Project Description: Priority Programme "Dynamic Wetting of Flexible, Adaptive and Switchable Surfaces" (SPP 2171)

Theoretical and experimental evaluation of magentostiction and electrostiction through controllable solid-liquid interfaces.

Gareth Monkman, Regensburg, Professor, permanent.

Project Description

1 State of the art and preliminary work

The Ostbayerische Technische Hochschule Regensburg (OTHR) and in particular the the laboratory of Prof. Monkman, the Mechatronics Research Unit (MRU), has a long history of smart materials and interface research. The research experience of Prof. Dr. Böhm also concerns smart materials (ferrofluids and magneto-sensitive elastomers) resulting from research within the DFG Priority Programs SPP 1681 and SPP 1104 as a researcher at the TU Ilmenau (Research Group headed by Prof. Dr. Zimmermann). Following previous work in smart fluids in the UK [Monkman, 1991], [Monkman, 1993], [Monkman, 1995] initial projects concerning hybrid polymers at the OTHR commenced in 2001 as part of the research project "Haptic Sensor-Actuator-System" (HASASEM), in which electrorheological and magnetorheological fluids were utilized for the purposes of haptic display development [Klein et al, 2004]. This was a joint BMBF project between the OTHR, the Institute of Microtechnology in Mainz, the Ruhr University in Bochum and the Fraunhofer Institute for Silicate Research in Würzburg.

A further BMBF project dealing with controllable solid-fluid interfaces "EAP with magnetically controllable elasticity for the interaction with connective tissue cells" (MagElan) commenced in 2009 in cooperation with the University Hospital Würzburg and under the coordination of the Fraunhofer Institute for Silicate Research ISC, Würzburg. The aim of this research project was the investigation of effects on in-vivo biological cells (durotaxis) through the hardening of MAP composite materials under the influence of an applied external magnetic field [Mayer et al, 2013]. Work on MagElan continued until the end of 2011. Results of the work were, in addition to the desired effects of MAP as a cell substrate, the improved knowledge in the production of MAP with soft and hard magnetic content [Böse et al, 2011] and the effect of external magnetic fields on the elastic modulus [Forster et al, 2012; Mayer et al, 2012].

Due to the promising results of the MagElan project, the OTHR decided to pursue in-depth research into MAP as part of another BMBF funding program. The follow-up project "Introduction of a novel mechatronic platform based on magnetoactive polymers for biomedical and industrial applications (EMMAUS)" between 2011 to 2014. Further work on MAP allowed the variation of the modulus of elasticity during sample preparation, the macro-, meso- and microstructuring of the samples and the extended admixture of different particles [Mayer et al, 2013].

The use of an electric field to change hydrophobic based fibrous polyaniline substrates to a hydrophillic state have been demonstrated [Zhang et al, 2016], [Weeber et al, 2018] and the use of electric fields for surface wetting control of polystyrene surfaces is known [Bhushan B. & Y. Pan 2011]. Magnetically controlled systems have also been developed [Drotlef et al, 2014], [Kim et al, 2015]. Even optically driven systems have been attempted [Uchida et al, 2010]. However, most of these systems rely on surface profiles rather than smooth or porous surfaces with field induced imbibition.

Since the beginning of 2016, research on the electrical properties of MAP have been continued by the MRU within the DFG Priority Program SPP 1681, also based on previous work [Monkman, 1994; 1997; 2003]. Within this DFG program, Mr. Dirk Sindersberger (OTHR) commenced a collaborative doctorate under supervision of Prof. Dr. Zimmermann (TU Ilmenau) and Prof. Dr. Monkman at the beginning of 2017 [Monkman et al, 2016], [Sindersberger et al, 2017]. Recent research at MRU has demonstrated an interaction between the applied magnetic field and the electric charge distribution within the MAP. This effect is one of the newest and most important findings in this research field, which combines the magnetoactive and electroactive properties of such polymers. Combining both effects would provides opportunities for the creation of novel sensors and actuators [Monkman et al, 2017] and potentially controllable surface imbibition.

