Structures and applications of micro- and mesoporous solids

OTKA final report

1. INTRODUCTION

The research and development of functional aerogels started in ca. 2005 in parallel to the implementation of new characterization methods for colloids at the University of Debrecen. The key infrastructure and expertise for the production of aerogels and the characterization of porous materials was established until 2014. These achievements served as the basis of the current project, together with the strong background of our research groups in reaction kinetics, solution phase mechanistic studies and coordination chemistry.

The current project aims to research and deliver new functional aerogels for biomedical and environmental applications, and develop new approaches for understanding the intimate natures of their functionalities utilizing novel and complimentary structural characterization methods in combination with in-depth mechanistic studies. Earlier results proved that versatile functional materials can be obtained by hybridizing inorganic oxides and biopolymers (proteins and carbohydrates), which can open new possibilities in drug delivery. The introduction of new functional groups into silica and biopolymer aerogels was within reach using well-established reactions in organic chemistry. Our most ambitious goal was however, to implement and adapt the tools of reaction kinetics, colloid chemistry and coordination chemistry to understand the molecular level mechanisms behind the desired functionalities of the newly produced aerogels.

As expected, some of the aerogel designs did not perform as expected, which required the modification of the research plan. Some heterogeneous systems showed very complicated behavior, which required the utilization of advanced characterization and data evaluation techniques. These cases inspired further research directions that are still in progress in our research group. Nevertheless, the major objectives of the current project outlined in the workplan have finally been achieved, as detailed in the following sections.

2. METHODS

The new aerogels were prepared using the sol-gel method, when needed in combination with co-gelation to obtain hybrids. The introduction of functional groups and the conjugation of active agents or metal complexes were mainly realized before gelation. The inorganic components of the backbone were modified using functional precursors. These also served the

basis for further modification. Well-established synthetic approaches were used to conjugate drug molecules to biopolymers. Multi-step solvent exchange was performed to ensure optimal conditions for drying and the removal of residual products and solvents. The final drying of the gels took place in high pressure reactors using first liquid, and later supercritical CO_2.

Special attention was paid to the in-depth characterization of the new aerogels, both in their dry states and in their hydrated states. The compiled characterization results were contrasted to the application related performance of the new functional aerogels in order to understand structure-properties relationships.

The as-prepared functional aerogels were characterized using low voltage scanning electron microscopy (LV-SEM), N_2-sorption porosimetry, small angle neutron scattering (SANS), infrared spectroscopy (FT-IR), solid-state nuclear magnetic resonance spectroscopy (ssNMR), electron paramagnetic resonance (EPR) spectroscopy, X-ray diffraction (XRD) measurements and X-ray photoelectron spectroscopy (XPS). Very close collaborations were established with the ELKH Centre for Energy Research, Neutron Spectroscopy Department (SANS) and within the University of Debrecen with the Department of Solid State Physics (LV-SEM and XRD). Some advanced techniques were used in collaboration with national and international partners, such as the ELKH Research Centre for Natural Sciences, Centre for Structural Science (EPR); the ELKH Institute for Nuclear Research (XPS) and the Università del Piemonte Orientale, Department of Science and Technological Innovation (ssNMR).

The hydration and the hydration induced structural changes of aerogels were studied using multiple non-conventional liquid state NMR methods (cryoporometry, diffusiometry, and relaxometry) in combination with special solid-state NMR and contrast variation SANS measurements. The colloid properties, such the size distribution and the Zeta potential of suspended aerogel microparticles were determined as a function of the pH and ionic strength of the aqueous medium.

The performance of the functional aerogels were tested under relevant conditions for the targeted applications. Drug release in aerogel suspensions were monitored by newly developed on-line UV-vis spectrophotometric methods providing 1 s time-resolution. Similar experimental methods were used in the sorption studies. Model development and curve analysis were performed by adapting the methodologies of solution phase reaction kinetics. The establishment of sorption equilibria, and the mechanism of the sorption of metal ions were investigated using the good practices of colloid chemistry and implementing coordination chemistry based methods and considerations.

