International Society of Bionic Engineering

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ISBE International Society of Bionic Engineering

2017 International Workshop on Bionic Engineering (IWBE2017)

“Energy and Bionics”

June 13-14, 2017, at DITF Denkendorf, Germany

Topics:

- **Energy harvesting and storage**
- **Surface phenomena for energy saving**

DAY 1 Energy harvesting and storage

Time	Title	Authors	Institute/Company	Country
13:00-13:20	Welcome words and presentation of DITF Denkendorf	Thomas Stegmaier	DITF Denkendorf	
13:20-13:30	Opening address	Julian Vincent	President of ISBE	UK
13:30-13:55	Smart Interfacial Materials from Super-Wettability to Binary Cooperative Complementary Systems	Lei Jiang	Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing; China School of Chemistry and Environment, Beihang University, Beijing	China
13:55-14:20	Bio-inspired wind turbine blade designs enable robust harvesting of wing energy	Hao Liu	Graduate School of Engineering, Chiba University	Japan
14:20-14:45	Electroactive polymer energy harvesting without hard electronics	Iain Anderson, Patrin Illenberger	Biomimetics Laboratory, University of Auckland; Department of Engineering Science, University of Auckland	New Zealand
14:45-15:10	Solar thermal energy harvesting	Stegmaier, Arnim, Sarsour, Scherrieble	DITF Denkendorf	Germany
15:10-15:30	**Coffee**			
15:30-15:55	Application of Bionics in the Design of Water Hydraulic Valve	He Xu, Haihang Wang, Chunwei Zhang, Baochao Zong, Chanil Pak, Mingyu Hu	College of Mechanical and Electrical Engineering, Harbin Engineering University	China
15:55-16:20	Investigation of leaf shape and edge design for faster evaporation in biomimetic heat dissipation systems	Petra Gruber, Ariana Rupp	University of Akron, Biomimicry Research and Innovation Center BRIC	USA
16:20-16:45	Barnacle cement proteins: Study of mechanism for biofouling and underwater adhesive	Zonghuang Ye, Xingping Liu,Jingyun Huang,Biru Hu	College of Science, National University of Defense Technology, Changsha	China
16:45-17:10	Exploiting frictional anisotropy from a passive scale-like material for energy-efficient locomotion of a bio-inspired walking robot	Poramate Manoonpong	The Maersk Mc-Kinney Moller Institute, University of Southern Denmark	Denmark
17:10-17:35	A Bio-Inspired Vibration Energy Harvester for Downhole Electrical Tools	Qinghai Yang	Research Institute of Petroleum Exploration and Development, PetroChina, Beijing	China
17:35-18:00	Nature inspired liquid migration for innovative heat pipe technology and applications to thermal management	Yuying Yan	Faculty of Engineering, University of Nottingham	Great Britain
18:00	End of lectures day 1; transportation to the hotels is arranged for you			
20:00	**Conference dinner in the Weinkeller Einhorn, Heugasse 17, 73728 Esslingen, Transportation from the hotels to the Weinkeller Einhorn and back is arranged for you (detailed plan is distributed on the conference)**			

DAY 2 Surface phenomena for energy saving

Time	Title	Authors	Institute/Company	Country
8:45-9:15	Biological surfaces and Biometic applications: from Lotus- to the Salvinia-Effect for drag reduction and other biomimetic innovations	M. Mail [1],[2], W. Barthlott [1]	Nees Institute for Biodiversity of Plants, University of Bonn; Institute of Crop Science and Resource Conservation (INRES), Bonn	Germany
9:15-9:40	Bio-inspired graphene-enhanced thermally conductive elastic silicone rubber as drag reduction material	Limei Tian [1], E Jin [1], Haoran Mei [1], Qingpeng Ke [1], Ziyuan Li [1], Guoru Zhao [2]	[1] Key Laboratory of Bionic Engineering, Jilin University, Ministry of Education, Changchun; [2] Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen	China
9:40-10:05	Stimuli-responsive secretion for controlling surface and optical properties	Huaixia Zhao [1],[2], Lizbeth Ofelia Prieto-Lýpez [2], Jiaxi Cui [1],[2]	[1] Institute of Fundamental and Frontier Sciences, University of Electronic Science and Technology of China, Chengdu; [2] INM-Leibniz Institute for New Materials, Saarbrücken	China, Germany
10:05-10:50	**Coffee in the polar bear pavilion**			
10:50-11:15	A smart switchable bioinspired material for oil-water separation	Yan Liu, Kaiteng Zhang, Bing Zhan, Yan Song, Wei Zhang	Key Laboratory of Bionic Engineering, Jilin University, Changchun	China
11:15-11:40	Deterministic Surfaces for Hostile Tribo-conditions: from Bio-Inspiration to Functional Design	Hisham A Abdel-Aal	Department of Mechanical Engineering and Mechanics, Drexel University, Philadelphia	USA
11:40-12:10	Bio-inspired surface for unidirectional liquid spreading	Huawei Chen [1], Pengfei Zhang [1], Liwen Zhang [1], Deyuan Zhang [1], Lei Jiang [2]	[1] School of Mechanical Engineering and Automation, Beihang University; [2] Technical Institute of Physics and Chemistry, Chinese Academy of Sciences	China
12:10-12:35	Study of a bionic lubrication design in reducing friction between rod and packing	Qinghai Yang	Research Institute of Petroleum Exploration and Development, PetroChina, Beijing	China
12:35-13:35	**Lunch**			
13:35-14:05	Water harvesting on surfaces with gradient micro- and nanostructures	Yongmei Zheng	Beihang University	China
14:05-14:30	Superhydrophobic Sand: A Hope for Desert Water Storage and Transportation Project	Zhiguang Guo	State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou	China
14:30-14:55	Spontaneous, directional liquid transport on natural and artificial surfaces	Zuankai Wang	Department of Mechanical and Biomedical Engineering, City University of Hong Kong	Hong Kong
14:55-15:20	Capillary rising and liquid transport properties within 3D porous structure	Hao Bai	State Key Laboratory of Chemical Engineering, College of Chemical and Biological Engineering, Zhejiang University, Hangzhou	China
15:20-15:35	Closing words	Thomas Stegmaier	DITF Denkendorf	
15:35	End of Conference			