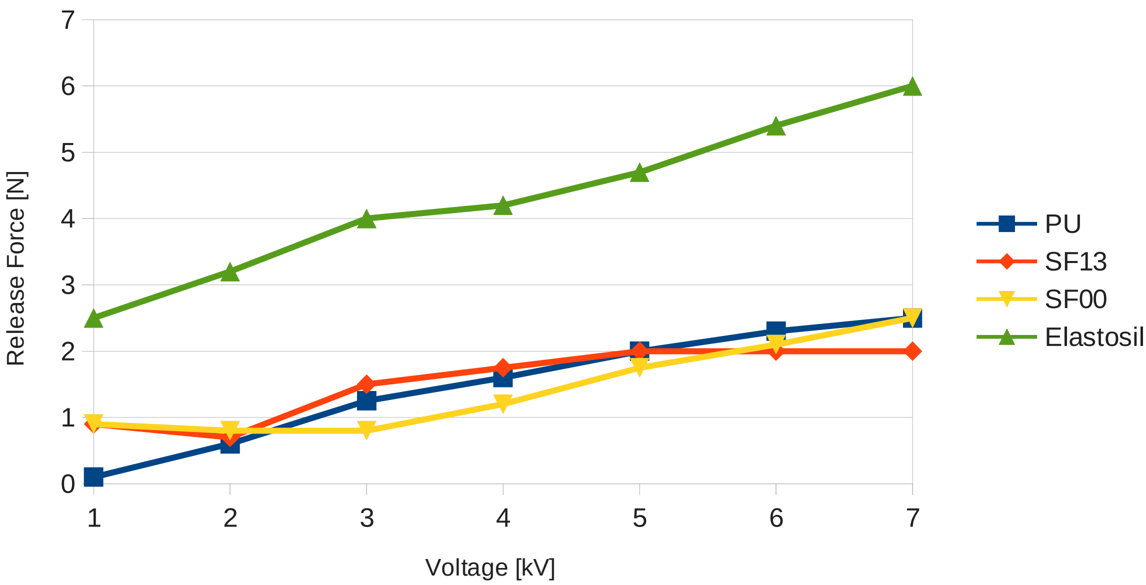

Figure 1 - Release force as a function of voltage for an electroadhesor.

From figure 1 it can be seen that for most dielectrics the electroadhesion force is similar. The exception being Elastosil with more than double the amount, though at the expensive of higher quiescent friction.

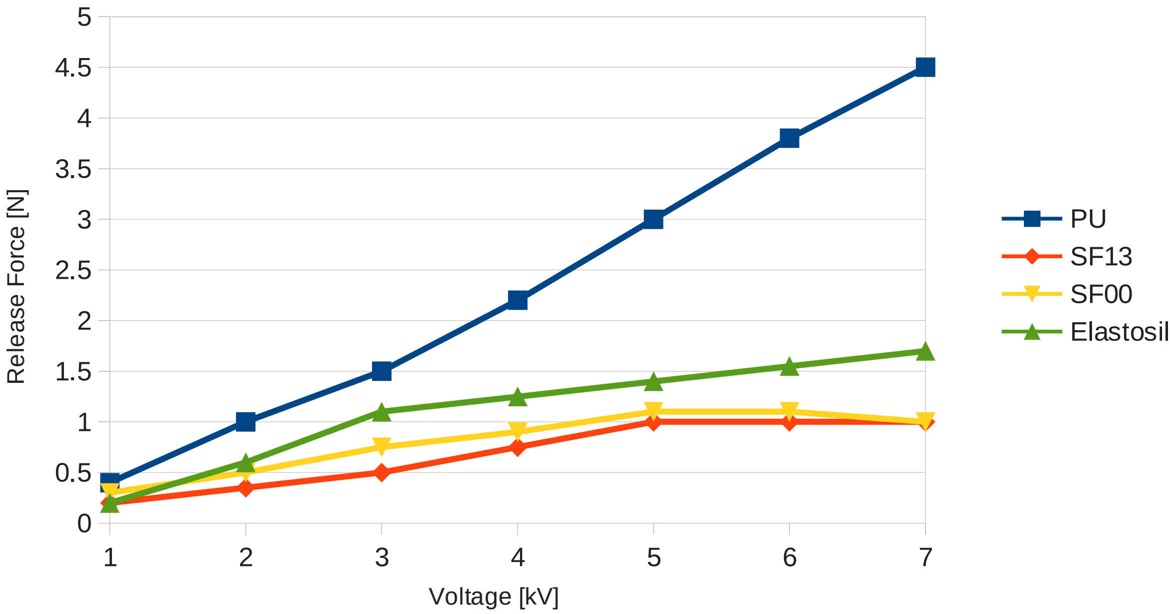

Figure 2 - Release force as a function of voltage for an electroadhesor with additional lubrication

Previous research has shown that a layer of dielectric fluid between the electrodes and gripper dielectric can improve electroadhesion [Monkman, 1992]. It is interesting to observe from figure 2, that with the addition of a layer of silicone oil between the gripper dielectric and the contact surface, the results for PU are significantly changed.

