Combining photonic crystals of different sizes and tuning structural colors by color addition

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Introduction

Photonic crystals (PCs) are dielectric materials, capable of controlling the propagation of light due to the photonic bandgap (PBG) and self-assemble in highly organized nano and microstructures. PCs are found in nature and can be used for signaling, communication or camouflage purposes. PCs structural coloration of textiles is ecological relevant due to the inherent considerable reduction of water and chemical requirements. Furthermore, PCs can be used to develop smart textiles able to change color through external stimuli such as: humidity, light, pH, electrical and magnetic fields. This textiles can be applied in anti-counterfeiting materials, wearable functional textiles, sensors, among others.

Results and Discussion

PCs with different sizes, 170 nm (violet), 190 nm (blue), 210 nm (green) and 250 nm (red) were mixed in different proportions (3:1, 1:1 and 1:3) and applied onto black polyamide (PA) woven fabrics (**Figure 1**). Color addition principal was denoted by the intermediate hues/shades colors obtained in comparison to the original structural colors.

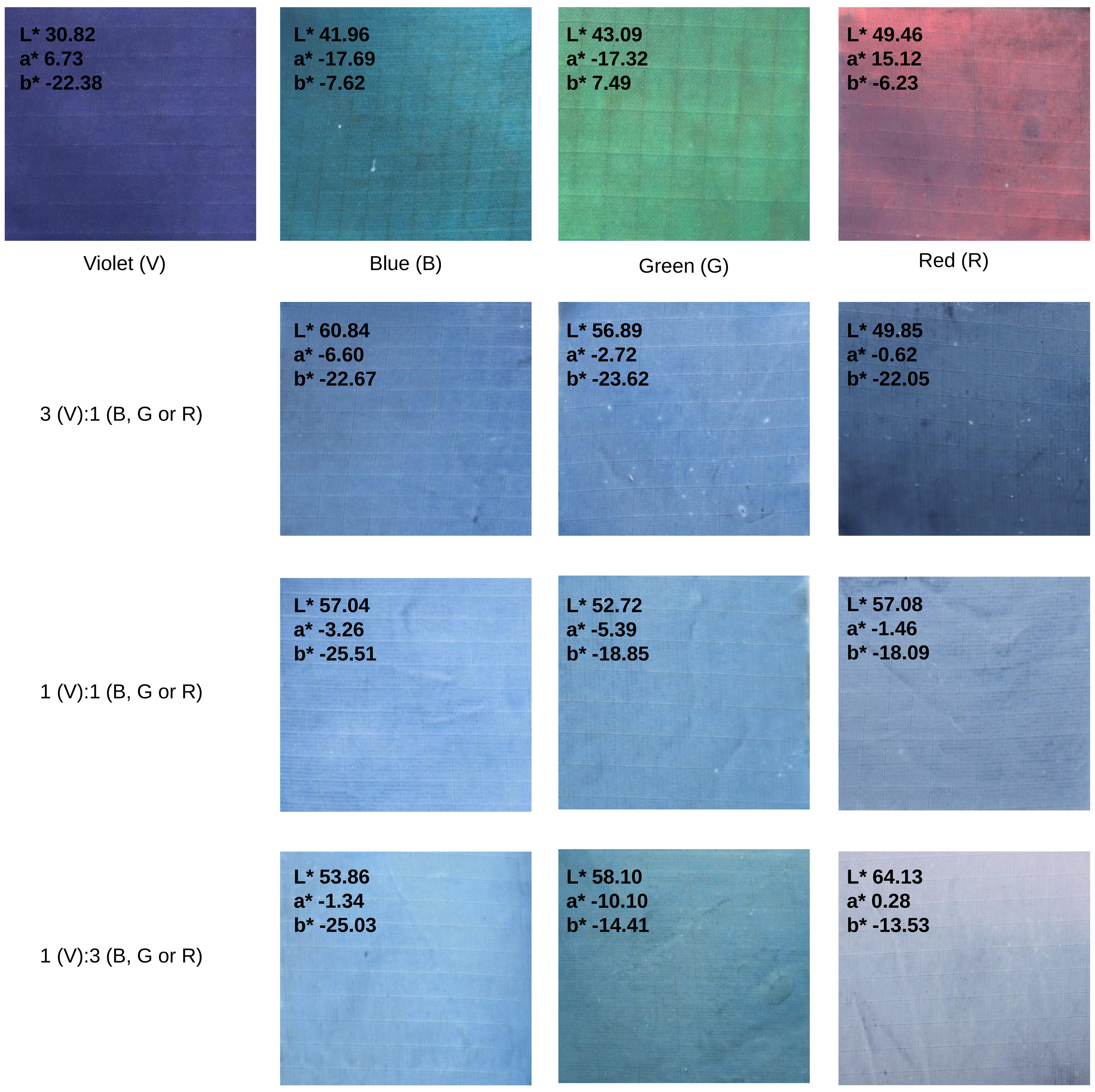

Figure 1 – Photographs of mixed photonic crystals onto PA fabric with the respective CIELab color coordinates.

