Silver-free low temperature curing epoxy powder coatings with antimicrobial properties

Michał **JACZEWSKI**[1], Urszula **PASZEK**[1] Sławomir **PIŁAT**[1], Leszek **KOMOROWSKI**[2], Agnieszka **KRÓLIKOWSKA**[2], Izabela **KUNCE**[2], Damian **WOJDA**[2], Katarzyna **ZACHARUK**[2], Małgorzata **ZUBIELEWICZ**[3], Sebastian **JURCZYK**[2], Grażyna **KAMIŃSKA-BACH**[2], Bartosz **KOPYCIŃSKI**[2], Ewa **LANGER**[3], Barbara **PILCH-PITERA**[4], Ewa **CISZKOWICZ**[4], Michał **KĘDZIERSKI**[5], Marta **PRZYBYSZ-ROMATOWSKA**[5], Irena **GRZYWA-NIKSIŃSKA**[5], Katarzyna **KRAWCZYK**[6], Michael **HILT**[7]

[1]Polish Corrosion Society, Gdańsk (Poland),
[2]Road and Bridge Research Institute, Warsaw (Poland),
[3]The Łukasiewicz Research Network - Institute for Engineering of Polymer Materials, Gliwice (Poland),
[4]Rzeszow University of Technology, Rzeszow (Poland)
[5]The Łukasiewicz Research Network - Institute of Industrial Chemistry, Warsaw (Poland)
[6]Fraunhofer Institute for Manufacturing Engineering and Automation IPA, Stuttgart (Germany)
[7]Forschungsgesellschaft für Pigmente und Lacke e.V., Stuttgart (Germany)

BACKGROUND

Silver is most often used in paint coatings with antimicrobial properties. Despite its high antimicrobial activity, the use of silver in paint products is not an optimal solution, among others due to the high cost of the precious metal and its limited resources, immunotoxic potential and bioaccumulation. The obtained powder paints contain natural and synthetic substances with biocidal properties, including chitosan derivatives, amino acids and peptides, which are additionally immobilized on layered carriers such as monmorillonite and hydrotalcite. Intercalation of the biocide contributes to the increase of its antimicrobial activity, and improvement of thermal stability, and facilitates the dispersion of the biocide in the powder paint. Controlled release of the biocide from the carrier extends the duration of antimicrobial action. The coatings are assessed for their biocidal activity, structure, degree of biocidal dispersion, mechanical and resistance properties, including resistance to UV radiation and water absorption. The test results will allow for the selection of a promising concept for obtaining powder paints cured at lower than conventional temperatures, characterized by good biocidal and protective properties, which can be an ecological alternative to solvent-based antimicrobial paints containing silver.

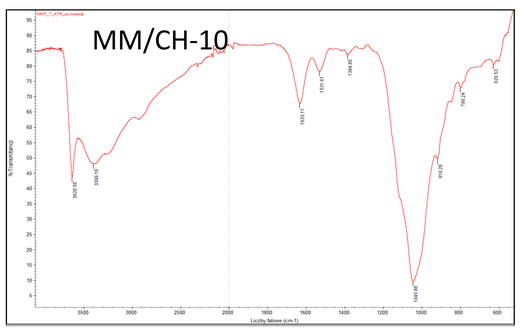
BIOCIDAL AGENTS

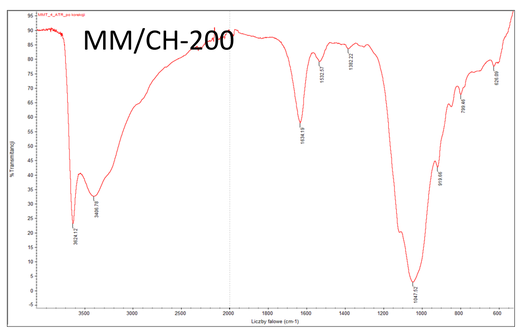
Silver-free antimicrobial powder coatings based on epoxy resin and the cationic biopolymer polylysine were successfully developed and characterized. Polylysine was applied in three different forms: as a pure additive, intercalated in montmorillonite (PLY/MM), and co-intercalated with aminododecanoic acid (PLY/MM/ADA). The aim was to enhance antimicrobial efficacy, reduce leaching, and improve compatibility within the coating matrix.

The results indicate that antimicrobial effectiveness depends not only on the chemical composition of the additive but also on its electrochemical surface distribution. Coatings with uniform cationic groups and stable surface potentials like the system with only PLY — exhibit the best antibacterial performance. Using polylysine, a biodegradable and renewable biopolymer, supports sustainable biomaterials for antimicrobial applications. Furthermore, eliminating silver enhances resource efficiency in designing antimicrobial coatings.