What is more significant is the reversal of effects vis-a-vis Polyurethane (PU) and Elastosil.

During previous research, and that within SPP1681, it became apparent that the repeatable production of test samples and devices demanded better fabrication techniques. To these ends 3D printing of pre-crosslinked silicone polymers was pioneered and introduced. This has resulted in a significant increase in design possibilities and the ability to produce finer structures than with conventional casting methods. As a consequence, it is possible to selectively and repeatably manufacture hybrid samples containing different materials and multiple layers. Passive, magnetoactive and/or electrically active and conductive structures can be printed within the same element.

3D printing has been further enhanced by applying magnetic fields to the injected MAP areas during the crosslinking phase. The particles or particle agglomerate follows the field gradient of the applied magnetic field. The freedom of movement of the particles increases by another three dimensions, which effectively introduces a further three degrees of freedom. The use of alternating fields also allows a diffusion of the particles with different density distributions. This provides a controlled graded dispersion of the particulate within the polymer matrix resulting in a 6D printing process [Sindersberger et al, 2018].

One result of the research into the dielectric properties of MAP has led to the development of the first magnetoactive electret. Using a polymer enriched with barium titanate, an enhanced electret is combined with an MAP to form a device which is capable of simultaneous magneto and electroadhesion. In short, such a device attracts objects made from almost all materials whether electrically conductive, insulating or magnetically susceptible or not [Monkman et al, 2017].

The embedding of electrically conducting tracks into soft silicone EAP can make the integration of electroadhesors [Monkman, 1992], [Guo et al, 2017] into MAP actuators and soft robotic joints possible. This provides a further viable means of astrictive robotic prehension.

In addition to 3D and 6D printing, very recent research at OTH-Regensbirg has made the deliberate and controlled introduction of magnetically controllable cavities into MAP possible [Sindersberger et al, 2019]. Such fabrication techniques are potentially very significant with respect to surface stucturing. This is expected to allow a greater degree of repeatability in magnetically controlled imbibition.

Advanced material characterization and the development of manufacturing techniques for smart materials led to the first technical applications, developed in close collaboration between the applicants. This collaboration between the Ilmenau und Regensburg research groups was estabilished within SPP1681 aimed at the development of sensor and actuator systems, focusing primarily on the realization of manipulation systems by using non-conventional material-behavior (e.g. field induced plasticity-effect of magneto-sensitive elastomer materials) [Volkova et al, 2017], [Becker et al, 2017]. The recent focus of this work lies in the development of advanced systems including of sensor and actuator functions [Zimmermann et al, 2017], [Prem et al, 2018]. In the meantime, Prof. Dr. Valter Böhm has taken a professorial position in the Mechanical Engineering Fakulty of the OTH-Regensburg and is also a co-applicant of this research proposal.

1.1 Project-related publications

1.1.1 Articles published by outlets with scientific quality assurance, book publications, and works accepted for publication but not yet published

Becker, T.I.; Raikher, Yu. L.; Stolbov, O. V.; Böhm, V.; Zimmermann, K.: Dynamic properties of magneto-sensitive elastomer cantilevers as adaptive sensor elements. *Smart Materials and Structures*, IOP Publ., 26/9(2017), 095035 (9pp).

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Klein. D, D. Rensink, H. Freimuth, G.J. Monkman, S. Egersdörfer, H. Böse & M. Baumann - Modelling the Response of a Tactile Array using an Electrorheological Fluids - *Journal of Physics D: Applied Physics*, vol 37, no. 5, pp794-803, Mar 2004. {DOI: 10.1088/0022-3727/37/5/023}

Mayer. M., R. Rabindranath, J. Börner, E. Hörner, A. Bentz, J. Salgado, H. Han, H. Böse, J. Probst, M. Shamonin, G. J. Monkman & G. Schlunck - Ultra-Soft PDMS-Based Magnetoactive Elastomers as Dynamic Cell Culture Substrata - *PLoS ONE*, Volume: 8 Issue: 10, October 18, 2013. {DOI: 10.1371/journal.pone.0076196}

Monkman. G.J. - Controllable Shape Retention - *Journal of Intelligent Materials Systems & Structures* - Vol 5, No. 4, pp. 567-575, July 1994.

