

Contrast-Enhanced Micro-computed Tomography and Scanning Electron Microscopy for Visualization of Microfibrillated Cellulose in Paper

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MOTIVATION

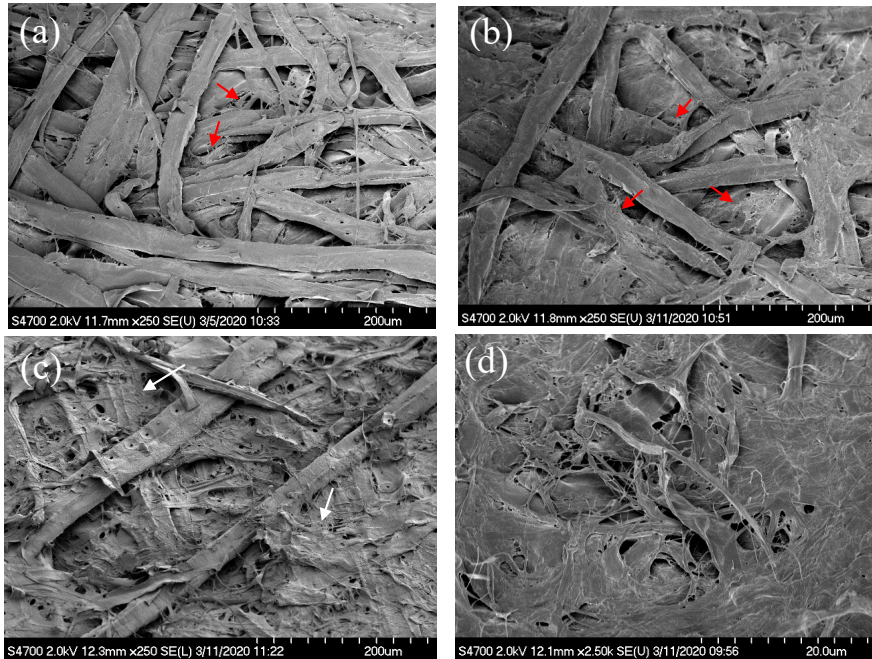
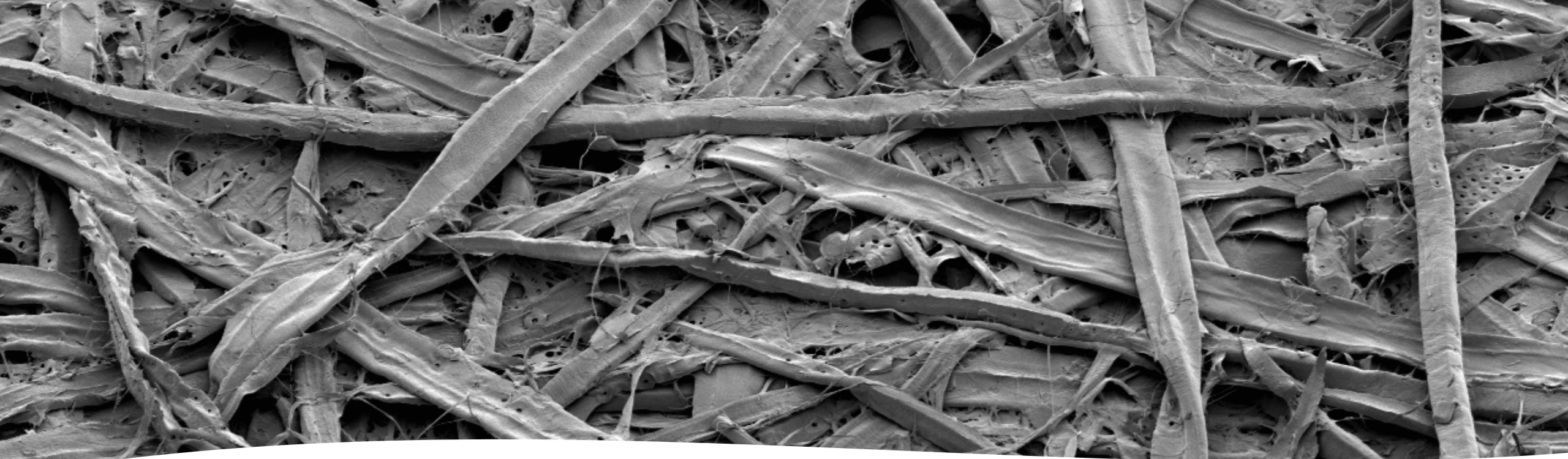


