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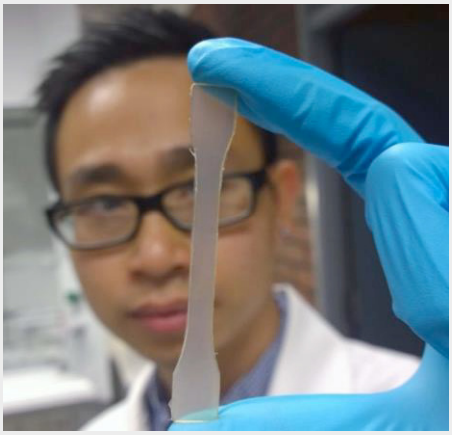

Bio-based polyamides for future

Impact case study
Department of Chemical and Metallurgical Engineering 2018

Aalto RAI 2018 Case Study

Field 3a: Chemical engineering and physics

Unit of Assessment (UoA): Department of Chemical and Metallurgical Engineering

Bio-based polyamides for future

1. Summary of the societal impact

The demand for plastics is expected to grow four fold by 2050 as they offer a multitude of solutions to improve the quality of living for the fast increasing global population. According to World Economic Forum report "The New Plastics Economy: Rethinking the future of plastics", plastics are also becoming a major player in circular economy. Hence, there is a great need to invent and develop novel, sustainable bio-based technical materials, as well as refine renewable bio-diesel into high-value and -margin technical materials*. Together with Neste, which is world's largest producer of renewable diesel from waste and residues, are developing unique bio-based polyamides to match the future needs of the society. This research and innovation of long-chain polyamides herein described is a continuation of the microbial fatty acid and lipids research conducted in collaboration within Aalto (Prof. Laakso). The synthesised polyamides present a clear advance in the state-of-the-art regarding their property profile (amongst the **highest impact resistance** and **lowest water absorption for polyamides**) and processability. This provides them with a distinct competitive edge over existing polyamides, as well as other polymer classes. Furthermore, the polyamides present an incentive for the bioeconomy, while also expanding on the existing knowledge regarding the preparation, processing and properties of these bio-sourced polymers.

2. Underpinning research/artistic activity related to Aalto activities

In February-March 2015, a literature review was conducted by Aalto University Polymer Technology research group with the aim of identifying bio-based polymers with potential for industrial-scale synthesis and commercialization. Polyamides were highlighted as a promising candidate polymer to investigate and develop regarding synthesis, material properties and commercial exploitation. From December 2015 to August 2016, novel polyamides derived from vegetable oil feedstocks, as well as novel sulphur-containing polymers, were successfully synthesised via polycondensation polymerisation in the group. Synthesised polyamides displayed high molecular weights and superior water resistance and adsorption properties than conventional, commercially-available polyamides. Furthermore, the novel polymers displayed lower melting temperatures than their commercial counterparts, showing great promise for further processing. In addition, the novel polyamides showed good tensile properties, and maintained their mechanical properties and structural integrity at temperatures above glass transition. The work was conducted in collaboration with Neste Corporation, yielding a Master's thesis and two patent applications.

These successful and promising results prompted the continuation of Neste Corporation's collaboration and research into polyamide synthesis and utilisation, with the first phase August 2016-November 2017. The work built on previous results and experience, with a focus toward upscaling and optimisation of synthesis techniques, determining structure-property relationships, and identifying potential markets and applications for these novel polyamides. Following the successful completion of this first phase, an additional year-long project phase was commenced in November 2017, which is ongoing. This current phase of the research focuses on producing larger volumes of polyamide and the development of demonstration products highlighting the exceptional properties of these materials.

The research utilised the expertise and understanding of polymer synthesis, structure-property relationship correlations and processing in the Aalto University Polymer Technology group; all synthesis, processing and characterisation was conducted at Aalto University, by Aalto researchers. As mentioned previously, the work builds on the microbial fatty acid and lipids expertise and research previously

* https://www.neste.com/en/companies/products/renewable-chemicals/neste-my-renewablepolymer

conducted within Aalto (Prof. Simo Laakso), while also falling under the *Materials and sustainable use of natural resources* key research area of Aalto University. The research made use of the facilities of the Aalto-VTT Bioeconomy Infrastructure across a broad spectrum of material development—from polymerisation to processing and characterisation/analysis.

