

SMART COATINGS AND AI:

THE NEXT LEAP TOWARD INFINITY DURABILITY

INTRODUCTION

Chemistry powers the universe.
Conventional multilayer coatings
are limited. Now is the time
to leap forward.



MULTIFUNCTIONALITY: LEARNING FROM NATURE

- Blood: Oxygen transport
- Skin: Environmental sensistestion
- Leaves: Photosynthesis

FROM PROTECTION TO RESPONSIBILITY

An industry's debt to nature —
Antifouling coatings that absorb microplastics



PRODUCTIVITY CONTROL WITH ARTIFICIAL INTELLIGENCE

- Predict
- Optimize
- Monitor



ADAPT OR DISAPPEAR

Strength without innovation
equals extinction



Smart Coatings and AI-Controlled Productivity: From Universal Chemistry to Infinity Durability

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Abstract

The development of multifunctional smart coatings is emerging as a disruptive transformation in the field of protective materials. Unlike conventional multilayer systems, these advanced coatings integrate several functions into a single layer, supported by insights from chemistry, physics, and mathematics, and increasingly enhanced by artificial intelligence (AI). This paper argues that coatings must now move beyond simple surface protection, embracing multifunctionality, sustainability, and digital intelligence. Such an evolution can reduce resource use, extend service life toward “*infinity durability*,” and even contribute actively to environmental protection.

1. Chemistry as the Foundation of the Universe

All scientific progress is rooted in chemistry. From stellar fusion to the biochemical cycles that sustain life, the universe is governed by chemical reactions [1]. Chemistry translates the abstract principles of physics into matter and provides mathematics with tangible systems to model. Without it, the applied sciences, including materials engineering, would have no foundation.

In protective coatings, chemistry dictates formulation, curing, adhesion, and long-term stability. It is through controlled chemical design that coatings achieve not only durability but also new functionalities.

2. Smart Coatings as Multifunctional Solutions

Conventional coatings primarily act as passive barriers. Smart coatings, in contrast, respond to environmental stimuli and adapt their properties in service. Reported functions include:

- *Self-healing* of scratches and microcracks using microcapsules or nanocontainers [2],

- *Corrosion resistance and biofouling prevention* via engineered chemistries [3],
- *Optical, thermal, and electrical responsiveness* for aerospace and automotive applications [4].

These developments align coatings with the multifunctional nature of living systems, offering reduced maintenance costs and longer lifetimes.

3. Multifunctionality in Nature as Inspiration

Multifunctionality is a design principle long perfected by nature. Human blood simultaneously transports oxygen, eliminates waste, regulates pH, supports immunity, and heals wounds. Skin protects, senses, and regulates temperature, while leaves capture light, exchange gases, and conserve water.

By learning from these biological systems, materials scientists have created coatings that combine multiple protective roles into one formulation [5]. This natural model demonstrates that multifunctionality is not a luxury but a necessity for efficiency and resilience.

4. Beyond Asset Protection: Environmental Responsibility

For decades, protective coatings were designed primarily to preserve infrastructure. Yet this narrow focus overlooks the environmental cost of releasing large volumes of synthetic chemicals. The next generation of coatings must serve a dual role: protecting structures and safeguarding the environment.

One emerging concept is antifouling coatings capable of absorbing microplastics from seawater [6]. Such technologies reframe coatings as *active environmental agents* rather than passive barriers. They represent a moral and scientific step forward acknowledging that industry owes a debt to nature and must contribute to its preservation [7].

5. Artificial Intelligence and Productivity Control

Artificial intelligence is transforming coatings development and application. AI enables:

- Predictive modelling of coating performance based on large datasets [8],
- Machine-learning optimization of formulation variables [9],
- Real-time monitoring of application processes to reduce waste,
- Digital twins for predictive maintenance and lifecycle management [10].

Through AI integration, coatings can move from static barriers to adaptive systems that optimize themselves in real time.

6. From Conventional Systems to Smart Coatings

Conventional multilayer systems (primer, intermediate, topcoat) have been reliable but inefficient. They require significant resources, extended application time, and present vulnerabilities if one layer fails. Multifunctional smart coatings, however, combine corrosion protection, self-healing, antimicrobial activity, UV stability, and antifouling into a single layer [6].

This mirrors disruptive shifts in other industries: circuits miniaturized into chips, combustion engines gave way to electric drivetrains, and general medicine evolved into nanotechnology-based targeted therapies [11]. The coatings industry must now embrace its own transformation.

7. Toward Infinity Durability

The next frontier is the concept of “infinity durability”: coatings that continuously repair, adapt, and resist multiple stressors, while being monitored by AI-driven systems [2,8,12]. By reducing VOC emissions, raw material use, and maintenance waste, such coatings can extend the service life of assets almost indefinitely. Crucially, they can also integrate ecological functions such as biofouling control and pollutant capture [6].

8. Adapt or Disappear

History demonstrates that strength without adaptation leads to extinction. Dominant landline telephone providers disappeared with the rise of mobile networks; early mobile manufacturers lost their position to touchscreen

smartphone pioneers; and film photography collapsed when digital imaging took over [13].

The protective coatings industry faces the same challenge. Those who fail to adopt multifunctionality, sustainability, and AI integration will eventually be displaced, no matter how established they are.

9. Conclusion

From the chemical reactions that power stars to the multifunctional systems that sustain life, nature demonstrates that adaptability and multifunctionality are essential for survival. Protective coatings are no exception.

By integrating chemistry, physics, mathematics, AI, and ecological responsibility, coatings can transition from passive barriers to active, multifunctional guardians, both of infrastructure and of the environment. The path forward is clear: “*adapt, innovate, and align with nature, or disappear*”.

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