Monkman. G.J. - The Electrorheological Effect under Compressive Stress - *Journal of Physics D: Applied Physics* - Vol. 28, pp 588-593 - Institute of Physics, 1995. {DOI:10.1088/0022-3727/28/3/022}

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Volkova, T.I.; Böhm, V.; Naletov, V.A.; Kaufhold, T.; Becker, R.; Zeidis, I.; Zimmermann, K.: A Ferrofluid Based Artificial Tactile Sensor with Magnetic Field Control. J. Magnetism and Magnetic Materials, Elsevier B.V., Vol. 431, (2017), pp. 277-280.

Volkova, T.I.; Böhm, V.; Kaufhold, T.; Popp, J.; Becker, F.; Mixanek, F.; Borin, D.; Stepanov, G.V.; Zimmermann, K.: Motion Behaviour of Magneto-sensitive Elastomers Controlled by an External Magnetic Field for Sensor Applications. J. Magnetism and Magnetic Materials, 431(2017), pp. 262-265.

1.1.2 Patents

1.1.2.1 Pending

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1.1.2.2 Issued

Böse. H., A. Hesler & G. Monkman - *Magnetorheologische Kompositmaterialien mit hartmagnetischen Partikeln, Verfahren zu deren Herstellung sowie deren Verwendung*. - Deutsche Patent DE 10 2007 028 663 A1. Priority: 21.06.2007. European Patent EP 2 160 741 B1 Granted: 17.08.2011.

Probst. J., R. Rabindranath, G. Schlunck, H. Böse, G. Monkman, M. Shamonin, M. Mayer, E. Forster und A. Bentz - „Magnetoactives oder elektroaktives Kompositmaterial, dessen Verwendung und Verfahren zur Beeinflussung von auf dem magnetoaktiven oder elektroaktiven Kompositmaterial angelagerten biologischen Zellen“, *Patent* DE 10 2011 010 757.6 B413, 13. September 2012.

Zimmermann, K.; Böhm, V.; Popp, J.: Vorrichtung und Verfahren zum translatorischen Bewegen von nichtmagnetischen Gegenständen. German Patent, DE 10 2007 044 442 B4, 2010.

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2 Objectives and work programme

2.1 Anticipated total duration of the project

The project is to be carried out over a period of three years, with a follow-up application planned for the second phase of the project.

2.2 Objectives

Stiction (sometimes referred to as “stick-slip”) is a word construction derived from friction and sticking. It represents the forces due to static friction which manifests itself as a cohesion force threshold which must be overcome to enable relative motion between otherwise stationary objects in contact [Yamamoto et al, 2001]. Following the onset of movement, resistance to motion is provided exclusively by dynamic friction. In engineering, stiction is usually considered to be a problem [Ruel, 2000]. However, in certain applications, stiction can be deliberately implemented to advantage.

It is not easy to make a clear distinction between adhesion and stiction. Both are related to inter molecular viscoelastic effects and both are influenced by surface roughness. Adhesion (for example magnetoadhesion and electroadhesion) concerns the application of an astrictive force which causes prehension whereas magnetostiction and electrostiction pertain to the control of friction though a magnetic or electric field respectively. Light adhesive force often manifests itself as stiction. Magnetoadhesion and electroadhesion embody the ability to control this force through an externally applied magnetic or electric field respectively.

Both magnetically and electrically switchable surfaces have been investigated by the MRU. One example is the use of porous silicone polymer substrates infused with ferrofluids. The application of a magnetic field behind the substrate results in the absorption of the ferrofluid into the pores resulting of a high friction surface. The ferrofluid can then be released onto the surface of the substrate on the removal of the magnetic field thus providing a low frictional lubricated surface. In order to prevent the ferrofluid leaving the surface completely, instead of passive silicone, the substrate may be in the form of a graded density magnetoactive polymer. This has the advantage of substrates being able to retain the ferrofluid by reducing the magnetic field to a nominal level rather than eliminating it.

The use of electroadhesion together with additional fluid dielectrics also provides electrically controllable tribological effects. In most cases the frictional coefficient between an electroadhesor dielectric and a passive surface is higher without an additional fluid dielectric film. However, there are certain dielectric polymers in which the reverse is true.

