Atomic layer deposited ZnO and Al_2O_3 on nonwoven fibre materials – improving antimicrobial properties and moisture resistance

Atomic layer deposition (ALD) is an excellent technique to produce different inorganic-organic hybrid materials. Self-terminating nature of ALD cycles helps attaining reliable coverage of the complex nonwoven fibre structures. Low-temperature deposition of metal oxides can be used to improve antimicrobial properties of the hybrid materials and to enable effective decontamination and moisture resistance.[1,2] These properties are beneficial in personal protective equipment, such as technical masks.

In this study we deposited zinc oxide (ZnO) and aluminum oxide (Al_2O_3) on nonwoven viscose (Lyocell) and foam-formed cellulose fibres (JKL, from VTT Jyväskylä pilot plant).[3] The 75-400 cycles of ALD ZnO were produced with Picosun R-200 ALD reactor from diethyl zinc (DEZ) and H_2O at 80 °C. Furthermore, additional 7 cycles of Al_2O_3 (TMA, trimethylaluminium + H_2O) on ZnO coatings were studied. The visual appearance and distribution of ZnO was analysed by SEM-EDS. Hydrophobicity (contact angle measurement) was tested with deionized water. Furthermore, antimicrobial properties, filtration efficiency and particle shedding were studied. For antimicrobial properties, modified ISO 22196, MS2 virus and S.Aureus bacteria were used.

According to the contact angle measurements, Lyocell with 150 c and 300 c of ZnO and additional 7 c of Al_2O_3 were hydrophobic. With JKL cellulose samples no proper hydrophobicity was reached. ALD coatings did not affect on filtration efficiency, even though the ZnO coating penetrated throughout the fibre sample sheets and the amount of ZnO was equivalent on both sides according to SEM-EDS results. Particle shedding results revealed the differences in stability of the ZnO and Al_2O_3 treatments between the two fibre substrates. In the case of Lyocell, the ALD coating seems to be firmly attached and prevents the fibre particle shedding as well. In the case of JKL samples, the number of shedded particles exceeds the reference sample with 150 cycles or more of ZnO ALD, indicating the shedding of the ALD coating material. Antimicrobial efficiency was notable since both fibre types performed well already with 75 cycles of ZnO. All samples were microbicidal for both bacterial and viruses, and many of the samples exceeded the microbicidal impact of 3 log cfu/sampe, which is considered as an excellent effectiveness (Figure 1). ZnO ALD coating seems to have stronger microbicidal impact when deposited on foam-formed cellulose (JKL) compared to viscose material (Lyocell).

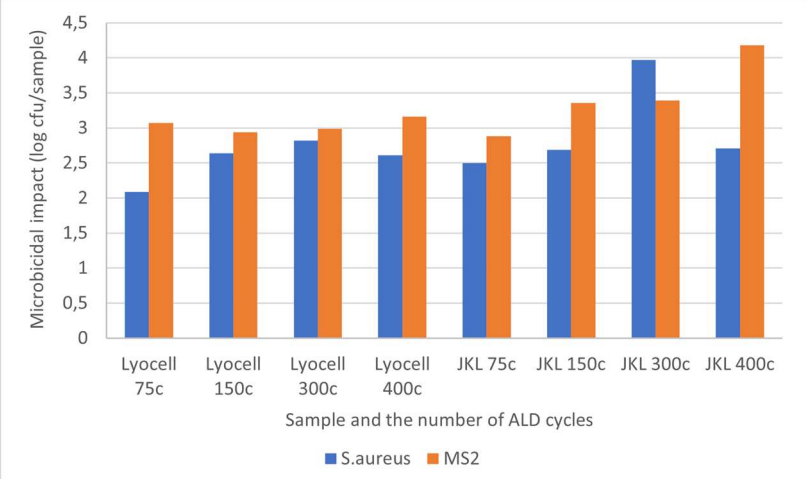

Figure 1 Microbicidal impact of ZnO ALD (75-400 cycles) on Lyocell and JKL samples.

[1] M.C. Popescu et al. *Applied Surface Science* 481 (2019) 1287–1298

[2] X. Xiao et al. *Applied Surface Science* 610 (2023) 155487

[3] The research has received funding from the Academy of Finland, project ID 340385