Fig. 4 SEM images from composite papers made from a) 8%, b) 27%, c) 44%, and d) 78% highly refined accept pulp B at SRE=1059 kWh/t

- Mechanical pulping: Sever decline in paper consumption
- The need for new products e.g. microfibrillated cellulose (MFC)
- Given its high aspect ratio, MFC can affect fiber interactions and alter paper properties.
- The effect of MFCs on the paper specifications is not clear yet.
- It has been challenging to elucidate the distribution of MFC inside the paper structure.

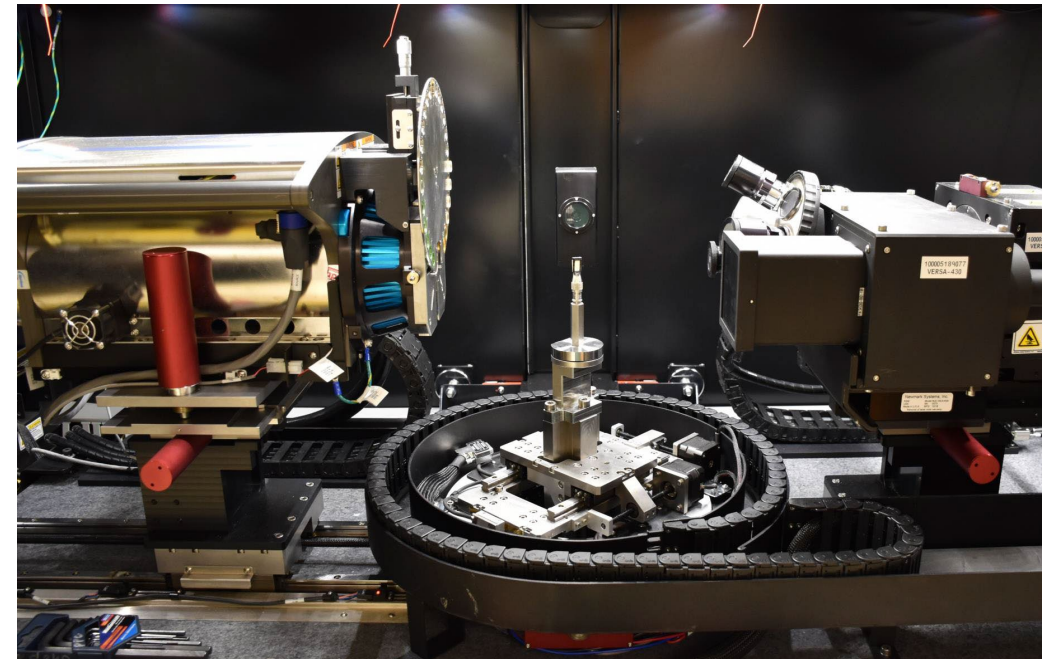
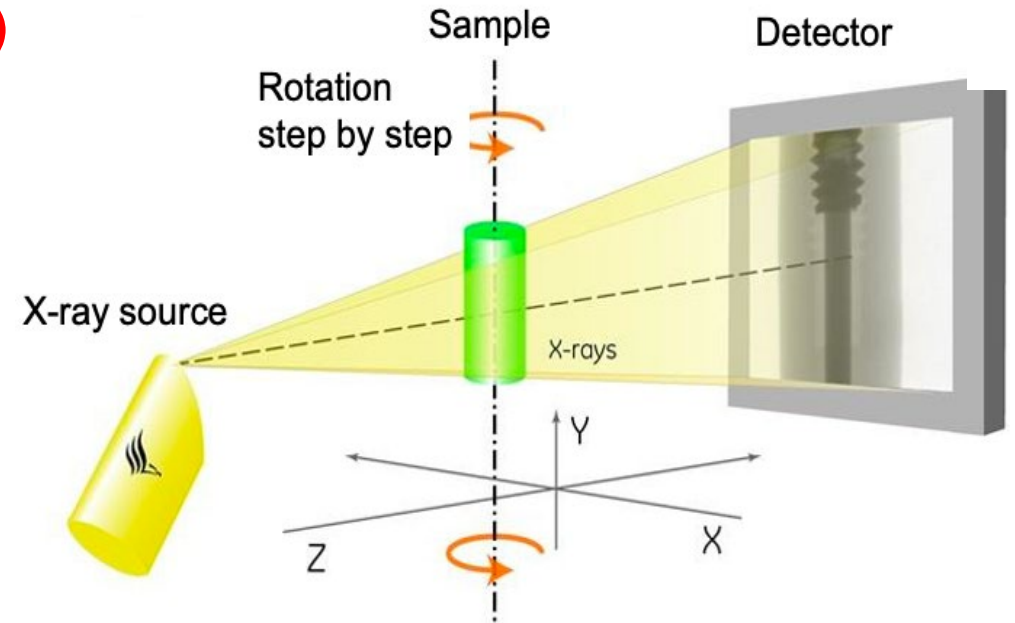


