a droplet, with initiation at the droplet interface, is explored.

The work was supported by Russian Science Foundation (grant No. 24-29-00411).

Microfluidic emulsification and deformation of double magnetic fluid droplets

P. Ryapolov[1], D. Kalyuzhnaya[1], E. Sokolov[1], A. Matarykin[1]
[1]Southwest State University, 305040, 50 Let Oktyabrya 94, Kursk, Russia
Corresponding author e-mail: r-piter@yandex.ru

Double emulsions possess significant potential in targeted drug delivery systems. Microfluidic emulsification is an appropriate method for synthesizing such systems. The utilisation of magnetic fluids (MFs) as one of the components of double droplets allows for the manipulation of droplet dynamics and shape through the application of an external magnetic field [1]. An O/O/W type double emulsion is formed within a microfluidic chip with dual flow focusing. The internal phase of the emulsion consists of synthetic oil. A magnetic fluid with a saturation magnetisation of 8.7 kA/m, based on mineral oil, is employed as the intermediate phase. The continuous phase comprises an aqueous surfactant solution. The diameter of the resulting oil droplets encapsulated in the magnetic fluid is 210 μm. The obtained emulsions undergo morphological changes during prolonged storage, under extended exposure to a magnetic field, and when stored in an alkaline environment added to the external phase. The internal droplets partially released from the magnetic fluid shell during prolonged storage in a gravitational field. The magnetic shell of droplets, which was consistently subjected to a transverse magnetic field, migrated towards the "equator" of the droplet. In the emulsion stored in an alkaline environment, the magnetic shell partially fractured into two halves over a short period, allowing the internal droplet to escape outward. The findings of this study could serve as a foundation for the development of transport systems for drug delivery in microfluidic applications.

The work was carried out with the support of the Russian Science Foundation grant No. 24-22-00309.

References

[1] A. Bat, C. Dog, E. Falcon (year). A paper about geological disposal. Mineralogical Magazine, vol, page range (year).

Electrochemical detection on microfluidic chips

M.A. Gritsay[1], D.Yu. Molodcov[1], V.M. Sklyarov[1], M.A. Soldatov[1]
[1]The Smart Materials Research Institute, Southern Federal University
Corresponding author e-mail: mikhailsoldatov@sfedu.ru

A significant shift from conventional biomarker detection to modern biosensors is observed lately. Such biosensors incorporate such fields as microfluidics, nanotechnologies, material science, electronics, and artificial intelligence. Biosensors use biological components and a physicochemical transducer to detect and measure biological responses [1]. Electrochemical transduction methods, such as amperometry, potentiometry, voltammetry, capacitance measurements, and impedance spectroscopy transduce biological interaction to electric signal. The simple scheme of biosensors is composed from active biological species and electrochemical cell with two or three electrodes.

This talk will focus on recent advances in electrochemical detection on microfluidic chips.

References

[1] D.S. Sharma, V.L. Jamwal, P.H.S. Siddharth, Sh.L. Angurana, S.G. Gandhi, D. Rath (2025). Electrochemical microfluidic biosensor for detection of cancer biomarkers miRNA. Talanta 294, 128282 (2025).

Synthesis and diagnostics of metal nanoparticles in droplet mode

Soldatov S.A.[1], Kupriianenko D.I.[1], Protsenko B.O.[1],
Molodtcov D.Yu.[1], Zagrebaev A.D.[1], Guda A.A.[1]
[1]The Smart Materials Research Institute, Southern Federal University,
344090 Rostov-on-Don, Russia
Corresponding author e-mail: sergeysoldatov@sfedu.ru

We have developed the microfluidic system for the synthesis of metal nanoparticles in droplet mode (exemplified by gold nanoparticle, or Au NP, synthesis). The system integrates high-throughput screening of reaction parameters with in-situ diagnostics via a fiber-optic UV-Vis spectrometer. This is complemented by real-time video stream analysis from a high-speed, high-resolution camera and an AI agent that processes the diagnostic data to autonomously schedule adjustments to synthesis parameters.

The droplets are generated inside 3d printed microfluidic reactor featuring a mixer, droplet generation zone and delay line for seed growth. For video processing, we implemented a real-time, large-object detection algorithm with integrated RGB analysis, specifically developed for in-situ applications. This method enables the tracking and analysis of objects, such as droplets, directly within their native environment. The system efficiently processes video streams and performs dynamic object tracking based on morphological and chromatic characteristics. Utilizing OpenCV for robust detection and a graphical interface, it allows for real-time user adjustment of detection parameters to optimize performance.