To further understand how the self assembly and respective intermediate colors are formed, scanning electronic microscopy (SEM) was performed on the fabric's cross-section in the sample where violet and red PCs are mixed 1:1 (**Figure 2**). No clear structural arrangement between 170 nm (violet) and 250 nm (red) PCs was observed in the cross section. Self assemble appears to be random, meaning that color is just dependent of PCs size.

The structural arrangement may affect the brightness of the samples since it was visually reduced in the produced intermediate colors. **Figure 3** (left), displays an average size of violet PCs 169.15±13.15 nm and red PCs of 239.62±15.92 nm. The percentage of 67.82% and 32.18% is attributed to violet and red particles, respectively.

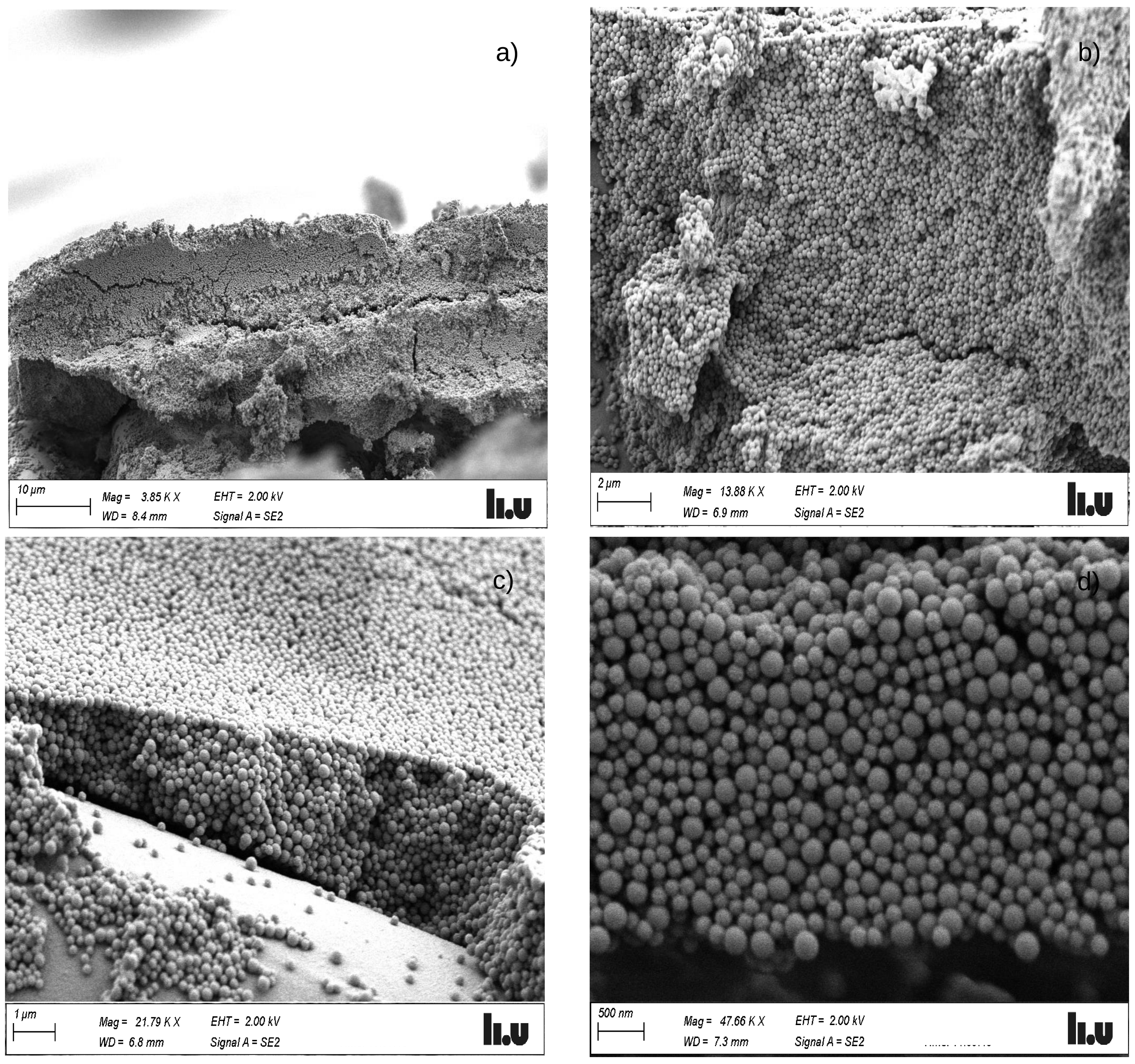

Figure 2 – SEM cross-sectional micrographs of premixed violet and red PCs (1:1) on PA at different magnifications, a) 4000x, b) 15000x, c) 20000x and d) 50000x.

Thus, 1:1 proportion exhibits consistency with the synthesis methodology since the amount of reactants used was the same but different sizes were obtained. A size distribution of the PCs on the bottom of the fabric was also performed (**Figure 3** (right)), denoting a percentage of 57.45% for violet PCs and 42.55% for the red PCs. A perfect structural arrangement of premixed PCs with two different sized is hard to obtain, unless a layer-by-layer methodology is used.