CHALLENGES AND POTENTIAL SOLUTIONS FOR FIBER VISUALIZATION

- Owing to the Chemical similarity between MFC and long fibers, differentiation between them is challenging.
- A potential solution is to increase the contrast in images. To do this, we stain or label the sample. In addition, a combination of imaging techniques can be used.
- Stain selection

X-RAY MICRO-COMPUTED TOMOGRAPHY (CT- SCAN)

- 1- X-ray radiations penetrate the object.
- 2- The object absorbs a part of radiation.
- 3- A projection is taken for each rotation step.
- 4- Reconstruction algorithm combines every projection to create the 3D image.



MFC STAINING

Osmium tetroxide (Os)

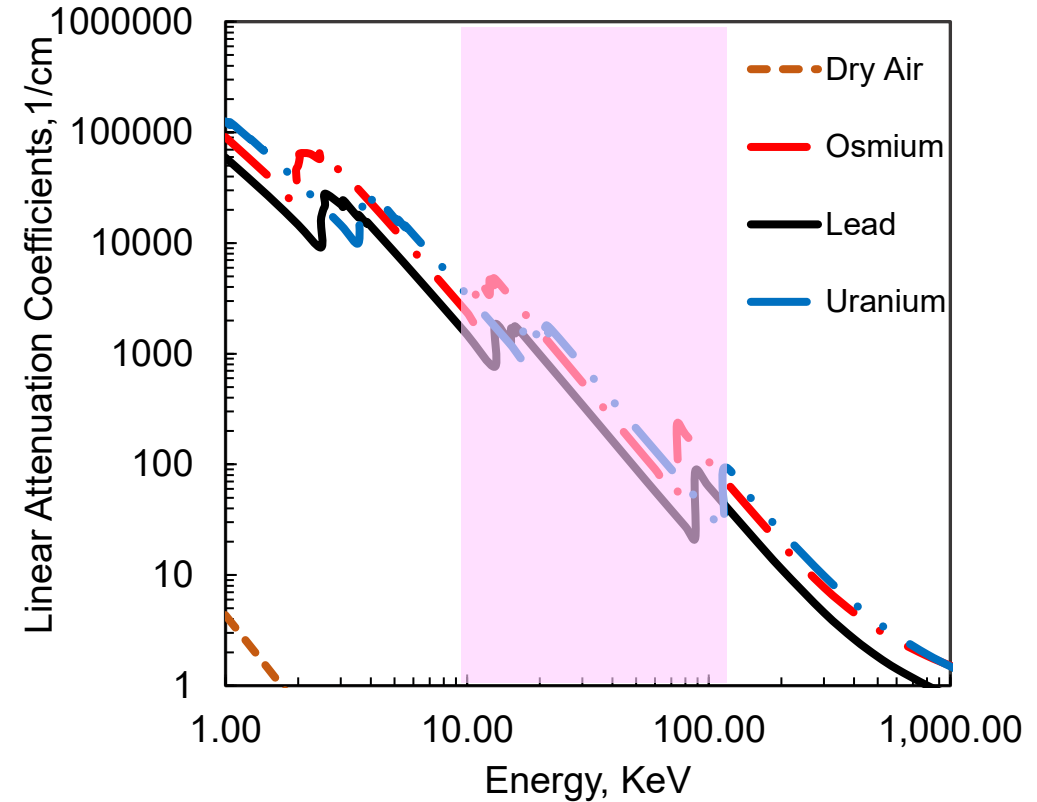
Os is used in electron microscopy as a contrast enhancer.