The AI agent employs a hybrid methodology, combining scientific data analysis with machine learning to predict resultant product properties. Subsequently, the system generates a dynamic experimental schedule, selecting optimal points within the parameter space to converge upon target product characteristics.

This integrated system is capable of autonomously conducting parameter screening, determining optimal synthesis conditions, and uncovering novel correlations. This represents a significant advancement toward the realization of fully autonomous, self-optimizing laboratories.

CAPEX-OPEX of microfluidic technologies when scaling up to industrial applications

Danila Sumovsky[1], Nikolay Nedelko[1], Sergey Rzhevsky[1], Dmitry Snetkov[1], Valentin Ershov[1]
[1]Microfluidika LLC
Corresponding author, email: office@microfluidika.ru

Microfluidic devices have long established themselves as laboratory devices for a wide range of applications. However, as with any new technology, scaling up presents a range of uncertainties that limit their use.

The key uncertainty stems from the virtual absence of open, verifiable, and auditable data on this technology, forcing indirect assessments. Planning requires considering not only CAPEX and OPEX costs, but also implementation time, technical complexities, and personnel training, which impact the timing and cost of production launches. Effective cost management optimizes the financial model and increases return on investment.

The authors propose a comprehensive approach based on both traditional software and calculations, as well as methods involving rapid preliminary assessment using AI technologies.

The methodology has been tested on internal projects and verifiable open data.

References

[1] Microfluidic chips for biological and medical research, A. A. Evstrapov, Russ. Chem. J. (Journal of the Russ. Chem. Society named after D. I. Mendeleev), 2011, Vol. LV, No. 2

Point-of-Care Diagnostics: Technological Advances and Market Prospects

A.V. Telegina[1], A.R.Agisheva[1], I.V. Maksin[1,2], E.A. Muchkinova[1]
[1] LLC "Rapid Bio",
[2] Lomonosov Institute of Fine Chemical Technologies,
86 Vernadsky Avenue, Moscow 119571
Corresponding author, email: atelegina@drdbiotech.ru

Modern medicine is increasingly focused on improving the efficiency, accessibility, and speed of healthcare delivery. One of the most transformative tools contributing to these goals is point-of-care (PoC) testing, which refers to diagnostic testing performed at or near the site of patient care. Unlike traditional laboratory-based testing, PoC diagnostics are conducted directly in a physician's office, ambulance, pharmacy, patient's home, or in remote and resource-limited settings, allowing results to be obtained within minutes rather than hours or days. This shift enables clinicians to make medical decisions in real time, significantly enhancing patient outcomes and clinical workflow.

Point-of-care testing is defined by three essential characteristics: proximity to the patient, rapid turnaround time, and ease of use. Most PoC devices are designed for operation by healthcare personnel without specialized laboratory training, and in some cases even by patients themselves. Typical results are available within 20 minutes, which makes this approach particularly valuable in emergency medicine, infectious disease control, and chronic condition monitoring. Technologically, modern PoC systems rely on several key analytical principles, including immunoassay, molecular, and electrochemical methods, as well as microfluidic technologies. Immunochromatographic analysis (lateral flow assays) is among the most widespread due to its simplicity, portability, and rapid results, although it generally provides lower sensitivity and specificity compared to centralized laboratory methods [1, 2]. Molecular techniques, such as polymerase chain reaction (PCR), offer superior accuracy and analytical precision but remain costly and equipment-intensive, limiting their widespread field application. Electrochemical biosensors that employ nanomaterials such as gold

nanoparticles and carbon nanotubes have demonstrated high accuracy in biomarker detection but require complex manufacturing and frequent calibration [3]. Meanwhile, microfluidic systems—capable of manipulating very small volumes of fluids—enable automation of sample preparation and analysis, reducing reagent consumption and enabling integration with digital platforms for data transfer and interpretation.

The global PoC diagnostics market reflects the growing demand for accessible and decentralized testing solutions. In 2024, its estimated value reached USD 47.8 billion, and it is projected to grow to USD 68.5 billion by 2030, with a compound annual growth rate of approximately 5.8 %[4]. The infectious disease segment alone accounted for over a quarter of global revenue, underscoring the crucial role of rapid diagnostics in public health. North America currently dominates the market, holding around 43 % of total global sales, while the Asia-Pacific region is the fastest-growing, with an expected annual growth rate exceeding 8 %. Such expansion is driven by rising demand for portable diagnostics, the proliferation of telemedicine and home testing, and increased awareness of preventive healthcare, particularly following the COVID-19 pandemic.

