The 2022 MWP Award – Full motivation

Citation

The 2022 Marcus Wallenberg Prize is awarded to Professor Ilkka Kilpeläinen and Professor Herbert Sixta for the development and use of novel ionic liquids to process wood biomass into high-performance textile fibres.
The collaboration of the research teams led by Professor Kilpeläinen and Professor Sixta has resulted in the development of high-performance textile fibres based on different qualities of wood pulp. The innovation builds on the design and synthesis of novel superbase ionic liquids that enable efficient dissolution of wood pulp in high concentrations and at a viscosity suitable as spinning solution (dope). This spinning dope can then be spun into high quality regenerated cellulose fibres for the textile industry.

Background

The future demand for textile fibres is growing due to global population growth. Fabrics made from natural cellulose fibres possess excellent properties such as hydrophilicity and breathability, hand feel, biodegradability, and biocompatibility. Production of cotton, the predominantly used cellulose fibre for textiles, is not expected to keep up with the demand (Shepherd 2019). Therefore, man-made cellulose fibres would be an excellent complement for cotton as these fibres have similar properties.

The main processes to produce man-made cellulose textile fibres are the viscose process, where cellulose is solubilized using alkali and carbon disulphide and the Lyocell process, where N-methylmorpholine-N-oxide (NMMO) is used to dissolve cellulose. The viscose process is the oldest and the most used process. The viscose process has, however, become environmentally controversial due to the use of toxic carbon disulphide as the main reagent. The Lyocell process on the other hand is hampered by the instability of the NMMO. Thus, stabilizers are needed in the spinning dope, but the basic problem with instability of the NMMO still remains (Jedvert and Heinze 2017).

These problems have led to extensive research on different solvent systems for cellulose to produce regenerated cellulose fibres. Ionic liquids have gained interest as green alternatives for organic solvents in different processes. Ionic liquids (ILs) are salts that can be melted below 100^{o}C and have unique properties including low vapour pressure, high thermal stability, and high dissolving capability of different organic and inorganic substances (Laus et al 2005). The first scientific publication on the use of ionic liquids to solubilise cellulosic substances was published by Rogers and co-workers in 2002 (Swatloski et al 2002). This pioneering work led to new efforts in the area of cellulose solubilization.

Prize Motivation: Man-made cellulose fibres from wood with properties that compare or exceed those for textile applications have been developed by two research teams in Finland, at the University of Helsinki and at the Aalto University. In this novel concept, the design and use of novel superbase ionic liquids to process wood pulp into high-

performance textile fibres was developed and currently tested for scaling-up. The team led by Professor Kilpeläinen at the University of Helsinki developed superbase ionic liquid solvents for dissolution of wood biomass e.g. bleached or unbleached pulp or recycled cellulose pulp. Professor Sixta and his team, at the Aalto University, developed the ionic liquid-based fibre shaping process based on dry-jet wet spinning. This unique collaboration has resulted in novel concept of textile fibres from wood.

Professor Kilpeläinen together with his team used physicochemical modelling of solution/molecular parameters to design and synthetize most suitable IL molecules for cellulose solubilization (Parviainen et al 2013). This modelling relied on Professor. Sixta and his team's understanding of requirements set by cellulose dissolution, spinning rheology and solvent recycling (Hauru et al 2012). As a result, a novel superbase ionic liquid 1,5-diazabicyclo[4.3.0]non-5-enium acetate ([DBNH]OAc) was designed for efficient dissolution of wood pulp in appropriate yields (Hauru et al 2014). The dissolved pulp was efficiently converted into textile filaments through a dry-jet wet spinning process by the Sixta team (Hauru et al 2014). Compared with the commercial NMMO-based Lyocell fibre process, the spinning could be conducted at higher cellulose concentration in the dope, while temperature during dissolution and spinning was maintained at a lower level. (Sixta et al 2015, Michud et al 2014). The combination of the two developments led to regenerated cellulose fibres of high technical quality, even exceeding the mechanical performance of Lyocell fibres (Sixta et al 2015, Bulota et al 2016). The developed process is also versatile with respect to the raw material used, as the designed IL also dissolves cellulose containing lignin, virgin and recycled paper grade pulp and recycled textile (Ma et al 2015).

This innovation by Professors Kilpeläinen and Sixta has stimulated world-wide research and industrial activity in the forest sector. The cellulose fibres obtained using the developed IL-based dissolution and regeneration process are characterized by excellent mechanical properties, which make them suitable for both textile and technical applications. The level of recycling of the IL and the impact of recycling on the process efficiency is currently further developed. The innovation is expected to result in a large range of new product and business opportunities for the forest industry.

Figure 1. IONCELL scale-up at the Aalto University (From ioncell.fi).

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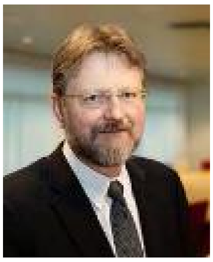
Ilkka Kilpeläinen

Professor Ilkka Kilpeläinen, was born in 1963 in Finland. He received his PhD in Organic Chemistry in 1993 at the University of Helsinki. In 1995 he was appointed docent degree in organic chemistry at the University of Helsinki and in 2003 in structural chemistry at the University of Oulu in Finland. Kilpeläinen was professor in chemistry at the University of Oulu, Finland, during the period between 2001 and 2003. Since 2003 he has been professor and of Organic Chemistry at the University of Helsinki. He has a strong background in biopolymers (protein structure and dynamics, lignin chemistry, wood chemistry) and nuclear magnetic resonance (NMR) spectroscopy. Before joining the University of Helsinki, he was the head of the National NMR lab and was based at the University of Oulu.

His current interests are in the design of ionic liquids for biomass processing, the chemistry and structure of lignin and cellulose chemistry. He is also Chairman of the board for Liuotin Group Oy, a development spin-off dedicated to scale-up ionic liquid production.

Professor Kilpeläinen has published 225 scientific articles and he is cited 7039 times. He is working with new types of solvents that are highly interesting in the area of organic chemistry and has designed novel types of ionic liquids that are effective to dissolve cellulose.

Herbert Sixta



Professor Herbert Sixta, was born in 1954 in Austria. He has a PhD in Physical Chemistry from the University of Innsbruck in 1982 and Habilitation at Graz University of Technology in 1995 in Wood, Pulp and Fiber technology. He has been professor at the Aalto University since 2007 and was the head of the Department of Bioproducts and Biosystems. Sixta has had a long industrial career at Lenzing AG Austria, focused on the development of industrial regenerated cellulose fibres and their processing.

His core interest is in the use of tailored ionic liquids for the selective dissolution of different biopolymers and biomass fractionation. In material science, his focus is on the development of high added-value cellulose material regenerated from ionic liquid solution as well as the synthesis of building block chemicals by conversion routes of polysaccharides using heterogeneous catalysis.

Professor Sixta has currently 292 scientific articles and he is cited 7002 times.