Uranyl acetate (UA)

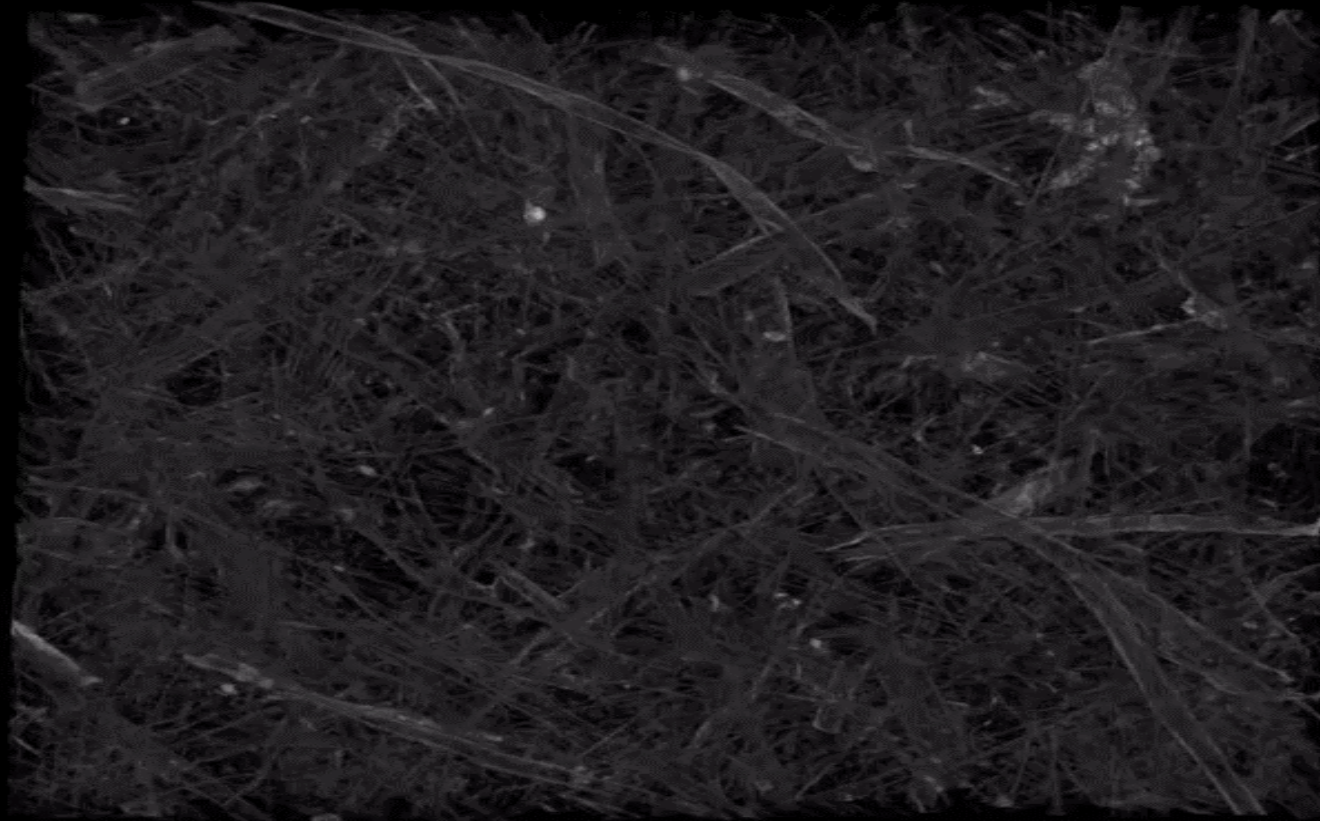
UA stains negatively charged molecules.