The research was funded and conducted in collaboration with Neste Corporation for an initial one-year period. The successful results and great potential in this **high value-added, renewable polymer** have encouraged Neste to continue its collaboration with Aalto University Polymer Technology for a second year-long phase.

3. References to research

1. Seppälä J, Spoljaric S, Nguyen PH, Nyman T, Koskinen P. 'Polyamides and methods for producing the same', 2016, Finland Patent Application No. 20165672, filled September 2016. Patent Pending.
2. Seppälä J, Spoljaric S, Nguyen PH, Nyman T, Koskinen P. 'Sulphur-containing polyamides and methods for producing the same', 2016, Finland Patent Application No. 20165671, filled September 2016. Patent Pending.
3. Seppälä J, Spoljaric S, Phan NH. '"Nylon-salt"-free, large scale polycondensation of long-chain aliphatic polyamides', November 2017, Aalto University Invention Disclosure, IPID 2089.
4. Seppälä J, Spoljaric S, Phan NH, Nyman T, Koskinen P. 'Novel sulphur-containing polyamides monomers and methods for production of these', April 2016, Neste Corporation/Aalto University Invention Disclosure, IPID 1857.
5. Seppälä J, Spoljaric S, Phan NH, Nyman T, Koskinen P. 'Novel polyamides with long chain monomers and methods for production of these', April 2016, Neste Corporation/Aalto University Invention Disclosure, IPID 1856.

4. Societal Impact, activities and roadmap for the case

The results of this project represent a clear advantage in state-of-the-art properties and processing of polyamides, while also confirming the potential to produce such polymers from bio-derived sources utilising conventional polymerisation techniques. This highlights the expertise and ability within the Polymer Technology group, while also exemplifying the Bioeconomy Infrastructure facilities in achieving such results. The primary beneficiaries of this technology are anticipated to be polymer manufacturers, processors and companies/industries that utilise polymer/polyamide components. This includes but is not limited to the automotive, consumer goods, construction, sporting, packaging and additive manufacturing industries, which have global markets. This societal impact is expected to achieve full effect in the medium- to long-term.

The route to impact began with identifying key technologies and processes to pursue; after careful consideration, polyamides were selected and the development of these polymers undertaken. This involved understanding the synthesis, structure-property relationship and processing profiles of these polyamides, while also identifying key competitive edges and potential application areas. The upcoming approaches to interact with non-academic users involve approaching perspective clients/users directly with ready-made demo products, engaging in feasibility trials with them, while also showcasing the polymers and materials through various outlets (e.g., media, conferences, etc.).

The progress of this societal impact is confirmed by the two patent applications filed in conjunction with Neste Corporation (see Section 3). This demonstrates the support an industrial partner has in the technology, while also providing a solid base for developing impact towards future's environmental and sustainable goals. Our collaborator, Neste, is ranked the 2nd most sustainable company on the Global 100 list of the world's most sustainable companies.

5. Sources to support the impact case

- Seppälä J, Spoljaric S, Nguyen PH, Nyman T, Koskinen P. 'Polyamides and methods for producing the same', 2016, Finland Patent Application No. 20165672, filled September 2016. Patent Pending.
- Seppälä J, Spoljaric S, Nguyen PH, Nyman T, Koskinen P. 'Sulphur-containing polyamides and methods for producing the same', 2016, Finland Patent Application No. 20165671, filled September 2016. Patent Pending.
- https://www.neste.com/en/neste-ranked-2nd-most-sustainable-company-world

6. Future goals

The project has identified key structure-property relationships, an understanding of synthesis and processing requirements, and potential application areas/competitive advantages for these bio-derived polyamides. Utilising this knowledge, the goals for the future include preparing specified polyamide grades with a clearly-defined property profile in sufficiently-large scales to allow for demonstration/ concept model production. These products are intended to highlight to potential industrial partners, clients and consumers the exceptional property/ performance advantages of these polymers, while also demonstrating applicability and versatility. Furthermore, future plans also involve continuously developing and optimising the synthesis, processing and properties of these and other bio-polymeric materials, while also constantly adding to existing knowledge and practices.