Point-of-care testing represents a genuine paradigm shift in modern diagnostics. It relocates analytical power from sterile laboratories directly to the patient, transforming diagnostic processes into fast, accessible, and clinically relevant tools for decision-making. Despite ongoing challenges related to quality assurance, cost control, and regulatory harmonization, the potential of PoC testing is immense. Continued advances in sensor design, miniaturization, connectivity, and integration with digital health ecosystems promise to make point-of-care diagnostics an essential standard of medical care in the near future—bringing precise, timely, and patient-centered diagnostics to the forefront of global healthcare.

References

[1] LiuY. etal. Ultrasensitive and Highly Specific Lateral Flow Assays for Point-of-Care Diagnosis // ACS Nano. American Chemical Society, 2021. Vol. 15, № 3. P. 3593–3611.

[2] Gavina K. et al. Molecular point-of-care devices for the diagnosis of infectious diseases in resource-limited settings – A review of the current

landscape, technical challenges, and clinical impact // Journal of Clinical Virology. Elsevier, 2023. Vol. 169. P. 105613.

[3] Kim J., Jeong J., Ko S.H. Electrochemical biosensors for point-of-care testing // Biodes Manuf. Springer, 2024. Vol. 7, № 4. P. 548–565.

[4] Recent Advances in Point-of-Care Diagnostics: Integration of Microfluidics and Biosensing Technologies // Frontiers in Lab-on-a-Chip Technologies. — 2024. — No. 1394752. — https://doi.org/10.3389/frlct.2024.1394752

Modern methods of FTIR and Raman spectroscopy in process & product monitoring: achievements and prospects

Tereshchenko A.A.[1], Zagrebaev A.D.[1], Bulgakov A.N.[1], Nechitailova I.O.[1], Guda A.A.[1]

[1]The Smart Materials Research Institute, Southern Federal University, Sladkova 178/24, 344090, Rostov-on-Don, Russian Federation

Corresponding author e-mail: tereshch1@gmail.com

Spectral control is key for successful technology transfer, providing reliable management of processes in both batch and continuous-flow reactors. In this work, we report on the role and development of spectral analysis in several ongoing projects. These include:

The halogenation of a polymer material, where conversion and the degree of bromination were evaluated using FTIR-ATR spectra (Fig. 1a);

The epoxidation of olefins, where the mass content of the target oxirane was assessed using ex situ Raman spectra (Fig. 1b);

The biphasic hydrosilylation of 1-octene, where border between reactants was monitored using ATR with 2D mapping.

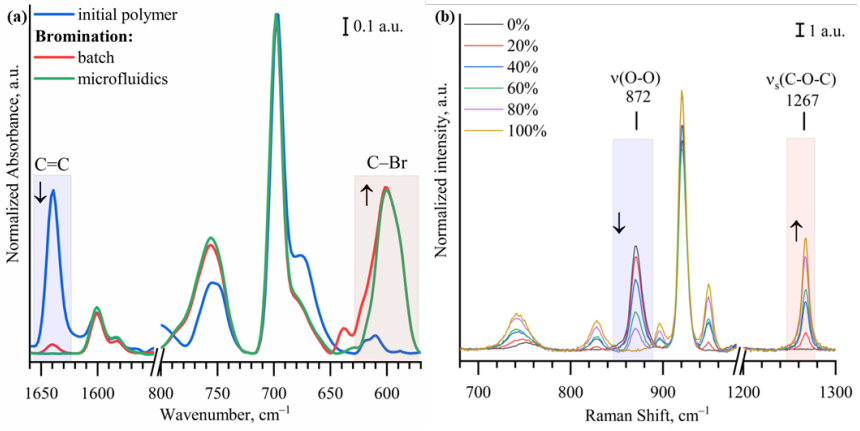


Figure 1. (a) FTIR spectra of polymer before and after halogenation; (b) Raman spectra corresponding to different conversions of alkene to epoxide.

Features of droplet microfluidics for supramolecular structures formation

Timralieva A.A.[1], Zagrebaev A.D.[2], Skorb E.V.[1]
[1]Infochemistry Scientific Center, ITMO University, Lomonosova str. 9, St. Petersburg 191002, Russia
[2]The Smart Materials Research Institute, Southern Federal University, Rostov-on-Don 344090, Russia
Corresponding author e-mail: timralieva@itmo.ru

Microfluidics technology is a prospective way for fast screening of functional materials and optimization of synthesis conditions [1]. However, microfluidics crystallization is accomplished with several challenges. A range of approaches is commonly used, such as the use of antisolvents, evaporation, temperature control, diffusion, spray drying [2]. These approaches are effective to provide crystallization which is weak or relatively impossible in non-confined space system.