Several *in vitro* and *in vivo* biological experiments were performed thanks to the close collaboration with the Department of Molecular Biotechnology and Microbiology and the Department of Pathology (Kenézy University Hospital) at the University of Debrecen.

3. RESULTS

3.1. Aerogels for drug delivery and other biomedical applications

1.) Iron(III)-crosslinked alginate aerogel beads (d = 3 – 5 mm) were prepared and loaded with ibuprofen by using the technique of adsorptive deposition from supercritical CO_2. Additional formulations were prepared where the aerogels were co-impregnated by ibuprofen and ascorbic acid. The release of ibuprofen from the Fe(III)-alginate is much faster in pH = 7.4 (PBS) than in pH = 2.0 (HCl), which can be explained by the faster dissolution and higher swelling of the alginate matrix in PBS. By decreasing the size of the beads and using a higher G content alginate the release rate could be slightly increased. A marked acceleration of drug release was achieved in both HCl and PBS by incorporating ascorbic acid into the Fe(III)-alginate aerogel preparations. The explanation is that in aqueous media ascorbic acid in situ reduces the crosslinking Fe(III) to Fe(II). The latter does not interact strongly with alginate, which promotes the hydration of the chains, thus the erosion and dissolution of the carrier matrix.

2.) Methotrexate functionalized silica-gelatin hybrid aerogel (SGM) was synthesized by the sol-gel method and co-gelation. The drug methotrexate (MTX) is covalently linked to the collagen molecules of the hybrid aerogel backbone by amide-bond. The characteristic MTX content of the functionalized hybrid aerogel is ca. 6 wt.% by the dry weight. The micronization of SGM aerogel in water yields cell sized (d = 10 – 20 μm) particles. The cytotoxicity of these microparticles against tumor cell lines (SCC VII and HL-60) is unprecedentedly high, it is approximately equivalent that of an equal dose of free (dissolved) MTX, as proved by *in vitro* experiments. Thus, the activity of MTX is intact after aerogel functionalization, and the mass specific cytotoxicity of SGM is high enough for medical applications. Drug release studies verified that MTX cannot be liberated from this drug delivery system solely by chemical hydrolysis, however, collagenase enzymatic activity releases MTX from the functionalized hybrid aerogel. The cytotoxicity of SGM towards various cancerous and non-cancerous cell lines correlates with the collagenase activities of cells. Therefore, conjugation with the hybrid aerogel provides a controlled release system for the antineoplastic agent MTX.

3.) Suspensions of fluorescein labelled silica-gelatin hybrid aerogel microparticles were injected into the peritoneum (abdominal cavity) of healthy mice in 52 and 104 mg kg^{-1} concentrations during a 3 week long acute toxicity experiment. No physiological dysfunctions were detected, and all mice were healthy. Autopsy revealed that the aerogel microparticles were not present in the site of injection in the abdominal cavity at the end of experiment. The histological study of the liver, spleen, kidneys, thymus and lymphatic tissues showed no signs of toxicity. The localization of the aerogel microparticles in the organs was studied by fluorescence microscopy. Aerogel microparticles were not detected in any of the abdominal organs, but they were clearly visible in the cortical part of the parathymic lymph nodes, where they accumulated. The accumulation of aerogel microparticles in parathymic lymph nodes in combination with their absence in the reticuloendothelial system organs, such as the liver or spleen suggests that the microparticles entered the lymphatic circulation. This biodistribution pathway could be exploited to design passive targeting drug delivery systems for flooding metastatic pathways of abdominal cancers that spread via the lymphatic circulation.