Lead citrate

is used as an enhancer for heavy metal staining in electron microscopy. It binds to Os and UA and enhances contrast in many structures



3-D CONSTRUCTION: STAINED MFC (25%)



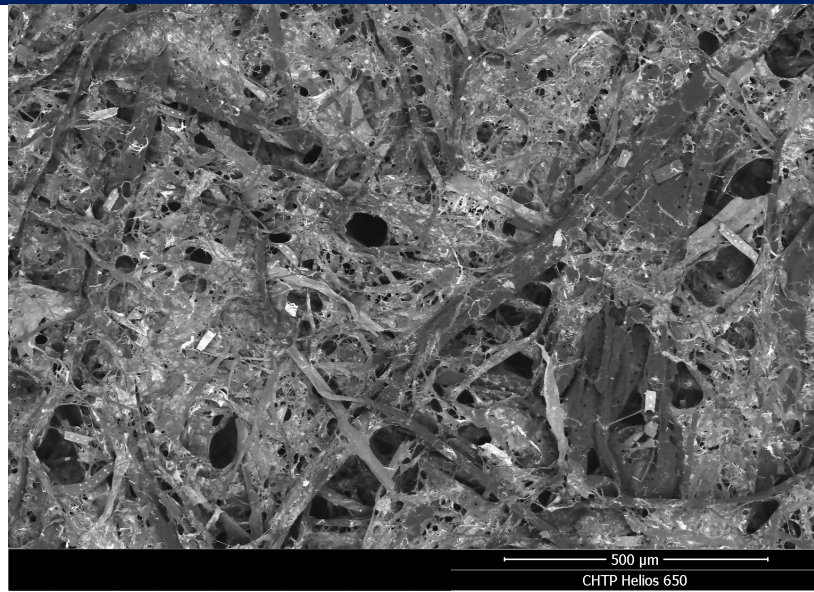
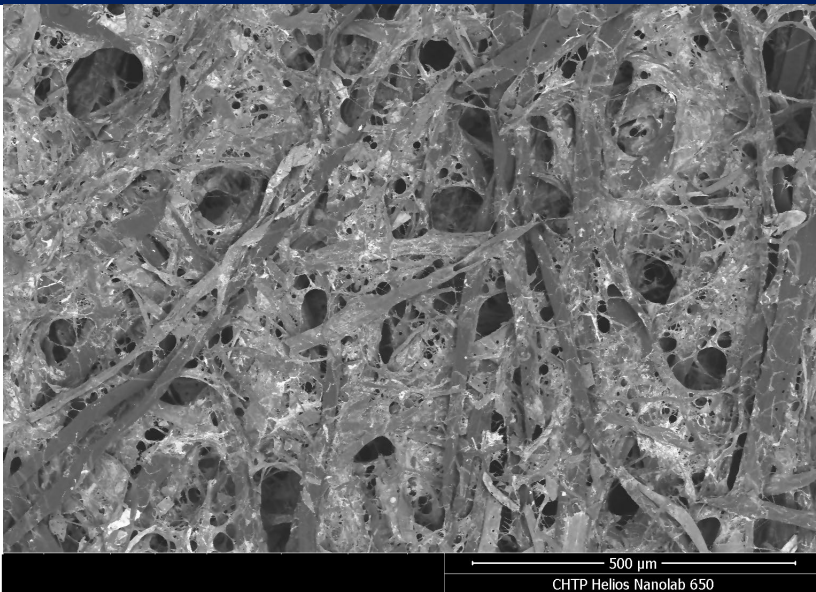
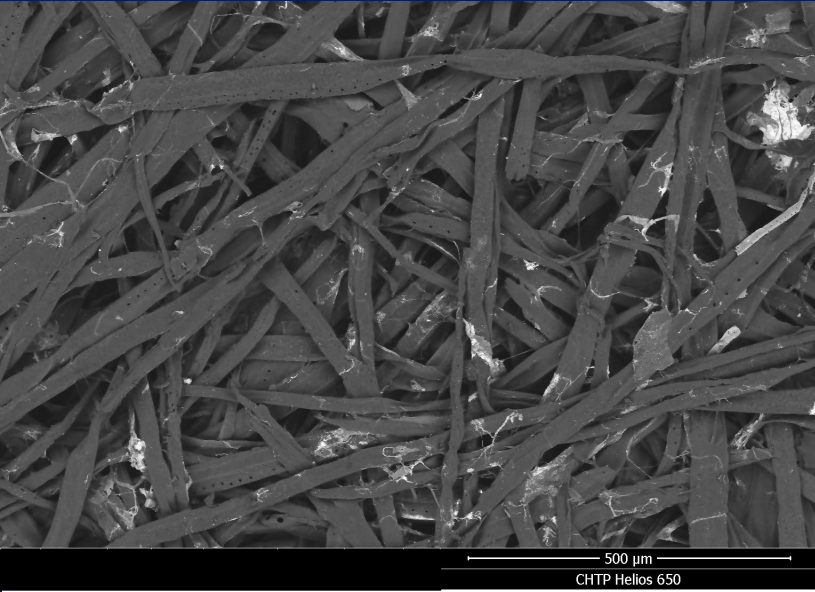
STAINED MFC COMBINED WITH LONG FIBERS

