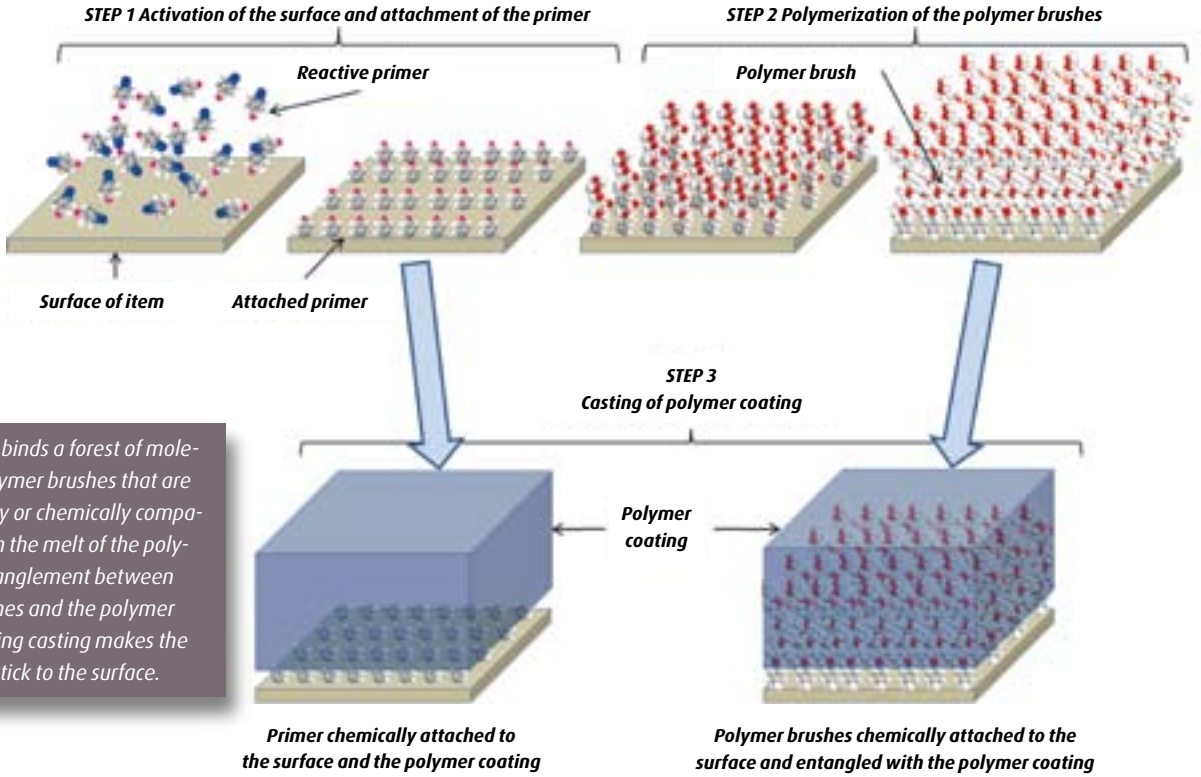
Towards durable surface coatings



A primer binds a forest of molecular polymer brushes that are physically or chemically compatible with the melt of the polymer. Entanglement between the brushes and the polymer melt during casting makes the coating stick to the surface.

Through carefully designed organic surface chemistry and advanced grafting techniques, it will be possible to modify the surface of a given item to obtain a protective polymer coating that attaches so strongly to the surface that it can withstand extreme physical and chemical environments.

By Mogens Hinge, Steen Uttrup Pedersen, Peter Kingshott and Kim Daasbjerg

We are surrounded by polymer-coated surfaces; the paint on the walls, the non-stick coating on our frying pans, and the easy-to-clean surface of a wooden kitchen table. Such coatings are applied in order to protect the underlying material, to cast the final shape, or to provide a surface with specific properties. New methods based on surface chemistry may lead to superior polymer coatings of consumer goods and industrial tools.

When coating an item the method of choice depends heavily on the physical and chemical properties of the surface, in particular the required attachment strength of the polymer coating. Today attachment is mostly achieved through mechanical interlocking or physical adhesion, but unfortunately, such forces can be too weak leading to poor attachment of the coating. Thus the coating cannot withstand the environment for which the product is intended. Therefore, the manufacturing industry seeks new and versatile solutions.