4.) The well-characterized bovine serum albumin (BSA) was chosen as a model protein to probe protein-aerogel interactions in the solution phase. Aqueous BSA was mixed with suspended silica aerogel microparticles, and the colloid system was monitored on-line by UV-vis spectrophotometry and turbidimetry. The global mathematical analysis of the time-resolved data reveals that the fast sorption of the protein on the aerogel microparticles follows a multi-step binding mechanism. The extensive sorption of the protein eventually induces the aggregation of the covered aerogel due to the alteration of the electrical double layer of the particles. The interaction of BSA and silica aerogel is the strongest between pH = 4 and 5, because their native surface charges are the opposite in this pH range, as indicated by their respective Zeta-potentials.

5.) The copper(II) complexes of 1,4,7,10-tetraazacyclododecane (cyclen) and 1,4,8,11-tetraazacyclotetradecane (cyclam) were covalently immobilized in mesoporous silica aerogels by the sol-gel method using functionalized silica precursors. The modified macrocyclic precursors are characterized by mass spectrometry (MS) and solution phase nuclear magnetic resonance (NMR) spectroscopy. The supercritically dried aerogels are characterized using low voltage scanning electron microscopy (LV-SEM), N_2-sorption porosimetry, infrared spectroscopy (FT-IR), electron paramagnetic resonance spectroscopy (EPR) and contrast variation small angle neutron scattering (SANS). The suspended aerogel particles act as

nanoenzymes, because they have significant SOD activities, dramatically higher than the corresponding dissolved Cu(II) complexes. The most important factors responsible for the altered reactivities due to the covalent immobilization of the complexes were elucidated based on the compiled results of the characterization methods. These are: *i*) the formation of new chemical environments and Cu(II) coordination modes; *ii*) the effective separation of the active Cu(II) centers in the aerogels; and *iii*) the confinement effect operative in the nanoporous network. As a perspective, the present functionalized aerogel microparticles can be developed into antioxidant pharmaceutical agents administered locally or subcutaneously.

3.2. Aerogels for environmental remediation

6.) Supercritically dried, mesoporous silica-gelatin hybrid aerogels of 4 – 24wt.% gelatin content show high selectivity for the adsorption of aqueous Hg(II) in the simultaneous presence of Cu(II), Cd(II), Co(II), Pb(II), Ni(II), Ag(I) and Zn(II), as demonstrated by batch adsorption experiments with multiple competing ions. The aerogels are characterized by SEM and N_2 porosimetry, and their aqueous particle size distributions and Zeta potentials are reported. The adsorption properties of the hybrid aerogels are studied as function of their composition, initial aqueous Hg(II) concentration, contact time and pH. The optimum pH for adsorption is 6.0, where the surface of the aerogel is already negatively charged, but Hg(II) does not completely hydrolyze. The Hg(II) uptake of the hybrid aerogels increases with increasing gelatin content and levels off at 24wt.% gelatin. The adsorption capacity of the 24wt.% gelatin hybrid is estimated to be $S = 209$ mg g^{-1} by fitting the isotherm with the Langmuir model ($K_L = 0.032$ L mg^{-1}). This translates to 91% Hg(II) removal at c_0(Hg) = 1.0 mg L^{-1} and c_0(agel) = 0.32 g L^{-1}. Gelatin provides the active sites for Hg(II) binding, thus higher gelatin content results in higher adsorption capacity. However, high gelatin content also induces the extensive swelling of backbone and the partial collapse of the open porous structure, which decreases the specific surface area. Time resolved experiments show that the adsorption equilibrium is established within 15 min contact time with aqueous Hg(II). Washing the equilibrated aerogels with a 2.5 mM solution of EDTA complexing agent quantitatively liberates bound Hg(II). The regenerated aerogels demonstrate practically intact adsorption capacities in 5 cycles of reuse. Coordination chemistry based considerations reveal that Hg(II) is selectively complexed by the soft Lewis-base side chains of collagen.