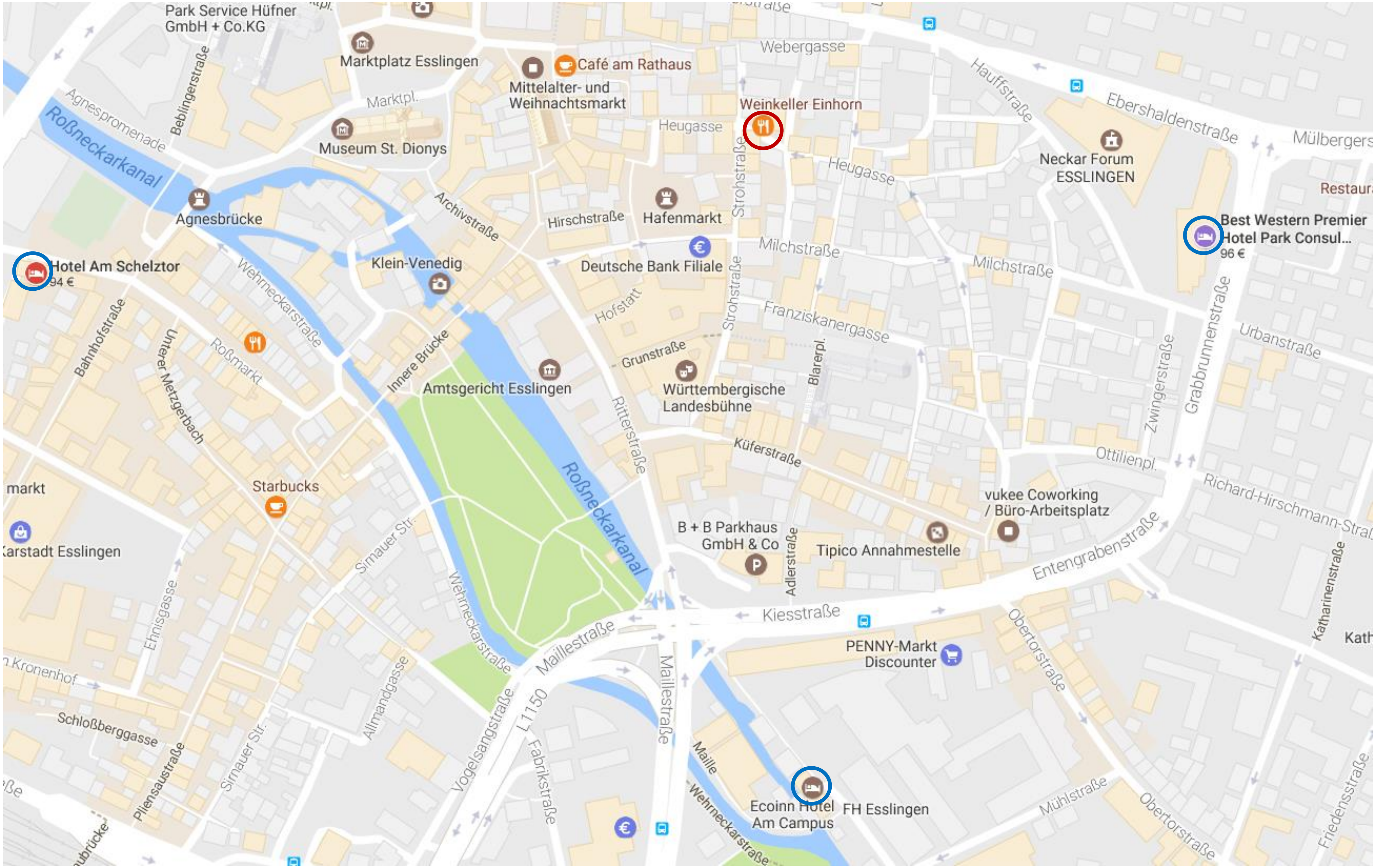
Locations and transportation:

1. **Conference site DITF Denkendorf (please organize your arrival to DITF on the first day of the Conference by yourself)**
   Address:
   Körschtalstr. 26
   73770 Denkendorf, Germany
   Transportation to DITF:
   - Arrival by plane: Airport Stuttgart, 12 km by Taxi to DITF
   - Arrival by train: from Stuttgart main station by metro ("S-Bahn" line S1) or by „Regionalbahn (RB)", line R1 or R8 to Plochingen; from Plochingen train station by Taxi to DITF 10 km

2. **Transportation from the DITF to the hotel that you booked and from there to the Conference Dinner and back to the hotel, as well as the transport from the hotel to the DITF on the second day is organized for you by the organizer of the Conference (detailed plan is distributed at the Conference)**
   Location of Conference Dinner "**Weinkeller Einhorn**":
   Address:
   Heugasse 17
   73728 Esslingen

3. **Departure after end of Conference: Taxis can be arranged for you on your own clearing**

Detailed map of hotels and location of conference dinner in Esslingen:



Bio-inspired wind turbine blade designs enable robust harvesting of wing energy

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Keywords: *energy harvesting, wing power, bioinspiredwind-turbine design, robustness*

Abstract

Wind power isa promising renewable energy source replacing conventional fossil fuel in terms of zero-emission of carbon dioxide, low-cost installation, and high efficiency of wind-turbine power generation. Wind energy production is now becoming a keypart in sustainable energy industrybutfacing new challenges to reducethe turbines cost and increase the farms size, andtobreak technological limitations of the turbine designs.Classical turbines are designed to operate within a narrow zone centered around their optimal working points, whichvarywith tip-speed ratios. Thisaerodynamic limitation leads to the uncertainty inachieving desirable energy harvesting performance under natural turbulent wind environment, normally involving significant energetic and economic losses. Here we propose a new concept of wind-turbine rotor designs inspired by bird and insect wings, whichhave been proven capable for achieving robust aerodynamic performance to passively adapt to various unsteady air conditions.Shaped with a swept-forward basal part and a swept-backward distal part, the bird-inspired wind-turbine rotor design remarkably enlarges the power coefficient vs tip-speed ratio zone while achieving the same optimal peak, largely improved the wind energy harvesting adaptabilityto a wide range of tip-speed ratio.A series of systematic studies combining computational fluid dynamic (CFD) simulations and wing tunnel experimentsas well as field tests have demonstrated that the versatility of the newtype ofwind-turbine rotors is promising capable for leading to an important increase of the converted energy ratein an integral manner over a broad tip-speed ratio zone. Thispoints to the importance ofanew wing-turbine design concept –achieving robustnesswhile high efficiency in harvesting wing energy, which can be realized through bio-inspired designs in a passive way.

References

1) H. Liu, R. Yoshimura, T. Fujii. Rotor. 2015. (Patent pending)
2) H. Tanaka, R. Yoshimura, T. Ikeda, R. Noda, T. Fujii, H. Liu. Bio-inspired wind turbine blade designs enable robust harvesting of wing energy, 2017. (in preparation)

Electroactive polymer energy harvesting without hard electronics

Iain A. Anderson[1,2] and Patrin Illenberger[1]

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KEYWORDS: Dielectric elastomers, Artificial muscles, Energy harvesting

Dielectric elastomer (electroactive polymer) generators (DEG) are ideal for harvesting energy from natural sources, including human motion, waves on the sea and wind. Such sources are stochastic and low frequency (< 10 Hz). DEG are essentially stretchable capacitors fabricated from very low modulus materials (e.g. silicone dielectric layers flanked by electrodes composed of silicone with a conductive filler). Electric charge is placed on the electrode surfaces while the DEG is being stretched or compressed. When the DEG is allowed to relax work is done on the electric charge thus converting stored elastic strain energy into electrical energy that can be harvested. DEG can be directly coupled to natural sources. For instance: walking energy can be harvested through DEG compression in a shoe heel or stretching within a garment; wind energy through direct attachment between the swaying branches of a tree and the ground; wave energy through up and down mechanical vibrations on a float or expansion of a rubbery membrane under water pressure. Electronics manage the movement of electrical charge onto and off of the DEG as it is deformed and also condition and store the harvested electric energy for later use.

For wearable and small and remote applications it is ideal for the charge management electronics to be lightweight, and operate passively, in response to the DEG alone and without external power. A portable, passive circuit for DEG charge management that does not require external power for its operation is the self-priming circuit (SPC) that consists of diodes and capacitors. Through partitioning of the DEG and the printing of soft piezoresistive switches on the DEG membrane it is possible to produce a SPC that is fully integrated with the DEG. We are investigating the flow of charge for the integrated SPC/DEG and developing prototype devices. This will lead to the elimination of hard electronics associated with the SPC/DEG, advancing the development of soft energy harvesters that are unobtrusive and wearable.