Collaboration within the priority program

The OTH-Regensburg is extremely well equipped for the testing and evaluation of polymeric materials and interfaces in conjunction with magnetic, electric and thermal fields. These facilities would be offered to all members of SPP2171 in the interests of scientific collaboration.

The research group of Jeanette Hussong and Evgeny Guerevich (Bochum) have a history of research into switchable substrates using flexible superparamagnetic filament arrays. Although fibrous surfaces are not a part of the OTH-Regensburg research program, collaboration in terms of experimental apparatus would be extremely useful here. An offer of collaboration has been made to them in this respect.

Using Lattice Boltzmann Electro Kinetics (LB-EK) with implicitly dissolved solvent and ions, the research group of Prof. Dr. Christian Holm (Stuttgart) seek a method for the fluid coupling to polymers. The control of pH through AC and DC electric fields is intended to control electrowetting on planar and corrugated polymers having responsive polymer brush surfaces. This conforms well with the research intentions at the OTH-Regensburg where facilities for simulation, fabrication and measurement are available.

2.3 Work programme including proposed research methods

Work package	Content and research methods
1	**Theoretical analysis of the solid-fluid interface.** The basis for all work within this project relies on a theoretical analysis of the physical mechanisms behind the solid-fluid interface to determine wettability and dewettability. A considerable amount of previous research concerning fluid-solid sorption as a function of interfacial tension and Laplace pressure for various liquid morphologies is extensively documented. A collation of these findings and their extension to surface tribology through wetting/dewetting is to form the basis of this research.
2	**Porous and non-porous polymer substrates.** This concerns the determination of suitable porous and non-porous viscoelastic polymer substrate materials for controllable stiction. The physical effects of viscoelastic polymer topology on imbibition dynamics comprises the core of this work package.
3	**Analysis of the effects of magnetic and electric fields on the solid-fluid interface.** Calculation and simulation of the effects of magnetic and electric field respectively, on the wettability and dewettability of substrates. This includes the effects of electrostatic fields on dielectric fluids at the molecular level where electrical polarization at the molecular and interfacial (space charge) levels plays a significant role. Taking the findings from work packages 1 and 2, the effects of such fields on imbibition are to be investigated. The development of polymer layers (single layer and sandwich layers) with actively controllable surface geometry (texture) is also necessary. This will place some demand on coupled magneto-mechanical FEM-simulation. The goal is the determination of suitable layer designs with structured / unstructured surfaces. These investigations include consideration of scalability (inducing surface deformation at the micro-level and macro-levels) and time-effects due to visco-elastic material layer properties.
4	**Compatibility of fluids for magnetostiction and electrostiction.** Determination of compatible fluids for enhanced magnetostiction and electrostiction. Few fluids are both magnetically as well as electrically susceptible. This work package deals with identifying such potential fluids and, where necessary, optimising on rheological effects resulting from fields possessing only one susceptibility.
5	**Experimental verification.** Experimental verification of theoretical and simulated data. This work package contains the core of this research project. Together with the results of work

	packages 1, 2, 3 and 4, the inclusion of findings from other research groups in SPP2171 are expected to be utilized and experimentally verified. Following basic considerations aimed at the realization of different, reversible variable, actively controllable textures, the development of optimized designs based on experimental results is to be considered during the second funding period.
6	**Demonstration.** Applications of controlled stiction are to demonstrated in the form of physical models. Particularly important are potential applications in 3D and 6D printing, tactile displaces for virtual reality and micro-prehension. These findings will then be used as feedback to support, refute or adjust theoretical models.
7	**Preparation and delivery of research results** Dissemination is expected to be a continuous process for other members within SPP2171 by means of seminars, inter-group collaboration etc. Publication of research results will follow in peer reviewed journals and conferences. Additional dissemination may be provided by OpenAccess servers of the OTH Regensburg, the internet domains www.mechatronics.org and www.mechatronik.org and in the form of a final reports to the DFG. Preparation of the application for phase 2 of the SPP2171.

Quarter	Work package 1	Work package 2	Work package 3	Work package 4	Work package 5	Work package 6	Work package 7
4rd 2019							
1th 2020							
2st 2020							
3nd 2020							
4rd 2020							
1th 2021							
2st 2021							
3nd 2021							
4rd 2021							
1th 2022							
2st 2022							
3nd 2022							
4rd 2022							

2.4 Data handling

In addition to the usual publications, research results obtained will be made available to other scientists in an Open Access procedure. It is planned to provide the data according to the recommendations of the DFG (Memorandum "Securing good scientific practice") through the full-text server of the computer centre of OTH Regensburg.