7.) The remediation efficacy of silica-gelatin hybrid aerogel sorbents were tested under realistic aquatic conditions by exposing cultures of *Paramecium caudatum* to Hg(II) and monitoring

the model cultures by time-lapse video microscopy. The viability of *Paramecium* was quantified by analyzing the pixel differences of the sequential images caused by the persistent movement (motility) of the cells. The viability of *Paramecium* displays a clear exposure-response relationship with Hg(II) concentration. Viability decreases with increasing Hg(II) concentration when the latter is higher than 125 μg L^{-1}. In the presence of 0.1 mg mL^{-1} aerogel adsorbent, the viability of the cells decreases only at Hg(II) concentrations higher than 500 μg L^{-1}, and 220 min survival time was measured even at 1000 μg L^{-1} Hg(II). The effective toxicity of Hg(II) is lower in the presence of the aerogel, because the equilibrium concentration of aqueous Hg(II) is low due to adsorption, thus *Paramecium* cells do not uptake as much Hg(II) as in the un-remediated cultures. Video imaging of *Paramecium* cultures offers a simple, robust and flexible method for providing quantitative information on the effectiveness of advanced materials used in adsorption processes for water treatment.

8.) For the recovery of palladium compounds from aqueous solutions, a mesoporous, polycarboxylate (pyromellitic acid monoamide) functionalized silica-gelatin aerogel was prepared by the sol-gel method and supercritical drying. It is characterized using low voltage scanning electron microscopy (LV-SEM), N_2-sorption porosimetry, small angle neutron scattering (SANS), infrared spectroscopy (FT-IR), solid-state nuclear magnetic resonance spectroscopy (ssNMR) and X-ray photoelectron spectroscopy (XPS). Its aqueous phase Zeta potential was investigated as a function of pH. The aerogel has excellent selectivity for binding Pd(II) around pH = 2.0 in the simultaneous presence of Pt(II), Pt(IV) and six other metal ions with a very high sorption capacity of 369 mg g^{-1} at pH = 2.3. The quantitative recovery of Pd(II) and the regeneration of the sorbent is possible using 5 mM methionine. The mechanism of binding is the reversible surface complexation of Pd(II) via the O-atoms of the adjacent carboxylate groups of the aerogel, as shown by XPS. This high stability coordination mode accounts for the excellent selectivity of the sorbent, and prevents the reduction of Pd(II).

9.) The covalent immobilization of the copper(II) complex of 1,4,7,10-tetraazacyclododecane [Cu(II)-cyclen] significantly alters its catalytic activity in the oxidation of phenol by H_2O_2 in aqueous solution. In order to understand this phenomenon, the functionalized aerogel was characterized by scanning electron microscopy (SEM), N_2 porosimetry, small angle neutron scattering (SANS), infrared spectroscopy (IR) and electron paramagnetic resonance spectroscopy (EPR). Aerogel morphology is typical of mesoporous silica aerogels, and the coordination mode of Cu(II) in the immobilized complex is well-related but not identical to

solution phase Cu(II)-cyclen. The mechanisms of the catalytic reactions involving dissolved and immobilized Cu(II)-cyclen were explored by fine kinetic experiments using capillary electrophoresis (CE) and on-line UV-vis spectrophotometry. Hydroquinone, pyrocatechol and the related benzoquinones were identified as the main intermediates in both reaction systems. A detailed kinetic model is postulated based on global data fitting, which clearly highlights the mechanistic differences in the two systems. Interestingly, the activation of the catalyst by H_2O_2 is more effective in the case of the aerogel, but the total conversion of phenol is slower due to hindered mass transport compared to using dissolved Cu(II)-cyclen.

3.3. Advanced characterization of aerogels

10.) It was demonstrated that even a 5 nm thick sputtered gold layer used for SEM imaging can dramatically alter the morphology and the surface structure of many different types of aerogels. Silica, polyimide, polyamide, calcium-alginate and cellulose aerogels were imaged in their pristine forms and after gold sputtering utilizing low voltage scanning electron microscopy (LVSEM) in order to reduce charging effects. The morphological features seen in the SEM images of the pristine samples are in excellent agreement with the structural parameters of the aerogels measured by N_2-sorption porosimetry. In contrast, the morphologies of the sputter coated samples are significantly distorted and feature nanostructured gold. These findings point out that extra care should be taken in order to ensure that gold sputtering does not cause morphological artifacts. Otherwise, the application of low voltage scanning electron microscopy yields high resolution images of pristine non-conducting aerogels.