Application of Bionics in the Design of Water Hydraulic Valve

Authors: He Xu, Haihang Wang, Chunwei Zhang, Baochao Zong, Chanil Pak, Mingyu Hu

Organization: College of Mechanical and Electrical Engineering, Harbin Engineering University

Lecture Summary:

With the acceleration of green energy and the objective requirement of sustainable development, it has become a significant topic of water hydraulic technology to replace the fossil oil medium with aqueous medium. Meanwhile, it means a higher requirement for water hydraulic valve to reduce abrasion generated by cavitation damage which shortens the service life of pipeline. The application of bionics in water hydraulics is rarely researched. And there are rarely related studies applying bionic theory in the design of hydraulic valve.

Using the principle of bionics, we analyze the similarity between the jet principle of shark gills and the hydraulic flow state, and apply it into the structure design of hydraulic valve. Furthermore, the designed valve with bionic characteristic will be validated on water hydraulic tested-bed with visual analysis of flow state inside of the water hydraulic valve via high-speed camera. .

Investigation of leaf shape and edge design for faster evaporation in biomimetic heat dissipation systems

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In previous projects theromodynamics of plants was identified as an interesting field delivering concept generators for technical, especially architectural application. So leaf morphology is determined by a variety of factors, and also significant for plant water and energy balance. However, how leaf design affects evapotranspiration and, consequently, leaf thermal performance and energy budget, has not been investigated in detail. Many leaf-inspired models in the literature overlook leaf hydraulics, capillarity, wetting phenomena in porous materials and the thermal properties of cellulose. To further the knowledge in this field, we have started to research on the relation between wetting, thermal dynamics and shape. We recorded with a thermal camera free convection of wetted models made of laser-cut paper towel, soaked in water and drying naturally. Families of shapes were abstracted from leaves of deciduous trees: white oak, for their crenations and lobes; maple, for their relatively large teeth; elm, for their smaller hierarchically-ordered serrations. In this abstracted experimental setup we observed distinct evaporation rates for models with normalized surface area but different boundary perimeters. Outward teeth prompt dewetting nucleation in shapes only differing geometrically, shedding some light on surface designs for heat dissipation versus designs for moist microclimate retention. The biomimetic approach taken will deliver a better understanding of the biological role of leaf structure and support the enhancement of fluid-assisted heat transfer systems, for which further threedimensional exploration and scale studies are conceptualized.

Barnacle cement proteins: Study of mechanism for biofouling and underwater adhesive

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Abstract: Barnacles isa dominant marine fouling oaganisms which secrets insoluble proteinaceous cement for tenacious and permanent attachment to various underwater substrates. Themechanism of underwater adhesionprovides a platform for both antifouling and bioinspired research. We have cloned *Ba*cp-19k gene from*Balanus albicostatus*, which plays a key role for surface coupling during underwater attachment. Then, recombinant *Ba*cp-19k protein is highly expressed in host strain *Escherichia coli* BL21 (DE3) and purified by affinity chromatography. Furthermore, we discovered a gel-like super adhesive aggregation produced by Trx-Balcp19k, a recombinant Balcp19k fusion protein which contains a thioredoxin (Trx) tagat the N-terminus. The sticky aggregation was designated as "Trx-Balcp19k gel", and the bulk adhesion strength, biochemical composition, as well as formation conditions were all carefully investigated. The Trx-Balcp19k gel exhibited strong adhesion strength of 2.10 ± 0.67 MPa, which was approximately fifty folds higher than that of the disaggregated Trx-Balcp19k (40 ± 8 kPa) and rivaled those of commercial polyvinyl acetate (PVA) craft glue (Mont Marte, Australia) and UHU glue (UHU GmbH & Co. KG, Germany). Lipids were absent from the Trx-Balcp19k gel and only a trace amount of carbohydrates was detected. We postulate that the electrostatic interactions play a key role in the formation of Trx-Balcp19k gel, by mediating self-aggregation of Trx-Balcp19k based on its asymmetric distribution pattern of charged amino acids. Taken together, we believe that our discovery not only presents a promising biological adhesive with potential applications in both biomedical and technical fields, but also provides valuable paradigms for molecular design of bio-inspired peptide- or protein-based materials.

Keywords: barnaclescement proteins; biofouling; underwater adhesive

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An Anisotropic Scale-like Material for Energy-Efficient Locomotionof a Bio-inspired Walking Robot

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Abstract:

Locomotion efficiency on rough surfaces is nontrivial; it can, however, be achieved or improved by employing the concepts of frictional anisotropy and mechanical interlocking between surfaces at the microscale. In principle, strong mechanical interlocking in one direction will allow a robot to grip the surface, thereby preventing it from slipping or sliding backward, while almost no mechanical interlocking in another direction will allow it to easily release itself from the surface while moving forward. In this talk, I will present howan anisotropic scale-like material (shark skin) can be employed to achieve energy-efficient locomotion of a bio-inspired walking robot.The robot experimental results show that the material can allow the robot to efficiently walk up different slope angles with different surfaces without the need for any sensory feedback, modifying our existing locomotion control, or even redesigning our robot structures.This makes the approach simple and cheap. Taken together, this study not only opens up a new way of achieving energy-efficient walking robot locomotion but also provides a better understanding of the functionalities and mechanical properties of anisotropic surfaces. That understanding will assist developing new types of material for other real-world applications.