SELECTED BIOCIDAL AGENTS

Symbol	Carrier	Active substance
CH-10	–	Chitosan 10
CH-200	–	Chitosan 200
CH-2000	–	Chitosan 2000
MM/CH-10	Montmorillonite	Chitosan 10
MM/CH-200	Montmorillonite	Chitosan 200
MM/CH-2000	Montmorillonite	Chitosan 2000
MM/AHA/CH-10	Montmorillonite	Chitosan 10 + aminohexanoic acid
MM/ADA/CH-10	Montmorillonite	Chitosan 10 + aminododecanoic acid
PLY	-	Polylysine
PLY/MMT	Montmorillonite	Polylysine
PLY/MM/ADA	Montmorillonite	Chitosan 10 + aminododecanoic acid
HAL/CH-Q	Halloysite	CH-Q
HAL/PLY	Halloysite	Polylysine
Ag_3PO_4	–	Ag
REF (Reference)	–	

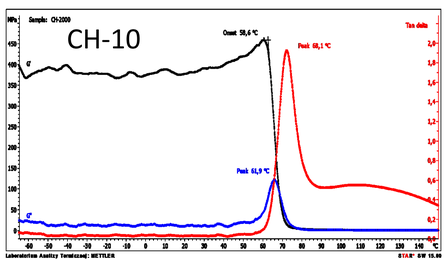


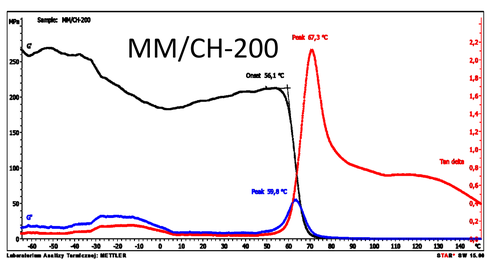


- ✓ FTIR spectra of chitosan on montmorillonite are dominated by the montmorillonite bands – approximately 1000 cm^{-1}
- ✓ Peaks at approximately 3200–3300 cm^{-1}, 2935 cm^{-1}, 1600 cm^{-1}, and 1550 cm^{-1} correspond to the vibrational modes of the amide group and the proton-stretching proton-protonating -NH_3^+ side chain groups, respectively
- ✓ Confirmation of the protonation of nitrogen atoms, which allows for interaction between the -NH_3^+ groups and the negatively charged sites of montmorillonite (MM)
- ✓ The presence of protonated ammonium groups – a key factor influencing the antibacterial properties

PHYSICOMECHANICAL PROPERTIES

DMA – there are no significant differences in the properties of coatings with different biocidal agents

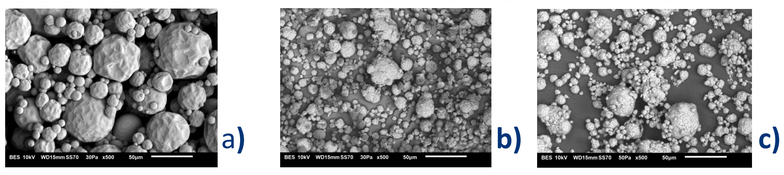




IMPROVING ADHESION TO THE SUBSTRATE - Minatec (Iriotec) pigment in nitrocellulose lacquer

Sample	H_2O CA [°]	SFE [mN/m]
Polyamide	79.93±2.17	40.11±2.48
Minatec 30B on polyamide	137.44±3.62	8.73±1.79
Minatec 30B on epoxide + fiberglass	136.54±3.81	8.67±2.18
Minatec 30B on epoxide + fiberglass + carbon fiber	138.24±5.84	8.55±1.66

MORPHOLOGY OF ANTIMICROBIAL ADDITIVES BY SEM



a) b) c)

SEM morphology of antimicrobial additives: a) polylysine (PLY), b) polylysine immobilized on sodium montmorillonite (PLY/MM) and c) polylysine immobilized on aminedodecanoic acid intercalated on MMT (PLY/MM/ADA)

BENEFITS

Benefits of using antibacterial coatings:
- ✓Limited growth of microorganisms – the active ingredients in the coating inhibit the growth of bacteria (staphylococcus aureus, escherichia coli).
- ✓Greater user safety – reduced risk of infection and disease transmission.
- ✓Longer surface durability – the coating protects against biological degradation, discolouration and unpleasant odours.
- ✓Increased product/service value – an innovative and health-promoting solution is a competitive advantage.
- ✓Compliance with market trends – growing demand for pro-hygienic solutions in an era of greater health awareness.
- ✓Experiences after the COVID-19 pandemic – increased social and regulatory expectations regarding hygiene in public and private spaces.

ACKNOWLEDGMENTS

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