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Chemistry

Crafting catalysts for a greener future

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Biologically degradable plastics: LMU chemist Sonja Herres-Pawlis is developing novel environmentally friendly catalysts designed to make the production of synthetic polymers more efficient and more economical.

Plastic bags, CDs, adhesives and many other everyday items contain organic polymers – long molecules made up of thousands of smaller subunits. Linkage of the petroleum-derived subunits is made possible by agents called catalysts, which accelerate chemical reactions without themselves being consumed. Once made, conventional plastics are difficult to degrade, persisting in landfills for decades and polluting the atmosphere when incinerated. Biodegradable plastics based on renewable feedstocks avoid many of these problems and offer a possible route to the sustainable production of synthetic materials. By developing innovative catalysts for the large-scale synthesis of plastics, LMU Munich chemist Sonja Herres-Pawlis is working to make this a reality.

Herres-Pawlis became Professor of Coordination Chemistry at LMU in November 2011, and is particularly interested in designing catalysts based on so-called transition-metal complexes for the activation of small molecules like oxygen, lactides and styrenes. And this focus led her into the field of biodegradable plastics. Polymerization of ring-shaped lactide monomers (which are related to the lactic acid found in sour milk) with the aid of a catalyst gives rise to the bioplastic polylactide (PLA). PLA can be converted into compost and, in the long-term, it could serve as an environmentally friendly substitute for much of the plastic packaging we use today.

But the current process for the manufacture of PLA suffers from several drawbacks. The catalysts used in its synthesis contain tin, and some of these compounds are toxic and environmentally harmful. Commercial production of PLA is also very costly, which explains why PLA has so far found only specialized applications – in surgical sutures, for instance.

Feedstocks for biodegradable plastics

However, the high price of oil makes the use of renewable raw materials increasingly attractive. “That’s why I hit on the idea that catalysts containing non-toxic guanidine-zinc complexes, which I had developed, might be useful for the production of PLA,” says Herres-Pawlis. The general consensus was that this approach was doomed to failure, because guanidine is electrically neutral, “but that just spurred me on,” she says.

And her persistence was rewarded. The guanidines turned out to be sufficiently reactive to catalyze the opening of the ring-like lactide molecules, which could then be linked together to form long polymers. Herres-Pawlis is confident that “If one looks in the right places, one will find other neutral systems that can perform the same task.”

For her work on the development of novel catalysts, she won the Innovation Prize awarded to young researchers by the State of North-Rhine-Westphalia in 2011. Her discoveries bring us a little closer to a world that is no longer cluttered with plastic waste – and will help to reduce resource consumption long after the present International Year of Sustainable Energy for All has come to an end.

The use of guanidine catalysts for the production of PLA has several other advantages. The agents are innocuous and insensitive to moisture and other contaminants in the starting material, and do not have to be removed from the final product, which avoids the need for expensive purification steps. These features promise to make the synthesis of biodegradable polylactides from sustainable feedstocks more economical in the future. As a consequence, these polymers could eventually replace conventional plastics in many applications.

But we are not quite there yet. Herres-Pawlis emphasizes that “It will take time to transform our laboratory findings into an industrial process.” Collaborations with the *Fraunhofer Gesellschaft* and chemical firms will facilitate the necessary transfer of know-how.

Herres-Pawlis will continue to devote herself to basic research and intends to

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focus on identifying the major factors that limit the efficiency of subunit polymerization. Her interest in biodegradable plastics represents only one aspect of this overall strategy. For instance, she is also searching for improved catalysts for use in a strategy called Atom Transfer Radical Polymerization (ATRP), which enables the synthetic chemist to control the length of the polymer chains. Materials based on chains of uniform length are of interest for a wide range of applications. For example, they have potential uses as valves in "lab-on-a-chip" architectures, in highly efficient absorbents or in heavy-duty adhesives such as those used in the aeronautics industry.

Other projects are concerned with metal complexes that catalyze oxidation reactions. Here, Herres-Pawlis is especially interested in bioinorganic chemistry, as such complexes play central roles in the metabolism of living organisms. She is closely involved in an interdisciplinary research group, which is supported by the German Research Foundation and, among other topics, is studying the enzyme tyrosinase. Tyrosinase contains two bound copper ions that are essential for oxidation of the amino acid tyrosine, the first step in the formation of the brown melanin pigment in the skin.

The goal is to design and synthesize copper complexes that mimic the action of the enzyme. In cooperation with researchers in Hamburg, Herres-Pawlis is investigating the detailed structure of biomimetic complexes and their mode of action, with a view to understanding how they manage to catalyze the selective transfer of a single oxygen atom from dioxygen gas. In the longer term, Herres-Pawlis hopes to incorporate this reaction mechanism into light-activated catalysts. She predicts that "Such compounds would be the molecular equivalent of the Swiss Army knife, and could be used in applications such as the synthesis of vitamins or for a whole spectrum of polymerizations."

Prof. Dr. Sonja Herres-Pawlis became Professor of Coordination Chemistry at LMU Munich in 2011. Born in 1979, Herres-Pawlis studied Chemistry at the University of Paderborn, obtaining her doctoral degree in 2005. After doing a postdoc at Stanford University (USA), she returned to Paderborn to lead a Junior Research Group. In 2009 she moved to the Technical University in Dortmund, as a Liebig Fellow sponsored by the *Fonds der Chemischen Industrie*. In 2011 she won the Prize for Innovation awarded annually to junior researchers by the State of North Rhine-Westphalia.

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