Samples associated with the data obtained will be stored at the OTH Regensburg and linked to the research data by appropriate nomenclature.

2.5 Other information

In addition to doctoral students, it is planned to involve undergraduate and post-graduate students in this work in order to allow them to actively participate in research.

2.6 Descriptions of proposed investigations involving experiments on humans, human materials or animals

There are no investigations on humans or animals.

2.7 Information on scientific and financial involvement of international cooperation partners

In the field of measurement technology, sensor development and magnetoactive polymers there has been extensive cooperation and several collaborations over the past decade (see publications).

3 Bibliography

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Drotlef. D-M, P. Blümler, P. Papadopoulos & A. del Campo - Magnetically Actuated Micropatterns for Switchable Wettability - *ACS Appl. Mater. Interfaces*, 2014, 6 (11), pp 8702–8707 {DOI: 10.1021/am5014776}

Guo. J, T. Bamber, Y. Zhao, M. Chamberlain, L. Justham & M. Jackson - Toward Adaptive and Intelligent Electroadhesives Robotic Material Handling - IEEE Robotics And Automation Letters, Vol. 2, No. 2, April 2017 .

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Monkman G.J. - Addition of Solid Structures to Electrorheological Fluids - *Journal of Rheology* - Vol 35, pp. 1385-7, October 1991.

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Weeber. R, P. Kreissl & C. Holm - Studying the field-controlled change of shape and elasticity of magnetic gels using particle-based simulations - *Archive of Applied Mechanics* (1-14), 2018.

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4 Requested modules/funds

4.1 Basic Module

Overall costs	
Funding for staff	166,185.00 €
Direct project costs	17,757.00 €
Travel Expenses	8,000.00 €
Publication Costs	1,400.00 €
Total project costs	**193,342.00 €**

4.1.1 Funding for Staff

The implementation of the proposed project requires the use of scientific personnel, for the financing of which the following personnel funds are requested. The breakdown is based on the categories of the DFG.

Doctoral student and equivalent:

The personnel resources of Professor Dr. Gareth Monkman consists of one doctoral student (75% funding in accordance with DFG Personalmittelsatz 2018) amounting to a total of **145.125 Euro** over 36 months. Doctorates are planed to be carried out in the form of cooperative doctorates with a suitable university within the priority program.

The main tasks of doctoral students concerns theoretical analysis together with project planning and the design and preparation of experimental configurations and the production of test samples. This, together with scientific documentation in the form of publications, will be carried out in cooperation with members of the SPP2171.

Assistants (scientific and student):

In addition, one SHK / WHK position is planned for a total of 36 months to support the research work of the doctoral student, especially in planning, construction and measurements. According to the local rate (€ 9 + € 2.70 per hour employer), an SHK / WHK is estimated to be € 585 / month for a maximum working time of 50h / month. This results in a total cost of **21.060 Euro.**

4.1.2 Direct Project Costs

Project costs	
Polymers and chemicals	1,875.00 €
Filler particles	2,150.00 €
Consumables	2,832.00 €
Screening Machine	2,800.00 €
Electrostatic Voltmeter	2,000.00 €
Optical Microscope	1,200.00 €
Workshop and Setup Material	4,900.00 €
Direct project costs	**17,757.00 €**

4.1.2.1 Equipment up to €10.000, Software and Consumables

The following values of individual items are presented in detail and are based on experience gained in the production and handling of polymers.

The sample preparation materials required in the research work are roughly divided into different polymers and chemicals needed to control crosslinking and material behaviour. The costs of silicones and chemicals occur annually per doctoral student:

Polymers	
Dragon Skin FX Pro	45.00 €
Ecoflex 0010	45.00 €
Elastosil RT604	67.00 €
Encapso	35.00 €
Flex Foam It! (PU)	38.00 €
SF00 2K-Silicone	105.00 €
SF13 2K-Silicone	105.00 €
ZK13 2K-Silicone	35.00 €
Chemicals	
Catalyst+Inhibitor+Crosslinker	113.00 €
Slacker	26.00 €
Thixotropic fluid	11.00 €
Sum of polymers and chemicals	**625.00 €**

