Modern Additive Technology - a view into the future

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Introduction

Reviewing the current literature of colloids and interfacial materials, there are numerous ideas and concepts especially in academic sciences which might have an impact on coatings as well. Many of these ideas are far beyond current technology and have not been realized yet. Amongst these topics are new approaches for selfhealing materials, adaptive surfaces and switchable properties.

One example is outlined in fig. 1 where a principle of switchable surface is schematically demonstrated. The generic structure shows a comb copolymer with two different types of branches, attached to a surface. The blue and green side chains covalently fixed at the backbone are different in terms of chemistry and physical properties. Depending on the chemical nature of the side chains a certain behaviour with impact on surface orientation can be activated. The activation is generated through external stimuli like moisture, temperature, light or combinations thereof. If the stimulus can be controlled in a reversible way like a trigger a switchable surface can be realized.

![Switchable Surface](image)

**Switchable Surface**

Responsive to the environment:
- Light
- Temperature
- Moisture

Fig. 1: Basic Scheme for a Switchable Surface

This approach can be applied in a straightforward way to a coating where it can generate a selfhealing surface using selfstratifying additives at the interface between air and coating.
Additionally today's scientific papers exhibit the trend that macroscopic properties at interfaces are determined more by supermolecular aggregates than by single molecules. Fig. 2 exhibits several examples for this type of structures covering the area from inorganic nanoparticles via biochemical assemblies to organic supermolecular structures.

![Figure 2: Examples of Supermolecular Nanostructures](image)

When these supermolecular structures are applied onto surfaces and coatings with the help of specific technologies and chemistries, specific surface patterns and structure-related properties are achievable. Some examples like the well-known Lotus® effect, artificial shark skin and the super adhesion used by various reptiles are given in fig. 3.

![Figure 3: Functional Surfaces via Hierarchical Structures](image)
Surface active Additives based on Structured Polymers

The transfer of modern scientific principles and research into the world of applied science resembled by paints and coatings is not an easy task. Bridging the gap for highly complex colloidal formulations consisting of solvents, binders, organic and inorganic pigments and fillers as well as other ingredients could be realized using specific additive technology based on sophisticated structured copolymers. Some general structural features for linear polymeric and oligomeric structures are shown in fig.4. Regardless of chemical composition this overview concentrates on block or comb structures using different chemical building blocks which are well defined. Additionally tapered and hyper branched structures will be shown in various examples.

A well-known application of special AB block copolymers are wetting and dispersing additives for organic pigments where pigments of all color shades have to be dispersed in a coating matrix. In order to control particle size and distribution of pigments, specifically designed polymers are used as additives. A sophisticated application for coatings with high resolution, low scattering, and high transparency are color filters for LC flat panel displays. Besides pigment dispersion, other parameters like solubility and processing have to be taken into account as well.

![Fig. 4: Overview for Additives based on highly structured Macromolecules](image)

Manufacturing and application of a coating is also related to viscosity. Depending on the coating system and market segment film thicknesses from microns to millimeters need to be realized by various techniques. On industrial scale this could be for example spraying, brushing, rolling, flushing, dipping, or spin coating. Depending on the application specific viscosity temperature profiles are needed during initial exposure and final drying of the wet film. Of course certain optical properties like flop or sparkling for effects pigments need to be fixed and controlled as well. If the profile needs a specific thixotropy with good recovery, ABA like rheology additives as described in fig. 5 are
highly suitable. They are able to form spontaneously a reversible network depending on the chemical environment of the coating matrix. Depending on the chemical composition these additive structures work for highly polar systems like water based formulations as well as low polar alkyd paints.

Fig. 5: Oligomeric blocklike thixotropic rheology additives

Beyond the above mentioned platform technologies surface control additives (SCA) play an important role for the optical appearance, mechanical resistance, ageing and haptic feeling and many other properties. Obviously, the surface properties of a coating are not only affected by the bulk chemistry and coating formulation: Microscopic and macroscopic surface structures in combination with surface-active components are often desirable for special properties.

Selfcleaning and selfreplenishing are just two effects which are definitively in the focus of the coating industry. Possible pathways using specifically designed SCAs will be described schematically below. The chemical toolbox for an additive approach is quite broad as illustrated in fig. 6, but needs sophisticated techniques in order to find an efficient solution.

Fig. 6: Suitable Chemistries for SCA (Surface Control Additives)
One common approach towards selfcleaning and selfreplenishing materials can be seen in the initial development and exploitation of macromonomer technology. BYK has made major efforts and progress to establish this scientifically well described technology on an industrial scale.

The difference of polymer structures derived from macromonomers in comparison to conventional siloxane-based polymers as well as the corresponding surface orientation is shown schematically in fig. 7. It is quite obvious that surface orientation and self-assembling tendency is remarkably different for the sketched structures. The macroscopic properties for self-cleaning will be explained during the lecture.

![Fig. 7: Conventional SCA technology versus BYK’s Macromonomer approach](image)

Additionally, similar building blocks can be used by itself or as part of a crosslinked coating matrix as displayed in Fig. 8. Theoretically hydrophobic free dangling chains should show enough mobility for surface enrichment and self-organization. These free changing units could be either fluorine-containing chain ends or well-defined siloxane-macromonomers as described in Fig. 8.

Currently these topics are part of a research program sponsored by the Dutch Polymer Institute (DPI) and run in the labs of Eindhoven University.
Of course there are always pros and cons in the performance of synthetic materials that mimic mother nature. The major drawback of synthetic material is the limited capability to establish renewable surface structures.

Therefore, the next challenges are hybrid materials like self-organizing biomolecules fixed on a specific surface such as those schematically shown in Fig. 9. Besides the theoretical performance BYK has already started to investigate the capabilities of bio-organic hybrids. More details will be presented in the lecture.
Future potential for additive applications

Talking into account the enormous flexibility and variability of modern additive technology as demonstrated it is easy to imagine a tremendous potential for new applications outside the current coatings where similar performance criteria are needed.

These examples cover a wide range from electronics via batteries to digital printing. For each mentioned application we will show a working demo and suitable technology. Thus showing the impact of interesting new structures for new applications.