Reference:

Manoonpong, P.; Petersen, D.; Kovalev, A.; Woergoetter, F.; Gorb, S.; Spinner, M.; Heepe, L. (2016) Enhanced Locomotion Efficiency of a Bio-inspired Walking Robot using Contact Surfaces with Frictional Anisotropy, Scientific Reports 6(39455) doi:10.1038/srep39455, Nature Publishing

A Bio-Inspired Vibration Energy Harvester for Downhole Electrical Tools

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Abstract: At present, downhole tools in petroleum industry are developing from mechanization towards automation and intelligence. More and more electrical devices are applied in wellbore control. Most of these devices adopt disposable batteries or rechargeable batteries as power supplies. When the batteries run out, it is necessary to fish up the devices using disposable batteries or to put the charger into the accurate downhole position to charge the rechargeable batteries. The operating processes are very tedious and the normal production is interrupted. Inspired by discharging characteristic of swimming electrophorus electricus, this paper proposes a bionics vibration energy harvester. The harvester mainly consists of bluff body, piezoelectric energy transducer, and the rectifying circuit. Flow field analysis shows that thecontinuous steady liquid flow in wellbore is destroyed and regular flow field is generated due to the existence of round bluff body. The piezoelectric energy transducer is made of supporting plate, bimorph, silver plate and insulating layer, and the size is 52mm*7mm*0.82mm (Length*Width*Thickness). PZT and PVDF were both regarded the potential bimorph. PZT is the solid solution of PbTiO3 and PbZrO3 with excellent temperature and time stability. PVDF is polyvinylidene difluoride, which is flexible material with high piezoelectric susceptibility. PZT was finally selectedconsidering the working condition, service life and awful operating process. With the driving of regular flow field, the transducer vibrates in micro amplitude just like an electrophorus electricus and then regular electric energy is generated through piezoelectric effect. The electric energy is used to charge the downhole battery after rectifying and filtering. Laboratory environment, similar with downhole wellbore, is constructed. The pipeline diameter and flow velocity are 25mm and 0.8m/s respectively. Testing results showed that the peak-to-peak output voltage of the harvester was 4.88V. In order to lower the resonant frequency and to increase the vibrating amplitude of the bimorph, a mass block was attached to the end of the bimorph. Then the output was improved to 44.9V, which could power the low power circuit directly or charge rechargeable batteries. The bionic vibration energy harvester offers an intriguing alternative to collect ambient energy for long-term power, especially in the deep harsh wells.

***Keywords**:* downhole electrical tools, bio-inspired, energy harvester, piezoelectric effect

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Nature inspired liquid migration for innovative heat pipe technology and applications to thermal management

Yuying Yan

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Abstract: Plant can migrate water from soil up to several metres high. Learning from the water migration process in plants has been attracting interests from scientist for over a hundred years. The water migration in plant stem, especially xylem, involves various driving forces including capillary effect, osmosis effect, marangoni effect and transpiration effect, etc. However, the mechanism by which water rises against gravity occurs are still controversially discussed despite many water migration mechanisms that have been proposed by different researchers. And also, there still lacks of a critical transportation model because of the diversity and complex xylem structure of plants.

The lecturer focuses on the water transport process within xylem and our innvative design of heat pipes for engineering thermal management.

Biological surfaces and Biomimetic applications: from Lotus- to the Salvinia-Effect for drag reduction and other biomimetic innovations

M. Mail[1,2] and W. Barthlott[1]

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www.lotus-salvinia.de

Abstract

Surfaces play a crucial role in the interaction of plants with their environment. Over the last 3.5 billion years an almost endless number of surface structures, chemistry and functionalities evolved – each of them perfectly adapted to its environment. Today we know of some 1.8 million different species (plants and animals) – but all assessments indicate the existence of more than 10 million species on earth. This means approximately 10 million living prototypes – an abundance of solutions for engeneers.

Inspiration by living nature is as old as mankind, but the first milestone of what today we call bionics or biomimetics was the construction of an electric battery based on observations of the Torpedo fish by Allessandro Volta in 1800.

Biological surfaces came surprisingly late into the focus of interest - starting with the simple biomimetic hook and loop fastener Velcro® in 1958 and the drag reducing shark riblets. After we described the self-cleaning *Lotus Effect* and its possible biomimetic applications in 1997, such extreme water repellency (superhydrophobicity), which is not known in abiotic nature (excluding technical products) became a focus of interest, as such surfaces bear great potential for different applications. Here we present a short survey of biological surfaces and their technical biomimetic applications. We concentrate on superhydrophobic surfaces - especially on the so called Salvinia Effect. This effect allows surfaces to keep an air layer when submerged in water – a promising feature for technical application. Such persistent air layers could be used e.g. for the construction of drag reducing and therefore energy saving coatings – here we present first prototypes showing a drag reduction of up to 30% - as well as for other applications (e.g. sensory functions).