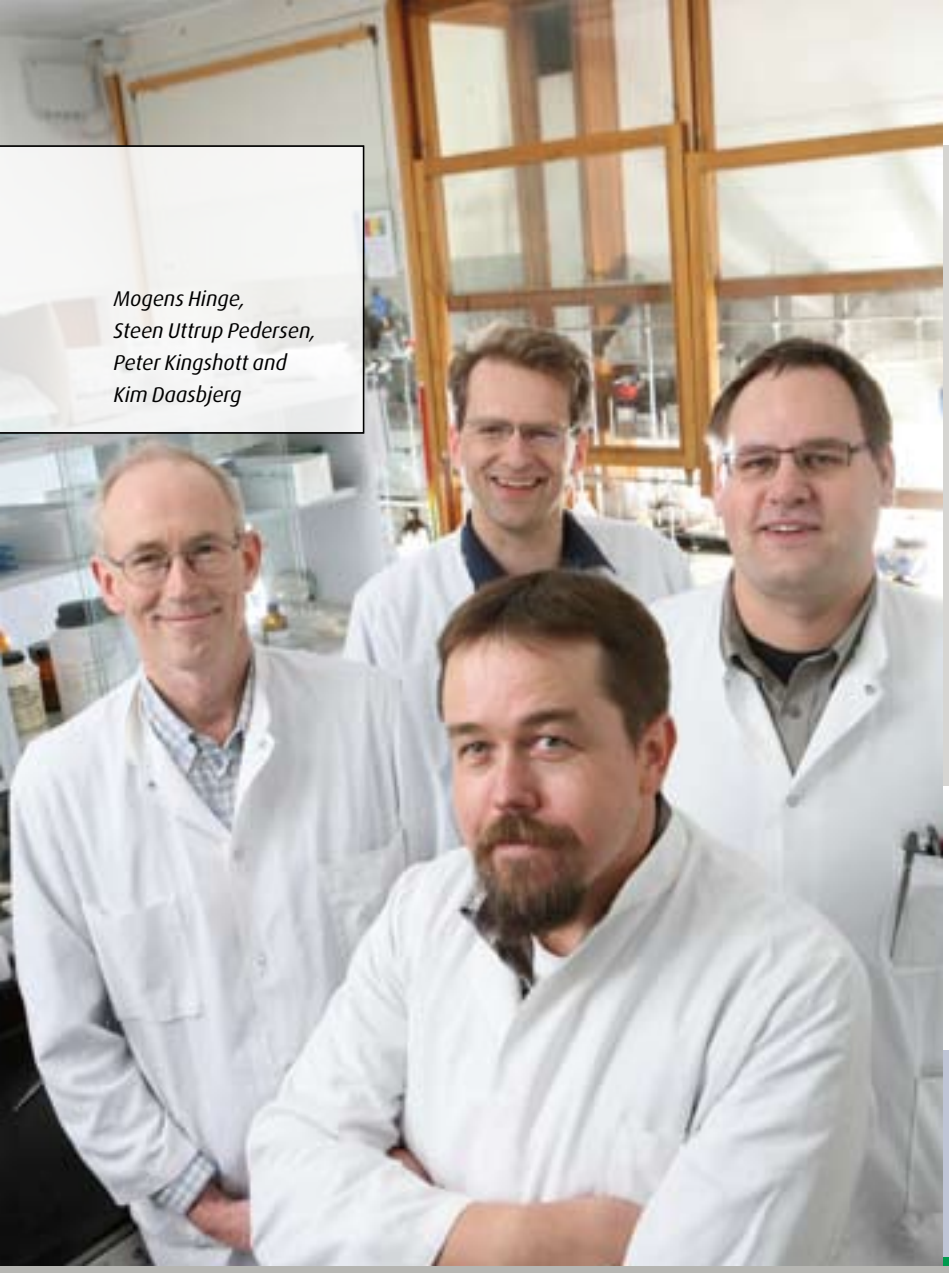
A keyword in this respect is chemisorption – that is the creation of strong chemical bonds between two otherwise incompatible materials. This is by no means a trivial task and requires fundamental knowledge about surface chemistry- and approaches for modifying and directing the chemical reactivity of surfaces.

