Prof. Dr. Ulrich Schwaneberg

(*17.06.1969, married, four children: 2001, 2004, 2007, 2009)

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Working group vision and contribution to catalaix

Based on owned developed methods for protein engineering, that allow us to generate, screen and analyse millions of protein variants per days, we elucidate fundamental structure-function relationships of proteins and provide tailor-made proteins to match industrial demands for a biological transformation of industries within a circular bioeconomy. Within catalaix we will focus on understanding material-specific binding to polymers and enhance the performance of depolymerizing enzymes from 'pure polymers) to mixed-plastic waste. The latter will be achieved in iterative cycles of combined computational & experimental work. Long-term vision is to achieve an *in silico* design of material-specific binding peptides. Molecular understanding will be obtained by two complementing protein engineering approaches: screening of material-peptide binding peptide libraries with all the natural diversity and directed evolution of material-binding peptides, which provide the datasets for machine learning and AI studies. Material-specific binding peptides will be fused to enzymes and chemical catalysts to enable material-specific/directed depolymerizing, which will ensure efficient and scalable depolymerisation processes for a circular or open loop use of plastic waste in a sustainable bioeconomy.

Current & Previous Positions

Since 2014	Member of the Scientific Board of Directors* DWI – Leibniz Institute for Interactive Materials
Since 2009	Professorship (W3),* / Chair of Biotechnology, RWTH Aachen *50 % appointment each
2002-2008	Professor of Biotechnology at Jacobs University Bremen (renamed in 2006 from International University Bremen), Faculty of Science, Bremen
1999-2001	Postdoc at the California Institute of Technology (CalTech fellowship), Division of Chemistry & Chemical Engineering, Pasadena, USA (group of Prof. F. Arnold; Noble laureate)

Education

1996-1999	Dr. rer. nat. (PhD) Institute of Technical Biochemistry, University Stuttgart (group of Prof. R. D. Schmid)
1990-1996	Study of chemistry at University Stuttgart and research of P450 catalysis at the Institute of Technical Biochemistry, University Stuttgart (group of Prof. R. D. Schmid)

Fellowships and Awards

2016-2020	BMBF-Awardee “Forschungspreis” for the next generation of bioprocesses (1.75 Mio€)
2018	Innovation award of the BioRegions’ Germany for the greenRelease technology
2015	Specially appointed professor at Osaka University
2010-2024	Representative of RWTH Aachen in the board of directors of the Bioeconomy Science Center (58.5 Mio€; see www.biosc.de)
2015-2019	Speaker of Henkel Innovation Campus for Advanced and Sustainable Technologies HICAST (5 Mio€ direct company funding)

Contributions to the science system

2022-2026	Speaker/Coordinator of the Bio4MatPro - Competence Centre for the Biological Transformation of Materials Science & Production Engineering (>50 partners; 26,3 Mio€)
2022-2026	Coordinator of the BioökonomieRevier – Innovation Labs ProtLab^{SF} and PlastiQuant 2.0 (10 PIs; 5.4 Mio€; BMBF)
Since 2021	Speaker of the RWTH profile area Molecular Science and Engineering
Since 2020	Vice president (CoChair) of the Division Biocatalysis of European Federation of Biotechnology
Since 2020	Board Member of CLIB (Cluster Industrial Biotechnology)
Since 2019	Member of the Expert Council for Bioeconomy at MWIDE Ministry in the state of NRW
2012 – 2014	Speaker of the ‘Department’ of Biology (Aachener Biologie und Biotechnologie ABBt; 18 professors Fachgruppe Biologie), RWTH Aachen University, Germany
Since 2002	21 former coworkers became professors in Chile, China, Egypt, Germany, Serbia, Pakistan, Turkey, UK, and Spain (7 thereof females (33%)); 8 visiting professors were hosted in the last 10 years, and >120 PhD trained.

Selected Projects

2022-2026	Speaker/Coordinator of the Bio4MatPro - Competence Centre for the Biological Transformation of Materials Science & Production Engineering (>50 partners; 26,3 Mio€)
2022-2026	Coordinator of the BioökonomieRevier – Innovation Labs ProtLabSF and PlastiQuant 2.0 (10 PIs; 5.4 Mio€; BMBF)

Most important scientific contributions

>360 Publications (Scopus), Citations: >9700 (Scopus)/ >14000 (Google Scholar), H-Index: 53 (Scopus) / 63 (Google Scholar).

Examples divided in three sections to illustrate competence of the Schwaneberg Group in protein engineering. Section 1 describes developed methodologies for protein engineering (Ref. 1, 4, 5) success stories to elucidate enzyme design principles (Ref. 3, 4) and competence in conjugating chemical catalysts to proteins (Ref. 2). Section 2 describes recent work on plastic/polymer depolymerisation in respect to screening systems for improved depolymerizing enzymes (Ref. 7), enhanced depolymerisation (Ref. 6), computational understanding/methodologies (Ref. 8) and detection (Ref. 9). Section 3 references the first direction evolution campaign towards a material-specific binding peptide for PLA and is a proof of principle for the proposed work to understand material specific binding (Ref. 10).