Literature and the state of the art in: *Barthlott, Mail & Neinhuis (2016): Superhydrophobic hierarchically structured surfaces in biology: evolution, structural principles and biomimetic applications. Phil. Trans., Roy. Soc. A, http://dx.doi.org/10.1098/rsta.2016.0191* and *Barthlott, Rafiqpoor & Erdelen (2016) in Knippers, Nickel & Speck (eds.) http://www.springer.com/us/book/9783319463728*

Bio-inspired graphene-enhanced thermally conductive elastic silicone rubber as drag reduction material

Limei Tian*[a], E Jin[a], Haoran Mei[a], Qingpeng Ke[a], Ziyuan Li[a], Guoru Zhao[b]

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[b]*Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China*

Abstract: This study presented a graphene platelet/silicone rubber (GPL/SR) composite as a drag reduction material, inspired by the boundary heating drag reduction mechanisms of dolphin skin. Graphene was added as a thermally conductive filler at weight fractions of 0.17, 0.33 and 0.67 w% to pristine silicone rubber (PSR). Tests of the thermal conductivity and tensile properties showed that the thermal conductivity of all three GPL/SR materials of 0.17, 0.33 and 0.67 w% graphene were 20%, 40% and 50% higher than that of the PSR, respectively, and the elastic modulus of the 0.17 w% GPL/SR materials was preferred. Droplet velocity testing, which can reflect the drag reduction mechanism of the heating boundary controlled by the GPL/SR composite, was performed between 0.33 w% GPL/SR, which typically exhibits good mechanical properties and thermal conductivity performance, and the PSR. The results showed that on the 0.33 w% GPL/SR, the droplet velocity was higher and the rolling angle lower, implying that the GPL/SR composite had a drag-reducing function. In terms of the drag reduction mechanism, the heat conductivity performance of the GPL/SR accelerated the heat transfer between the GPL/SR composite surface and the droplet. The forces between the molecules decreased and the droplet dynamic viscosity was reduced. The drag of a sliding water droplet was proportional to the dynamic viscosity, which resulted in drag reduction. The application of GPL/SR material to the control fluid medium should have important value for fluid machinery.

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Stimuli-responsive secretion for controlling surface and optical properties

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Secretion-inspired biomimetic strategies are leading to a lot of functional materials, such as self-healing materials, slippery systems, anti-fouling coatings etc. However, the example of (multi)responsive secretion behaviors in synthetic materials without compromising structure integrity has not been reported yet. Herein, I would like to present our attempt on the development of the responsive liquid-secretion behaviors of a class of droplet-embedded gel films and demonstrate its control on the surface and optical properties of the materials. Breath figure method is used to create a rough surface on the gel films. This rough surface makes the films water-sticky and opaque. Upon external stimuli, such as mechanical stretching/pressing, solvent casting, or heating, the oil stored in the embedded droplets is triggered to secrete quickly to form a thin liquid overlayer on the top of the films, which makes the films become slippery and transparent. This stimuli-responsiveness is not only repeatable but also spatially controllable. We believe that the way of stimuli-responsive liquid secretion will give the new prospect of the design and synthesis of optical materials, switchable interface, patterning structure etc.

A smart switchable bioinspired materials for oil-water separation

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Key Laboratory of Bionic Engineering (Ministry of Education), Jilin University, Changchun 130022, P.R. China

Abstract

Oily wastewater have caused serious water pollution. The development of effective and cheap oil/water separation materials is urgent for treating this problem. We mainly focus on prepared superhydrophobic superoleophilicity materials for oil-water separation where they can be classified into three kinds as follows: (i) preparation of superhydrophobic copper mesh by electrochemical deposition, (ii) immersion and then modification process to prapared superhydrophobic stainless steel meshes, (iii) copper foam with smart surfaces are obtained by electroless silver deposition followed by surface modification with a mixed solution of thiol containing carboxylic groups and methyl groups ($HS(CH_2)_{11}CH_3$ and $HS(CH_2)_{10}COOH$). The as-prepared mesh surface is both superhydrophobic and superoleophilic. In addition, the wettability of as-prepared copper foams can switch reversibly between superhydrophobicty and hydrophilicity according to pH response. As-prepared copper foam can easily remove the organic solvents either on water or underwater. Furthermore, as-prepared samples can be applied to separate an oil-and-water mixture bidirectionally and exhibited excellent oil-water separation efficiency including petroleum, toluene, hexane, gasoline and diesel, even after being recycled ten times. This study provides a simple and environmentally friendly route to fabricate oil-water separation materials which has prospective application in industrial fields such as water treatment and petroleum refining. Especially, this smart surface can be switchable under various pH conditions.

