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Characterization of coating distribution on paper substrates

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Abstract:
This study investigates the deposition and interaction mechanisms between coatings and paper substrates. Sample preparation, image acquisition, and statistical analysis were conducted to characterize the coating distribution. The findings demonstrate that proper selection of the paper substrate, particularly its surface structure, is crucial for achieving the desired functional and barrier properties. Further research is required to fully assess the performance and application prospects of bio-based coatings in sustainable packaging.

Keywords: Bio-based coating, paper, surface properties, experiment approach, statistical analysis

Introduction:

Bio-based coatings hold significant promise for enhancing the properties of paper substrates, while addressing sustainability and recyclability challenges in the packaging industry[1]. These coatings offer a range of benefits, including improved barrier and antimicrobial properties as well as surface modification capabilities[2]. This study explores the use of bio-based coatings for paper substrates with the objective of evaluating their potential for sustainable packaging solutions.

Experiment and Methods:

Coating was applied to paper substrates using the Film press technique with a semi-automated coating unit available at LUCENSE. Different types of coated samples for further evaluation of their performance and properties were prepared on two types of paper: Paper A with conventional surface treatment and Paper B with clay-coated surface treatment: The role of the primer is to enhance adhesion and improve compatibility between the paper substrate and the coating. Surface images were acquired (see Figure 1) using a confocal microscope available at the MUSAM-Lab in the IMT School for Advanced Studies Lucca. A custom image processing code in MATLAB was used to evaluate the deposition mechanism and coating distribution on the paper substrate.

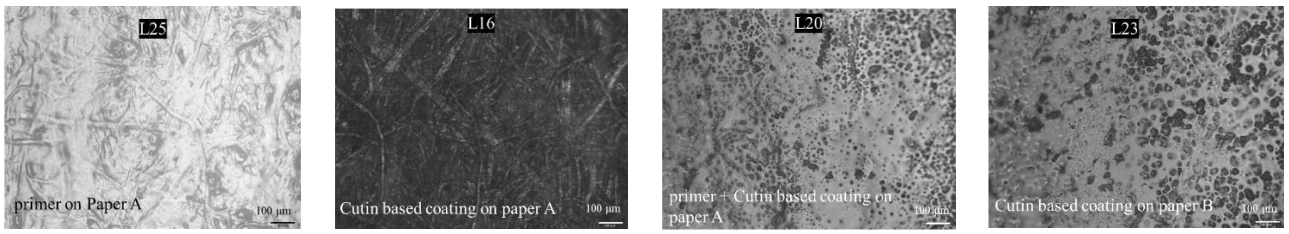

Figure 1. Surface images of coated samples under confocal microscope.

Results and Discussion:

The qualitative analysis reveals that Cutin penetration on Paper A is evident without primer, as indicated by visible fibers in L16. Applying a primer on Paper A demonstrates the importance of surface preparation in modifying the interaction between the coating and paper surface. Thus, the coating's purpose should be considered, with L16 being suitable for antimicrobial or antioxidant properties, while a continuous layer is crucial for barrier properties such as water and grease repellence. Furthermore, the comparison between L20 and L23 highlights the importance of paper surface properties in coating distribution on the substrate.

The developed statistical model analyzes random images taken from samples to evaluate the coating distribution. The algorithm applies image-specific thresholding to distinguish between coated and uncoated areas, determining the percentage of each. Through statistical interpretation, the mean values converge as the number of samples increases. The described approach allows a semi-quantitative evaluation of coating distribution and coverage area on paper substrate.

Coated samples were characterized in terms of mechanical and barrier properties to water, demonstrating the association between different deposition mechanisms and barrier performance of the final product. The results demonstrate that careful selection of the substrate in terms of surface treatment, and a proper application of both primer and Cutin coating can significantly enhance the water barrier properties of the final product. Therefore, consideration of the coating distribution is crucial in achieving the desired barrier properties.

Finally, evaluation of the impacts of coatings on recyclability with paper of the final products will be reported.

Conclusion:

Through the comprehensive methodology encompassing sample preparation, image acquisition, and statistical analysis, this study provides valuable insights into the coating distribution. The results affirm that achieving the intended barrier properties requires thoughtful consideration of the substrate's surface properties in conjunction with an appropriate combination of application parameters of coating, including preliminary surface preparation. Further investigation is necessary to fully explore the capabilities of bio-based coatings in sustainable packaging applications.

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Biography

Hamed Zarei is a post-doc researcher at IMT School for Advanced Studies Lucca, working in collaboration with LUCENSE. He holds a Ph.D. in Mechanical Engineering from Iran University of Science and Technology (IUST). With expertise in Advanced Mechanical Testing, Failure Analysis & Fracture Mechanics, Microscopy-based Characterization Techniques, and Data Analysis, Dr. Zarei has made notable research contributions in the field of material failure and fracture. He also served as a post-doctoral research fellow at IMT Lucca and BOSCH GmbH in 2020.

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