11.) Polyurea-crosslinked Ca-alginate (X-Ca-alginate) aerogels were prepared by reacting an aliphatic or an aromatic triisocyanate with the pre-formed biopolymer network post-gelation, and drying in supercritical CO_2. The morphology of native Ca-alginate aerogels together with those of the different X-Ca-alginate aerogels were investigated using low-voltage scanning electron microscopy (LV SEM), N_2-sorption porosimetry and contrast variation small angle neutron scattering (SANS). Native Ca-alginate aerogels are built from primary nanoparticles (8.3 ± 0.1 nm in radius) that attach to one another forming secondary particles. In X-Ca-alginate aerogels, the aliphatic and the aromatic polyureas attach to primary nanoparticles (which increase in size up to 10.0 ± 0.1 nm) via urethane linkages and then they extend into the empty space within secondary particles in different ways. Crosslinking with an aliphatic triisocyanate leads to the formation of a dense polyurea layer over the primary nanoparticles, following the

contours of the Ca-alginate skeletal framework. The rigid aromatic triisocyanate forms a looser and randomly oriented polymer structure that more-or-less fills the empty space between the primary nanoparticles within secondary particles. Both processes leave the primary Ca-alginate structure practically undisturbed, while it does affect the structure at the most fundamental level, increasing the primary particle size and reducing porosity.

3.4. Understanding structure-properties relationships in aerogels

12.) The macroscopic properties of monolithic, structurally stable zirconia (ZrO_2) aerogels can be fine-tuned by the appropriate thermal treatment of the amorphous aerogels. Therefore, the thermally induced phase transitions of ZrO_2 and yttria-stabilized zirconia (YSZ) monolithic aerogels were investigated. All aerogels were produced by an acid-catalyzed sol-gel technique and subsequent supercritical drying (SCD). A complete reaction mechanism is proposed for the formation of the wet gel network. Also, the phase transformations taking place during calcination were followed as a function of the temperature by *in-situ* X-ray diffraction measurements. Composition and size of the forming crystallites were calculated from the XRD data. Phase transition is controlled by the temperature-dependent growth of crystallite size during calcination up to 1200 ^oC. Both tetragonal and monoclinic zirconia form in pure ZrO_2 aerogels, and a single tetragonal phase forms in YSZ aerogels.

13.) Starting from TMOS and implementing co-gelation in the sol-gel method, silica was hybridized with an industrial formulation of bovine casein. The hybrid alcogels were dried in supercritical CO_2 to yield crack-free silica-casein aerogel monoliths of casein contents ranging from 4.7wt.% to 28wt.%. Cross-linked hybrid aerogels were produced from formaldehyde treated alcogels. The microstructures and the morphologies of the silica-casein aerogels highly resemble to that of pristine silica aerogels. The primary building blocks are spherical particles that interconnect into mesoporous networks (average d_{pore} = 20 nm and S_{BET} = 700 nm^2/g), as shown by SEM, small-angle neutron scattering (SANS) and N_2 adsorption-desorption porosimetry. Contrast variation SANS experiments show that silica and casein form homogeneous nanocomposite backbones. The interaction of water with silica-casein aerogels was investigated by SANS, and by NMR cryoporometry, relaxometry and diffusiometry. Even when fully saturated with water, the hybrid silica-casein aerogels retain their original, highly permeable, open mesoporous structures that formed under supercritical drying. This represents a unique and advantageous wetting mechanism among hybrid inorganic-biopolymer materials,

since the strong hydration of the biopolymer component often causes the deformation of the backbone and the consequent collapse of the porous structure.