Section 1: Protein engineering methodologies, success stories and conjugation expertise

1. Feng, L., Gao, L., Besirlioglu, V., Essani, K., Malte, W., Kurkina, T., Ji, Y., Schwaneberg, U. (2023). *A Flow cytometry-based ultrahigh-throughput screening method for directed evolution of oxidases*. Angewandte Chemie, 62, e202214999.

2. Wittwer, M., Markel, U., Schiffels, J., Okuda, J., Sauer, D. F., Schwaneberg, U. (2021). *Engineering and emerging applications of artificial metalloenzymes with whole cells*. Nature Catalysis, 4, 814-827

3. Cui, H., Eltoukhy, L., Zhang, L., Markel, U., Jaeger, K. E., Davari, M. D., Schwaneberg, U. (2021). *Less*

unfavorable salt bridges on the enzyme surface result in more organic cosolvent resistance. Angewandte Chemie, 60, 20, 11448-11456
4. Cui H., Jaeger K. E., Davari, M. D., Schwaneberg U. (2020). *CompassR yields highly organic solvent-tolerant enzymes through recombination of compatible substitutions*. Chemistry - A European Journal, 27, 8, 2789-2797
5. Markel, U., Essani, D. K., Besirlioglu, V., Schiffels, J., Streit, W. R., Schwaneberg, U. (2019) A*dvances in ultrahigh-throughput screening for directed enzyme evolution*. Chemical Society Reviews, 49, 233-262.

Section 2: Protein engineering success stories in plastic management (degradation, detection, computational understanding):
6. Lu, Y., Hintzen, K. W., Kurkina, T., Ji, Y., Schwaneberg, U. (2023). *Directed evolution of material binding peptide for polylactic acid-specific degradation in mixed plastic wastes*. ACS Catalysis, 13, 12746-12754.
7. Puetz, H., Janknecht, C., Contreras, F., Vorobii, M., Kurkina, T., Schwaneberg, U. (2023). V*alidated high-throughput screening system for directed evolution of nylon-depolymerizing enzymes*. ACS Sustainable Chemistry & Engineering; https://doi.org/10.1021/acssuschemeng.3c01575.
8. Meng, S., Li, Z., Zhang, P., Contreras, F., Ji, Y., Schwaneberg, U. (2023). *Deep learning guided enzyme engineering of Thermobifida fusca cutinase for increased PET depolymerization*. Chinese Journal of Catalysis, 50, 229-238 (IF 12.9).
9. Bauten, W., Nöth, M., Kurkina, T., Contreras, F., Ji, Y., Desmet, C., Serra, M. Á., Gilliland, D., Schwaneberg, U. (2022). *Plastibodies for multiplexed detection and sorting of microplastic particles in high-throughput*. Science of The Total Environment, 860, https://doi.org/10.1016/j.scitotenv.2022.160450.

Section 3: First manuscript on design of material-specific binding peptide (proof of concept)
10. Lu, Y., Hintzen, K. W., Kurkina, T., Ji, Y., Schwaneberg, U. (2023). *A competitive high-throughput screening platform for designing polylactic acid-specific binding peptides*. Advanced Science, DOI: 10.1002/advs.202303195.

Patents

• Patents: in total 24 patents in the last 14 years; many with companies that approach to tailor their enzymes for improved performance based on the protein engineering methodologies that we developed, e.g. Henkel (WO2012119955, EP3067411, WO2015044206, WO2017097590, WO2017162440, WO2020002308, WO2020002308), Roche (WO2019122520, WO2014114810), Evonik (WO2014114810), AB Enzymes (WO2019122520, WO2020099719) and seven RWTH/DWI patents (WO2017157662; EP3854221, EP3269812, EP3348326, WO2019011922, see 2 highlights below).
• Highlights: greenRelease patent (EP3261435B1; RWTH-patent; granted in EU with top claims; see below) and microplastic detection patent (EP20180178726; WO2019EP66535; DWI-patent). The greenRelease patent is a material-science innovations to reduce pesticide use in agriculture with plant leave binding peptides; these “Peptide glues” immobilize pesticide loaded microgel containers or fused anti-microbial peptides to wax layers of plant leaves (see Science news article E. Stokstad (2019) Science, 364, doi: 10.1126/science.aax8199), business competition awards of bioregions in Germany (2018) and 1st place in “Bio-Gründer” competition (2019)). Successful field trials in 2021 for the greenRelease technologies. The microplastic detection and quantification using material-binding peptides enables for the first a high-throughput detection and quantification of submicrometer particles.