The RadiSurf Project

The goal of the RadiSurf project at iNANO is to develop methods to generate strong chemical bonds between polymer coatings and various surfaces. This is particularly important for items made of industrial metals such as iron and stainless steel as well as for commodity and engineering plastics.

The basic idea is to modify the surface chemically with a primer that is either reactive towards or compatible with the polymeric matrix of the coating. After laboratory testing the primers are optimized and eventually implemented into industrial processes.

The RadiSurf project will contribute significantly to the development of future coating solutions for corrosion protection, reduction of wear, and cheaper maintenance. The research is carried out in close collaboration with two industrial partners: Grundfos, one of the world's leading pump manufacturers, and SP-Group that produces moulded plastic components and polymer coatings in Denmark, Poland, and China.



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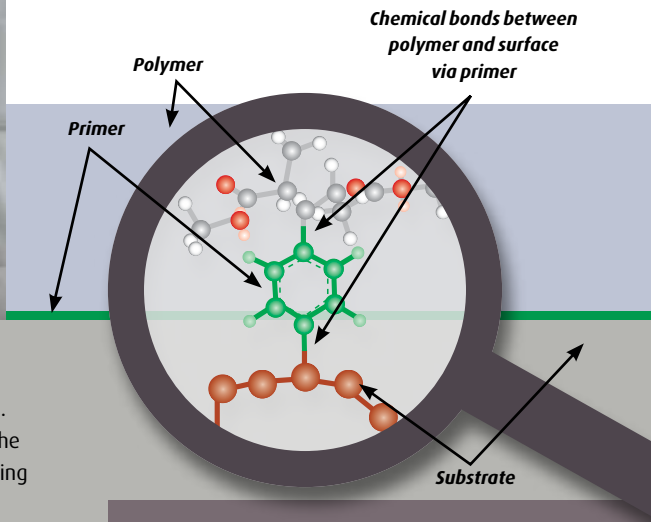
Surface coatings can change the properties of a surface; e.g. make it less water repelling. This can be desirable for coatings of industrial tools with water contact.

An uncoated surface repels a water drop

The same surface coated with a primer becomes less water repelling



A primer enables the formation of covalent bonds between a surface and a coating leading to a very strong attachment.

Attachment of primers to surfaces

In the case of conducting materials such as metals, the initial activation of the surface can be accomplished electrochemically by applying an electric potential to the surface. In this manner, an inert surface can become strongly oxidizing or reducing, depending on the potential applied. This facilitates the creation of covalent bonds to a primer. The primer should contain not only a group that is electrochemically reactive towards the surface, but also a functional group, which is compatible with the coating to be applied. For non-conducting materials such as plastics, the initial activation of the surface is accomplished by plasma activation methods followed by a chemical reaction with an appropriately designed primer. Both processes are easy to scale-up for our industrial partners.

The strength of the chemical bond between the surface and the primer is of crucial importance, because this bond has to withstand large thermal variations during the manufacturing process. Our results based on infrared measurements show that bond stability up to at least 250°C on metal surfaces can be achieved. Future research will focus on improving the thermal properties by chemically modifying the primer.

Attachment of polymers to primers

The next step is to produce a durable bond between the primer and the polymer coating. The most promising pathway is to use chemically reactive primers that form covalent bonds to the polymer directly during casting.

Alternatively, the necessary reactivity of the primer can be accomplished by synthesizing a forest of polymer brushes that are chemically and physically compatible with a melt of the polymer. The resulting entanglement between the brushes and the polymer melt casted onto the surface during industrial moulding is sufficiently large to ensure an overall strong bonding. The design of suitable brush candidates is challenging, because it depends strongly on the exact chemical properties of the final polymer coating.

Based on experiments, theory and simulations we aim to develop models to predict the best candidate primers for the most commonly used polymer systems. Before implementation, the industrial partners will put the modified surfaces through thorough long-term as well as accelerated mechanical and chemical tests. Passing these tests will ensure that the new generation of coatings maintains the required adhesion and protective properties even when they are exposed to extreme thermal fluctuations and aggressive chemical environments.