14.) Silica-gelatin hybrid aerogels of varying gelatin content (from 4wt.% to 24wt.%) can be conveniently impregnated with hydrophobic active agents (e.g. ibuprofen, ketoprofen) in supercritical CO_2 and used as drug delivery systems. Contrast variation neutron scattering (SANS) experiments show the molecular level hybridization of the silica and the gelatin components of the aerogel carriers. The active agents are amorphous, and homogeneously dispersed in these porous, hybrid matrices. Importantly, both fast and retarded drug release can be achieved with silica-gelatin hybrid aerogels, and the kinetics of drug release is governed by the gelatin content of the carrier. In this paper, for the first time, a molecular level explanation is given for the strong correlation between the composition and the functionality of a family of aerogel based drug delivery systems. Characterization of the wet aerogels by SANS and by NMR diffusiometry, cryoporometry and relaxometry revealed that the different hydration mechanisms of the aerogels are responsible for the broad spectrum of release kinetics. Low-gelatin (4 – 11wt.%) aerogels retain their open-porous structure in water, thus rapid matrix erosion dictates fast drug release from these carriers. In contrast to this, wet aerogels of high gelatin content (18 – 24wt.%) show well pronounced hydrogel-like characteristics, and a wide gradual transition zone forms in the solid-liquid interface. The extensive swelling of the high-gelatin hybrid backbone results in the collapse of the open porous structure, that limits mass transport towards the release medium, resulting in slower, diffusion controlled drug release.

15.) The most relevant properties of polysaccharide aerogels in practical applications are determined by their microstructures. Hydration has a dominant role in altering the microstructures of these hydrophilic porous materials. In order to understand the hydration induced structural changes of monolithic Ca-alginate aerogel, produced by drying fully crosslinked gels with supercritical CO_2, the aerogel was gradually hydrated and characterized at different states of hydration by small angle neutron scattering (SANS), liquid-state nuclear magnetic resonance (NMR) spectroscopy and magic angle spinning (MAS) NMR spectroscopy. First, the incorporation of structural water and the formation of an extensive hydration sphere mobilize the Ca-alginate macromolecules and induce the rearrangement of the dry-state tertiary and quaternary structures. The primary fibrils of the original aerogel backbone form hydrated fibers and fascicles resulting in the significant increase of pore size, the smoothing of the nanostructured surface and the increase of the fractal dimension of the

matrix. Due to the formation of these new superstructures in the hydrated backbone, the stiffness and the compressive strength of the aerogel significantly increase compared to its dry-state properties. Further elevation of the water content of the aerogel results in a critical hydration state. The Ca-alginate fibers of the backbone disintegrate into well-hydrated chains, that eventually form a quasi-homogeneous hydrogel-like network. Consequently, the porous structure collapses and the well-defined solid backbone ceases to exist. Even in this hydrogel-like state, the macroscopic integrity of the Ca-alginate monolith is intact. The postulated mechanism accounts for the modification of the macroscopic properties of Ca-alginate aerogel in relation to both humid and aqueous environments.

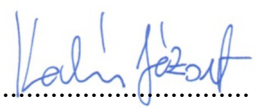
4. SUMMARY OF RESULTS

- Articles published: **20** (14 D1/Q1; 6 Q1)
  Articles under review: **2**
  J.K. as first / last / corresponding author: **17** of 22
  Sum. impact factor published: **123.672**
  Independent citations for above articles: **256**
  Oral presentations in international conferences (invited / keynote): **11** (4)

- Ph.D. dissertations of participants (year of defense): **3**
  Péter Veres (2018.), Gábor Király (2019.), Petra Herman (2021.)
  New Ph.D. students involved (starting year): **3**
  Krisztián Moldován (2018.), Zoltán Balogh (2021.), Dániel Pércsi (2022.)
  Related OTDK thesis works: **5**
  Related M.Sc. thesis works: **11**

- New EU project as task leader: HORIZON-CL4-2022-SPACE-01-81 – *Insulation Solutions Based on Aerogels* (ISBA) (2022 – 2025.)