Deterministic Surfaces for Hostile Tribo-conditions: from Bio-Inspiration to Functional Design

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Abstract

Surface texturing has been recognized as a method for enhancing the tribological properties of surfaces for many years. Adding a controlled texture to one of two faces in relative motion can have many positive effects, such as reduction of friction and wear and increase in load capacity. To date, the true potential of texturing haven't been realized not because of the lack of enabling texturing technologies but because of the severe lack of detailed information about the mechanistic functional details of texturing in a tribological situation. Experimental as well as theoretical analysis of textured surfaces define important metrics for performance evaluation. These metrics represent the interaction between geometry of the texturing element and surface topology. To date, there is no agreement on the optimal values that should be implemented given a particular surface. More importantly, a well-defined methodology for the generation of deterministic textures of optimized designs virtually does not exist.

Nature, on the other hand, offers many examples of efficient texturing strategies (geometries and topologies) specifically applied to mitigate frictional effects in a variety of situations. Studying these examples may advance the technology of surface engineering.

This presentation provides a comparative review of surface texturing that manifest viable synergy between tribology and biology. We attempt to provide successful emerging examples where borrowing from nature has inspired viable surface solutions that address difficult tribological problems both in dry and lubricated contact situations. In addition, we introduce latest efforts by the presenter and collaborators to define and implement a viable ontology for bio-inspired engineering of deterministic surfaces inspired by snakes.

Bio-inspired surface for unidirectional liquid spreading

Huawei Chen[1*], Pengfei Zhang[1], Liwen Zhang[1], Deyuan Zhang[1], Lei Jiang[2]

1 School of Mechanical Engineering and Automation, Beihang University, China

2 Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, China

ABSTRACT

Unidirectional liquid spreading is of significant interest for a wide range of applications, such as microfluidic devices, self-lubrication, controllable chemical reaction, and biomedical. Although the surfaces with wettable gradient or asymmetric nanowires could harness the liquid to spread unidirectionally, the spreading is remarkable slow over a short distance and just occurs with specific surface chemistry property. Nature inspired one-dimensional fibers from spider silks and cactus spines give a way of combining surface energy gradient and curvature gradient to drive the droplet directionally, while they are difficult to be applied as two-dimensional surfaces anticipated in microfluidics devices, biomedical devices and so on. Recently, we discovered the fast continuous unidirectional water transport mechanism on the peristome surface of *Nepenthes alata*. Inspired by this novel mechanism, we fabricated biomimetic surface to achieve fast unidirectional liquid spreading on two-dimensional surfaces. By grafting thermoresponsive poly(N-isopropylacrylamide) on the artificial peristome, fabricated by replica moulding method, we successfully fabricated a smart artificial peristome with dynamically temperature-controlled unidirectional water spreading. We also have successfully fabricated surfaces with peristome-mimetic structure using two steps UV exposure photolithography, and made the liquid exhibit a unidirectional spreading on this surface. We believe our finding offers new opportunities to control liquid flow especially in the design of controllable microfluidics and medical devices.

Short BIOGRAPHY

Chen Huawei, Professor/Chair of Department of Mechanical Manufacturing and Automation. Dr. Chen's research interests include bio-inspired functional surface, micro/nano fabrication and micro/nano fluid. He is a JSPS fellow, High-level Oversea Talents of Beijing, Guest Professor of Tokyo Institute of Technology and Wollongong University. Dr. Chen has published more than 80 papers in *Nature, Small, Angew. Chemie, ACS Applied Materials & Interface* etc.

Study of a bionic lubrication design in reducing friction between rod and packing

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Abstract: Pumping units are widely used in oil fields around the world, and much electric energy is wasted in overcoming the friction resistance between rod and packing on the wellhead. Base on the joint lubrication principle, a bionic lubrication design of rod has been invited and applied in oil production. The bionic lubrication device could fabricate a layer of lubricating oil film on the rod surface, which evidently reduces the friction between rod and packing. More than 10 kWh per day was saved for a pump unit, and the service life of rod and packing was increased for a few times. The bionic lubrication devices of rod have broad application prospect in the aspect of saving energy.

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Water harvesting on surfaces with gradient micro- and nanostructures

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Biological surfaces provide endless inspiration for design and fabrication of smart materials. It has recently been revealed to have become a hot research area in materials and science world[1-4]. In nature, the capture silk of the cribellate spider Uloborus walckenaerius collects water through a combination of multiple gradients in a periodic spindle-knot structure after rebuilding. Inspired by the roles of micro- and nanostructures in the water collecting ability of spider silk[2], a series of bioinspired gradient fibers has been designed by integrating fabrication methods and technologies such as dip-coating, Rayleigh instability break-up droplets, phase separation, strategies of combining electrospinning and electrospraying, and web-assembly. Through such fabrications, “spindle-knot/joint” structures can be tailored to demonstrate the mechanism of multiple gradients (e.g., roughness, smooth, temperature-respond, photo-triggering, etc.,) in driving tiny water drops. A water capturing ability can be developed by the combination of “slope” and “curvature” effects on spindle-knots on bioinspired fiber. The heterostructured fibers have been fabricated by electrohydrodynamic strategies, are intelligently responding to environmental humidity. A temperature-responsive fiber can realize the directional transport of droplet effectively. The multi-geometric gradient fiber achieves the droplet target transport in a long range along as-designed bioinspired gradient fiber[1-2]. In contrast, biological surfaces such as plant leaves and butterfly wings with gradient structure features display the effect of water repellency. Smart bioinspired surfaces can be fabricated by combining machining, electrospinning, soft lithography, and nanotechnology. The gradient surfaces exhibit robust transport and controlling of microdroplets[3-5]. These bioinspired gradient surfaces would be promising applications into anti-icing, liquid transport, anti-fogging/self-cleaning, water harvesting, etc.