In order to generate the desired material characteristics, the polymer matrix is admixed with different particles in different amounts:

Filler particles	
Carbonyliron HQ	50.00 €
Carbonyliron SQ	50.00 €
NdPrFeCoZrTiB powder	250.00 €
Graphite powder	300.00 €
Aluminiumgraphite powder	500.00 €
Carbon Black powder (different types)	500.00 €
Barium Titanate Powder	500.00 €
Sum of the filler particles	**2,150.00 €**

Various consumables in the form of laboratory accessories and sample containers are manufactured and charged annually as follows:

Consumables	
Einmal-Kanülen Sterican®, stumpfer Schliff	9.00 €
Einmalspritzen Injekt®, mit Luer-Anschluss	8.00 €
Einmalspritzen Injekt®, mit Luer-Anschluss 5ml	8.00 €
Einmalspritzen Injekt®-F 1ml	17.00 €
FFP-Masken Smart Pocket, ohne Klimaventil	22.00 €

Löffelspatel, mit flachem Löffel	6.00 €
Mehrzweckbecher mit Schraubverschluss, unsteril	71.00 €
Nitril-Einmalhandsch. TouchNTuff® 92-500	17.00 €
Pinzetten, gebogen, spitz 130mm	8.00 €
Rotilabo®-Kunststofftrichter	4.00 €
Rotilabo®-Schnappdeckelfläschchen ND18/ND22	14.00 €
Rotiprotect®-Latexhandschuhe Typ 2 puderfrei	11.00 €
Rotizell Wischtücher Wypall L20	30.00 €
Aceton 2,5 L	15.00 €
Isopropanol 2,5 L / 75%	15.00 €
Isopropanol 2,5 L / 99%	25.00 €
Ethanol 2,5 L	15.00 €
Petrischalen d=52mm	200.00 €
Petrischalen d=35mm	200.00 €
Silikonöl	245.00 €
Schnappdeckel	4.00 €
Sum of the consumables	**944.00 €**

To prepare the filler particles, a screening machine is to be procured in order to determine the grain sizes of the particles. The cost of such a machine together with various sieve inserts, amounts to about **2.800 Euro**.

For the measurement of surface charge on the polymers an electrostatic Voltmeter is necessary. Suitable models for this purpose cost about **2.000 Euro**.

The modification of the existing measurement equipment and the extension of the 3D printing process include various workshop services and materials. The conversions are expected to include aluminium profile assemblies, corresponding fasteners, linear drive systems and plastic parts. Furthermore, motors and motor controls are required to control the measuring system. Measurements on the experimental apparatus require various sensors and electronic components.

The design and assembly of the experimental apparatus will be carried out by members of the OTH Regensburg, for which no additional costs will be incurred. Assembly of hardware in the OTH workshops will only be necessary in cases where standard parts are not available. This results in one-time costs for the construction amounting to **4.900 Euro** based on experience.

4.1.2.2 Travel Expenses

For participation in colloquia, employee meetings, the visit of the project partners and conferences on topics of the SPP2171 a total amount of around **8.000 Euro** Is foreseen.

The costs include the applicable conference fee, travel and on site accommodation. The costs also include the pre-planned employee meetings and doctoral student meetings, which amount to **6.040 Euro** over the complete project duration**.**

4.1.2.3 Visiting Researchers (excluding Mercator Fellows)

As part of the application, we do not intend to provide funding for scientific guests. Where relevant, visits by researchers not directly involved in the project will be financed as part of the OTH Regensburg exchange program.

4.1.2.4 Expenses for Laboratory Animals

There is no experimental work on animals.

4.1.2.5 Other Costs

In addition to the above mentioned funds, no additional funds will be requested in the application.

4.1.2.6 Project-related publication expenses

The costs for publishing research results in scientific journals are set to an amount of **1400 Euro**.

4.1.3 Instrumentation

4.1.3.1 Equipment exceeding Euro 10.000

There are no plans to purchase equipment over 10.000 Euro.

4.1.3.2 Major Instrumentation exceeding Euro 50.000

There are no plans to purchase equipment over 50.000 Euro.

4.2 Module Temporary Position for Funding

The application does not request any funding to finance own posts.

4.3 Module Replacement Funding

The application does not request funds to finance any replacements.

4.4 Module Temporary Clinician Substitute

The application does not request funds to finance temporary clinician substitutes.