In the study, crystallization in the water-oil system in 3D printed microfluidic chips with complex channel topology was performed to provide the formation of micro-sized supramolecular functional materials. One of the most important challenges was to provide a mixing zone not covered with the reaction product as this type of supramolecular assembly is spontaneous and fast. Several chip topologies were tested, and the key recommendations for each of them are presented to achieve the crystals with desired morphology.

References

[1] S. Gimondi, H. Ferreira, R. L. Reis, N. M. Neves (2023). Microfluidic Devices: A Tool for Nanoparticle Synthesis and Performance Evaluation. ACS Nano, 17 (15), 14205-14228

[2] J. Jang, W.-S. Kim, T. S. Seo, B. J. Park (2024). Over a decade of progress: Crystallization in microfluidic systems. Chemical Engineering Journal, 495, 153657

Computer Vision and Machine Learning Methods for Microdroplet Analysis

Israel Alejandro Huaman Escobar[1], Pavel Zun[1], Ekaterina Skorb[1]
[1]Infochemistry Scientific Center, ITMO University, St. Petersburg, Russia
Corresponding author e-mail: ihuaman@itmo.ru

Abstract:

The analysis of microdroplets is vital for biochemistry but is often bottlenecked by manual microscopy. We introduce an automated analysis pipeline [1] using deep learning to characterize microdroplet morphological (area and roundness), geometrical (Voronoi tessellation and entropy) and physical (velocity, acceleration, kinetic energy and trajectory) metrics. Our method employs deep neural networks for segmentation, object detection and tracking to reliably analyze clusters of droplets that levitate by the interaction of different thermodynamical forces [2-3]. As a result, we are able to study microdroplets dynamics, patterns, and phenomena product of the change of temperature in the system. This work provides a robust, open-source solution that enables high-throughput, quantitative microdroplet analytics, paving the way for more efficient and scalable microfluidic workflows.

References

[1] Huaman, I. A., Zun, P. S., Fedorets, A. A., Nosonovsky, M., & Skorb, E. V. (2025). DropClust: A platform for microscopical image and video analysis applied to levitating droplet clusters. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 138153.

[2] A.A. Fedorets, L.A. Dombrovsky, E. Bormashenko, M. Nosonovsky, Levitating droplet clusters, Begell House, New York, USA, 2023.

[3] Alexander A. Fedorets, Dmitry V. Shcherbakov, Leonid A. Dombrovsky,

Edward Bormashenko, Michael Nosonovsky, Impact of surfactants on the formation and properties of droplet clusters, Langmuir 36 (37) (2020) 11154–11160.

Experimental study of streamline control in a pillar array for a tunable microfluidic sorter

Maxim Shestakov[1], Anna Yagodnitsyna[1]
[1]Kutateladze Institute of Thermophysics SB RAS
Corresponding author e-mail: maximvsh@gmail.com

Particle sorting and separation in a carrier flow are pivotal across pharmaceuticals, biomedical research, and clinical diagnostics. Deterministic lateral displacement (DLD) pillar arrays are among the most effective hydrodynamic sorting methods, but a key limitation is that the critical sorting diameter is fixed by the chip geometry. This study aims to realize a controllable DLD-based sorter by controlling streamline inclination via lateral fluid injection/suction in an array of cylindrical pillars. The transparent chip with symmetric pillar array (without the lateral row shift characteristic of conventional DLD) was fabricated using 3D photolithographic printing. Each lateral side of the chip was equipped with eight inlet/outlet ports. We studied how inlet, outlet, and combined inlet–outlet flow-rate ratios relative to the bulk flow affect streamline inclination. Using PIV, we mapped velocity fields and quantify the streamline inclination angle, establishing its dependence on the injection/suction flow-rate ratio and the bulk flow rate. The particle trajectories for different diameters were tracked, confirming the proposed method functionality. This control enables dynamic tuning of the effective critical sorting diameter without altering chip geometry, pointing toward adaptive microfluidic systems with programmable hydrodynamic sorting.

The work is supported by RSF (project No. 24-79-10291).

Active and adaptive control of two-phase microflows: from pulsations to reinforcement learning

Anna Yagodnitsyna[1,2], Alexander Kovalev[1], Alexander Seredkin[2], Oleg Gobyzov[1], German Bartkus[1], Konstantin Pervunin[1], Artur Bilsky[1]
[1]Kutateladze Institute of Thermophysics SB RAS
[2]Novosibirsk State University
Corresponding author e-mail: yagodnitsinaAA@gmail.com

Advances in active and adaptive control of two-phase microflows are presented. The first part of the study focuses on flow-rate pulsations of the dispersed phase in T-junction microchannels. Using the micro-PTV technique, we reveal the mechanisms of parallel flow destabilization and identify distinct regimes of plug formation as a function of pulsation frequency, amplitude, and dispersed to continuous phase viscosity ratio1. The influence of pulsation characteristics on plug-flow dynamics is studied.