References

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For liquid transport mechanisms in analogy to the capillary effect and cohesion theory of trees and leaves

Superhydrophobic Sand：A Hope for Desert Water Storage and Transportation Project

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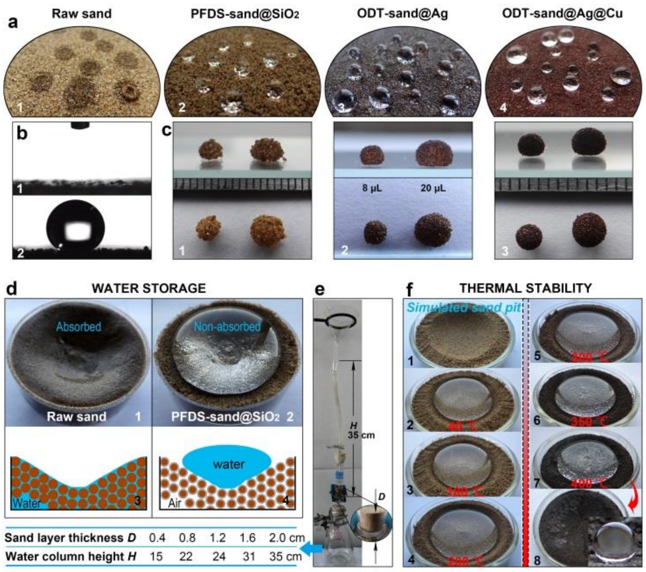
Abstract: Sand as an abundant natural resourcecauses severe ecological environment in desert, such as water shortage and sand storm. Because of the strong hydrophilicity, the water can be quickly absorbed by sand, which greatly impedesdesert water storage and transportation project. In contrast to this conventional understanding of sand (*i.e.*, superhydrophilicity), we conceive to design the superhydrophobic sand. In experimental, three hydrophobic sandswith different wettabilityare successfully prepared by cladding inorganic nonmetal (SiO_2) and metal(Ag and Cu) materials on sand surfaces and then modifyingthem with low-surface-energy chemicals. Combined with the environment and resources issues, such superhydrophobic sand (PFDS-sand@SiO_2) is shown to have extremely highthermal stability up to 400 ℃ when used for water storage, which is unprecedented and enough to face the high-temperature condition of desert. As a result, the water can stably stay and flow on such sand surface without permeation, showing great water-holding capacity. Furthermore, the simulated superhydrophobic sand channel exhibits great anti-flow-dragging effect during water transportation. All of these manifestations imply significant potentials of such"superhydrophobic sand" in the applications of desert water storage and transportation.

Keywords: sand; desert;superhydrophobic; water storage; water transportation



Spontaneous, directional liquid transport on natural and artificial surfaces

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Developing various surfaces or systems that break wetting symmetry has attracted plenty interests due to its ability for efficient mass, energy and momentum exchange, but has proven to be challenging. Propelled by the advances and surge in the micro- and nanotechnologies over the past few decades, it has been possible to rationally design materials and systems to achieve directional droplet motion for various applications. This lecture will discuss diverse surfaces, systems and mechanisms that propel droplet directionally under various conditions, ranging from benign environment such as room temperature to extreme environments involving low temperature and high temperature. In particular, through the experimental and analytical analysis, we will summarize how the triple-phase interactions are tailored by the interplay between various factors including structural topography, chemical properties, and temperature and so on. The insights getting from the characteristics of previous studies can provide important inspirations for the rational design of new materials that allow efficient and robust liquid transport under different conditions.

Capillary rising and liquid transport properties within 3D porous structure

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ABSTRACT

The long-distance and spontaneous liquid transport is not only an important scientific question but also critical for many real applications. The capillary rising and liquid transport properties within 3D porous materials is significantly related to their applications in many fields such as tissue engineering, supported catalysis, electrode, and separation. Therefore, it has been arousing more and more people’s attention. Many natural materials, such as desert beetle’ s back, spider silk, and cactus’ s spine, have shown excellent liquid transport ability. However, the up-to-date research is limited in gradient fiber and flat surface system and the long-distance, spontaneous liquid transport still remains a great challenge. In my talk, I will focus on our recent work on the controlled fabrication of 3D porous materials, and how liquid spontaneously transport within such materials with capillary effect.