4.5 Module Mercator Fellows

The application does not request funds to finance a Mercator Fellow.

4.6 Module Workshop Funding

The application does not request funds to finance a project-specific workshop.

4.7 Module Public Relations Funding

The application does not request funding for public relations.

5 Project requirements

5.1 Employment status information

Monkman, Gareth, Professor (Beamter) at the OTH-Regensburg.

5.2 First-time proposal data

This application is not a first-time application.

5.3 Composition of the project group

Gareth Monkman, Professor at the OTH-Regensburg, Beamter Freistaat Bayern.

Valter Böhm, Professor at the OTH-Regensburg, Beamter Freistaat Bayner.

Florian Moosbauer, Laboratory Engineer at the OTH-Regensburg, permanent employee Freistaat Bayern.

Sindersberger, Dirk, Research Assistant at the OTH-Regensburg and doctoral student in collaboration with the AG Zimmermann, TU Ilmenau (SPP1681), expected fixed-term until 2020.

Schorr Philipp, Research Assistant at the OTH-Regensburg and doctoral student, expected fixed-term until 2020.

Prem, Nina, Master student with planned position as research assistant and collaborative doctoral student, expected fixed-term until 2021.

5.4 Cooperation with other researchers

5.4.1 Researchers with whom you have agreed to cooperate on this project

Prof. Dr. Klaus Zimmermann, TU Ilmenau
Prof. Dr. Valter Böhm, OTH Regensburg

5.4.2 Researchers with whom you have collaborated scientifically within the past three years

Prof. Dr. Klaus Zimmermann, TU Ilmenau
Prof. Dr. Stefan Odenbach, TU Dresden
Prof. Dr. Elena Kramarenko, Lomonosov, Moscow
Dr. Emilia Wisotzki, Universität Leipzig
Gennedy Stepanov, GNIIChTEOS Moscow
Prof. Dr. Sergey Ganichev, University of Regensburg
Prof. Dr. Christian Back, University of Regensburg
Prof. Dr. Peter Angele, University Klinikum Regensburg
Dr. Richard Kujat, University Klinikum Regensburg
Dr. Matthias Kronseder, University of Regensburg
Prof. Dr. Günter Auernhammer, TU Dresden
Prof. Dr. Markus Kästner, TU Dresden

5.5 Scientific equipment available

Device	Manufacturer	Type
Digestorium	Waldner	MC6
Rheometer	Anton Paar	MCR 301
Tempering Oven	MEMMERT	UF30plus
Micro Hardness Measuring System	Fischer	FischerScope HM2000
Magnetizer	M-Puls	3470
Gaussmeter	BROCKHAUS	450
Labormikroskop	HUND Wetzlar	H600/12
Impendanz Spektroskop	Zurich Instruments	HF2IS
Network Analyzer	Agilent	E5071B
Network Analyzer	Rhode & Schwarz	ZNB20 20GHz
Piezometer	Piezotest	PM300
Quartz Crystal Microbalance	Stanford Inst.	QCM200
Modal Exiter	Brüel & Kjaer	4826
Digital Lock-In Amplifier	Zurich Instruments	HF2LI
3D Magnetic field camera	Matesy	CMOS-magView XL
3D Drucker	Ultimaker	Ultimaker 3 Extended
Micro Welding Equipment	Campert	PUK U3
Gaussmeter	LakeShore	445 DSP
Kraft-Drehmoment-Sensor 6DOF	Schunck	ATI 300N
Kraft-Drehmoment-Sensor 6DOF	Schunck	ATI 15N
Roboterarm 6DOF	Stäubli	RX60
Roboterarm 6DOF	Stäubli	RX130
Roboterarm SCARA	Stäubli	RS40

5.6 Project-relevant cooperation with commercial enterprises

There is no cooperation with a commercial enterprise planned.

5.7 Project-relevant participation in commercial enterprises

There is no participation of a commercial enterprise planned.

6 Additional information

Our goal is to increase the effectiveness of the Priority Program through our research work. Cooperation with the various research groups is therefore very important to us. Strong scientific cooperation and scientific exchange are seen as a high priority.

Much of the evaluation of relevant smart materials has been conducted in DFG SPP1681. SPP2171 concentrates on a particular aspect of this research area not covered by SPP 1681.

The supervision of doctoral candidates is a central part of all DFG projects. In addition, Master and Bachelor students will be integrated into the research within SPP2171.