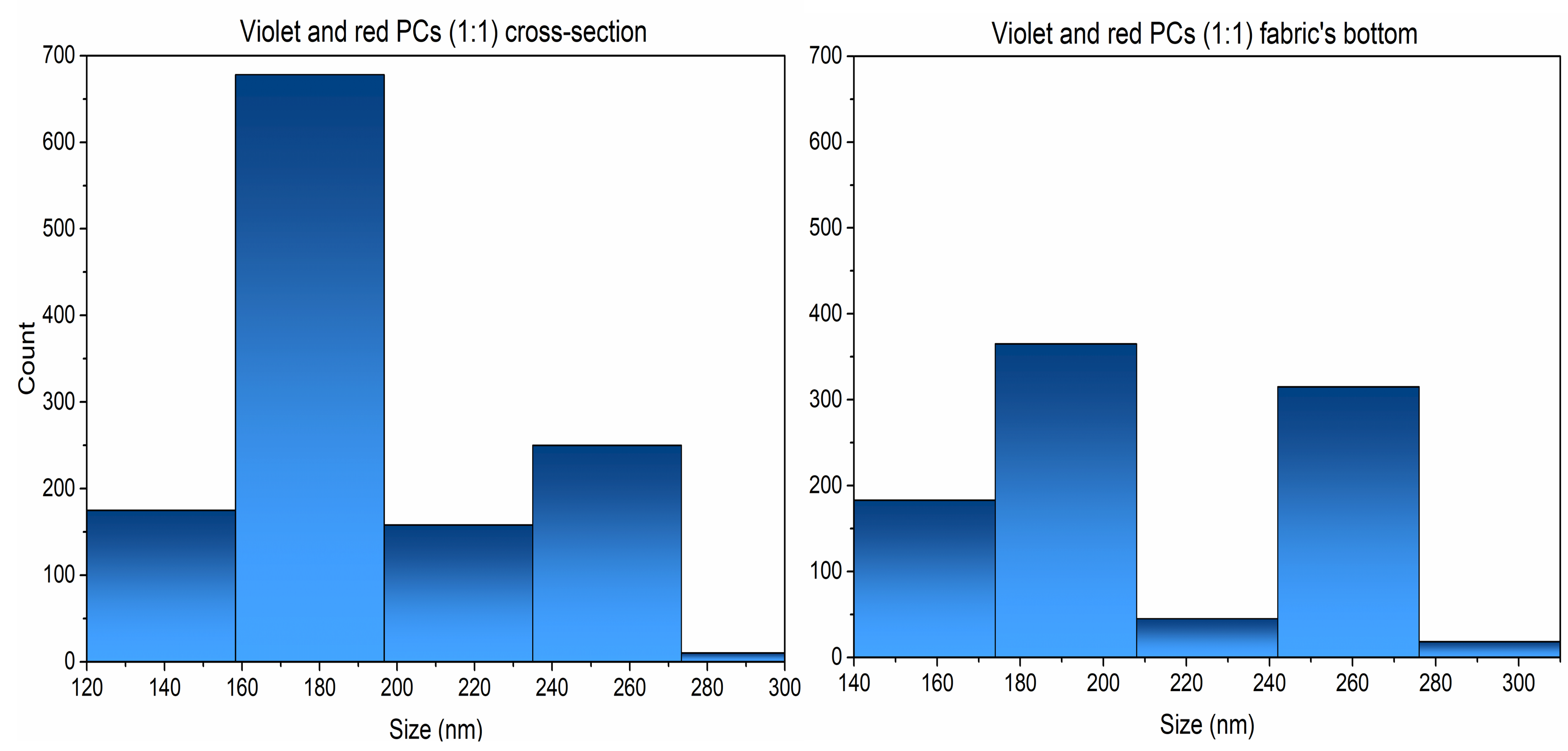

Figure 3 – Nanoparticle size distribution in the cross-section (left) and on the bottom of the fabric (right). (cross section n=1271; bottom n=926)

Conclusions

- PCs can be mixed to obtain intermediate colors from the original structural colors;
- Color relays on PCs sizes while brightness is dependent of their structural arrangement;
- Mixed PCs follow the principle of color addition;
- Water and chemical consumption is drastically reduced in structural coloration, making the process eco-friendlier. The future of textile coloring could lie in structural coloration, which exhibits outstanding light fastness.

Acknowledgments

This research was funded by FEDER funds through the Operational Competitiveness Program–COMPETE, under the projects POCI-01-0247-FEDER-068924 and POCI-01-0247-FEDER-047124, and by National Funds through Fundação para a Ciência e Tecnologia (FCT), under the project UID/CTM/00264/2020. Rui D.V. Fernandes acknowledge FCT, MCTES, FSE and UE PhD grant SFRH/BD/145269/2019. Authors also acknowledge Anna Elsukova and Linköping University (LiU) for the access to ARTEMI, the Swedish national infrastructure of advanced electron microscopy, funded by the Swedish Research Council (VR), grant number 2021-00171, and the Swedish Foundation for Strategic Research (SSF), grant number RIF21-0026.