~5% MFC

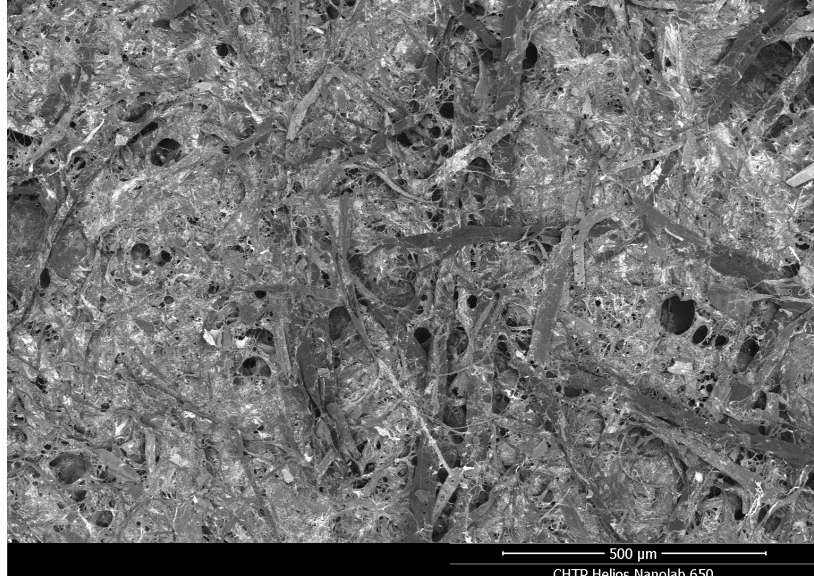
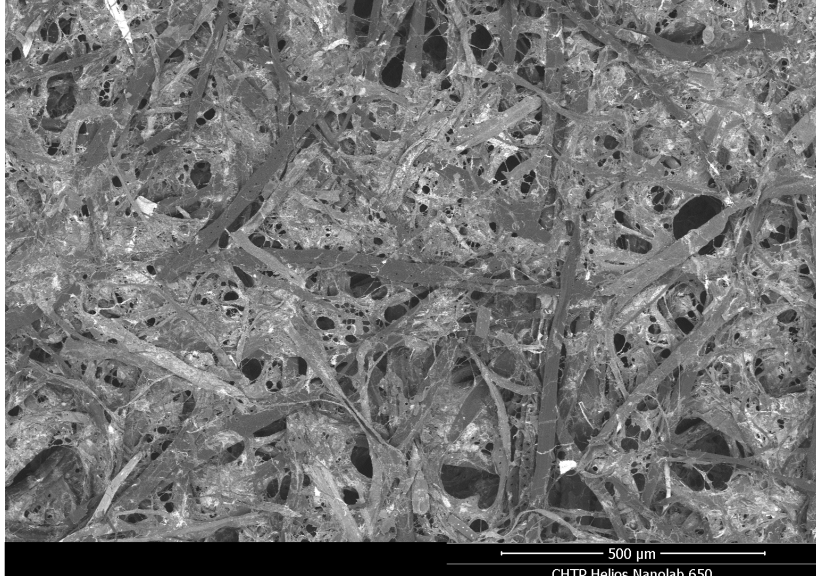
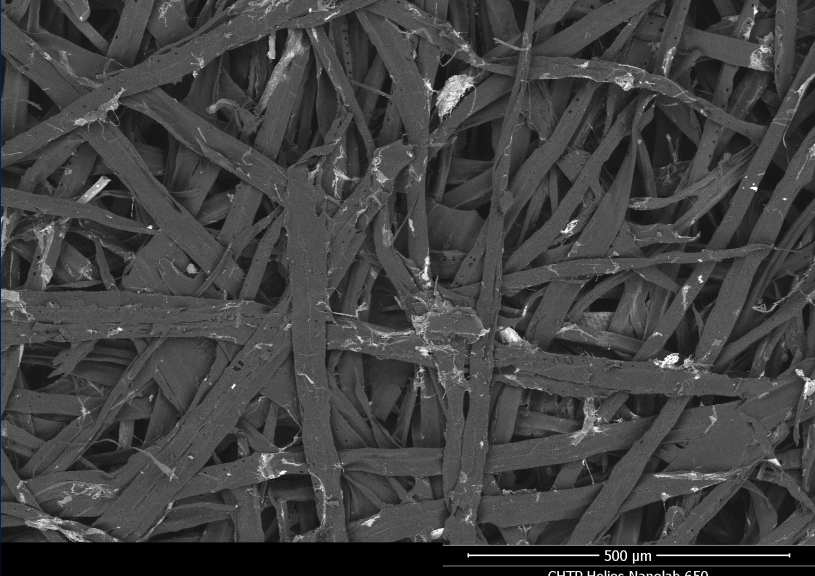
25% MFC