Building upon experimental results, we explore machine learning approaches for flow pattern prediction and control. Dimensional analysis provides universal criteria for transitions between segmented and continuous flows, while neural-network models allow reliable flow pattern classification across a broad parameter space. Furthermore, reinforcement learning frameworks are demonstrated as a promising approach for adaptive control of plug length and velocity in real time.

The integration of experimental diagnostics with ML-based prediction and control offers a pathway toward advanced strategies for two-phase microfluidics in chemical, biomedical, and lab-on-a-chip applications.

This work was carried out under state contract with IT SB RAS № 121031800215-4.

References

[1] Kovalev, A. V., Pervunin, K. S., Bilsky, A. V. ,Yagodnitsyna, A. A. (2024) Influence of dispersed phase flow-rate pulsations on the liquid–liquid parallel flow in a T-junction microchannel. Chem. Eng. J. 488, 150734.

MICROFLUIDIC CHIPS IN REPRODUCTIVE MEDICINE: A NEW APPROACH TO SPERM SELECTION

Makarova N.P.[1], Yakimova A.S.[1], Seliverstova A.A.[2], Kichko I.S.[1], Ekimov A.N.[1], Sysoeva A.P.[1], Gavrilov M.Yu.[1], Zingerenko B.V.[1], Kalinina E.A.[1]

[1] V.I. Kulakov National Medical Research Center for Obstetrics, Gynecology and Perinatology, Ministry of Health of Russia, Moscow, Russia

[2] Peoples' Friendship University of Russia (RUDN), Moscow, Russia.

Introduction

Microfluidic technologies represent a revolutionary approach to sperm selection, fundamentally differing from traditional semen preparation methods used in assisted reproductive technology (ART) programs. This approach emphasizes the gentle handling of male gametes, closely replicating the physiological conditions of natural fertilization. Unlike conventional centrifugation techniques, microfluidic chips enable sperm selection without applying high mechanical stress, which is crucial for preserving the integrity of genetic material and maintaining sperm functionality. Studies have demonstrated a statistically significant increase in blastocyst formation rates when microfluidic-based sperm selection is used in ART (Makarova et al., 2025; Hart et al., 2025). This improvement is attributed to the more efficient isolation of high-quality spermatozoa with intact DNA and optimal morphology. However, clinical data on the genetic status of human embryos obtained through this method remain limited.

Objective

To evaluate the genetic status of embryos obtained using spermatozoa selected via microfluidic chips during in vitro fertilization (IVF).

Materials and Methods

A total of 114 infertile couples undergoing ART were included in the study. The study group (n = 45) underwent fertilization using sperm selected with microfluidic chips (FERTILE PLUS, Turkey), while the control group (n = 69) used density-gradient centrifugation (PanECO, Russia). Embryos were cultured under standard conditions using LifeGlobal media (Origio, USA). On day 5,

blastocysts were biopsied and subjected to preimplantation genetic testing for aneuploidy (PGT-A) using next-generation sequencing (DNA-Technology, Russia). In total, 127 embryos from the study group and 194 from the control group were analyzed. Statistical analysis was performed using SPSS Statistics (USA); the Mann–Whitney U test and chi-square test were applied. Odds ratios (ORs) with 95% confidence intervals (95% CI) were calculated for binary data. A p-value < 0.05 was considered statistically significant.

Results

No statistically significant differences were found between the study and control groups in clinical characteristics or semen parameters. However, embryological outcomes showed a statistically significant increase in the number of blastocysts obtained in the microfluidic group compared to the control group ($p = 0.03$). The proportion of euploid embryos was similar between groups (29.9% vs. 32.4%; OR = 0.88). Although no significant differences were observed in embryo genetic status, microfluidic sperm sorting demonstrated a positive effect on embryological performance, likely due to the more efficient exclusion of spermatozoa with DNA fragmentation, abnormal morphology, or low motility.

Conclusion

Microfluidic sperm sorting shows promising potential in reproductive medicine by providing a gentle and effective approach for selecting functionally competent spermatozoa with intact DNA. The method may be particularly beneficial in cases of male factor infertility or genetic abnormalities. Further studies are required to comprehensively evaluate its impact on the genetic quality of preimplantation human embryos.