Debrecen, 2022. okt. 30.



Dr. Kalmár József

Tisztelt Dr. Kalmár József!

Pár nap csúszás nem okoz problémát, a november 4-i határidő elfogadható a Hivatal részéről.

Tisztelettel,

BUKOVSZKI Nikolett
Referens
Kutatói Kiválósági Főosztály / Műszaki és Természettudományok Osztálya

Nemzeti Kutatási, Fejlesztési és Innovációs Hivatal
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From: Turcsán Zsolt
Sent: Tuesday, October 25, 2022 12:54 PM
To: Bukovszki Nikolett
Subject: Fw: KM1: 124571 kutatás zárójelentése

Kedves Niki!

Továbbítok egy KM1 kérést ügyintésére.

Köszönettel:
Zsolt

Feladó: Kalmár József <kalmar.jozsef@science.unideb.hu>
Elküldve: 2022. október 25., kedd 12:23
Címzett: Turcsán Zsolt
Másolatot kap: Gémesné Deák Júlia
Tárgy: Re: KM1: 124571 kutatás zárójelentése

Tisztelt Turcsán Zsolt!

Kérem szépen engedélyezzék számomra, hogy OTKA_124571 azonosító számú "Mikro- és mezopórusos szilárd anyagok szerkezete és alkalmazási lehetôségei" lezárult pályázatom szakmai zárójelentését haladékkal, 2022. nov. 04-ig rögzítsem az elektronikus rendszerben!

Kérvényem indoka szakmai: egyik külföldi együttműködő partneremtől, az ő akadályoztatása miatt még nem érkezett meg hozzám egy kézirat, ami a projekt fontos részét képezi, és szerepelnie kell a beszámolóban.

Kérem értesítsen a döntésről! Köszönöm a segítségét!

Üdvözlettel:
Kalmár József

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2022-09-15 16:34 időpontban Gémesné Deák Júlia ezt írta:
> Tisztelt Kalmár József!
>
> Az OTKA/NKFI Hivatal által támogatott, 124571 azonosító számú
> """"Mikro- és mezopórusos szilárd anyagok szerkezete és alkalmazási
> lehetôségei"" címû kutatás lezárult, ezért az elvégzett
> kutatómunkáról, valamint annak eredményérôl szakmai zárójelentést kell
> benyújtania. Kérjük, hogy az elmúlt 2017-10-01 - 2022-09-30 idôszakra
> vonatkozó szakmai záróbeszámolóját szíveskedjék elkészíteni, és azt az
> elektronikus rendszerben legkésôbb a projekt zárását követô harminc
> napon belül rögzíteni.
>
> Amennyiben az Ön projektje 2012. szeptember 1-je után indult és az
> Élettelen Természettudományok Kollégiumába vagy az Orvosi és Biológiai
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> szakmai beszámolót angol nyelven készítse el.
>
> A szakmai zárójelentést nyomtatott formában, aláírva, egy példányban
> postán is meg kell küldeni az NKFI Hivatalnak a projekt zárását követô
> hatvan napon belül.
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> Kérjük, hogy mielôtt a záró beszámoló elkészítéséhez hozzákezd,
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> elolvasni:
> https://nkfih.gov.hu/palyazoknak/szakmai-beszamolo/epr-rendszerben.

Nemzeti Kutatási, Fejlesztési és Innovációs Hivatal | EPR rendszerben benyújtott pályázatokhoz kapcsolódó dokumentumok

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> nyilvános hozzáférésû repozitóriumban való elhelyezésével.
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> Tisztelettel:
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> Ez egy rendszerüzenet. Kérjük, ne válaszoljon rá.
>
> A választ a Gémesné Deák Júlia julia.deak@nkfih.gov.hu címre
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