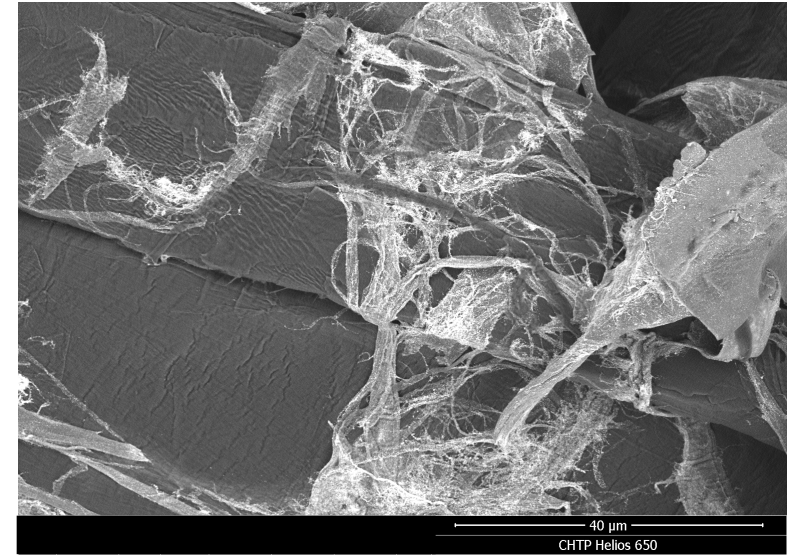
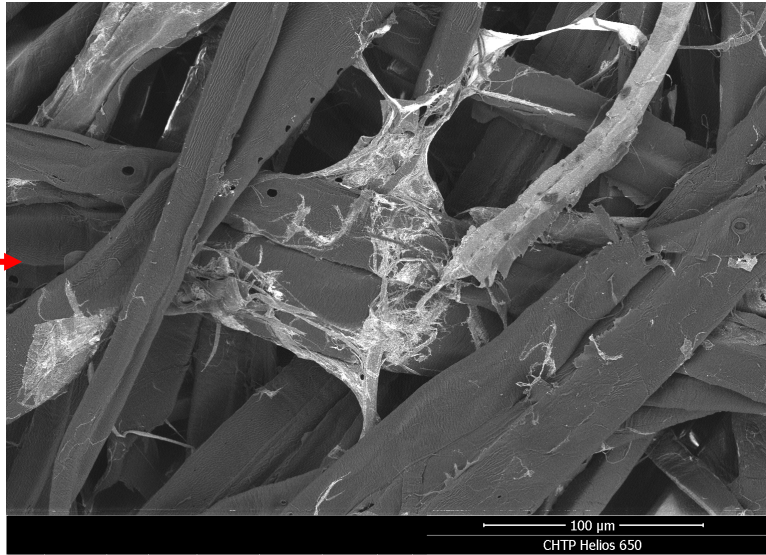
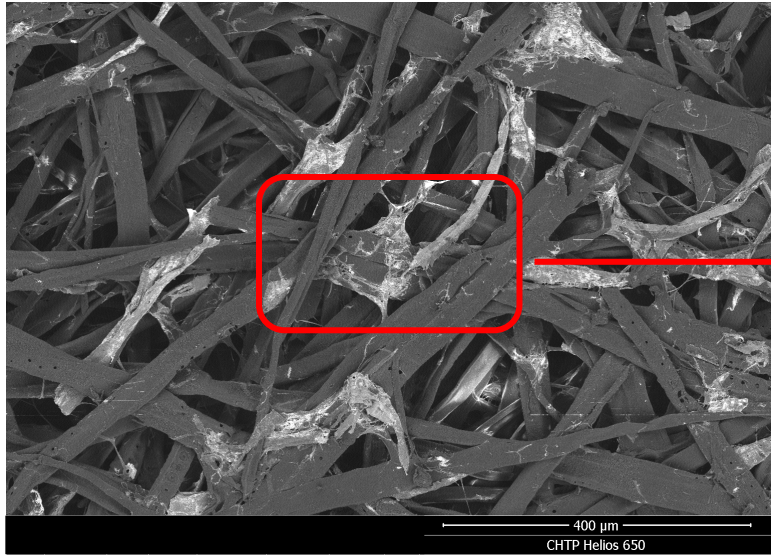
50% MFC

Top surface

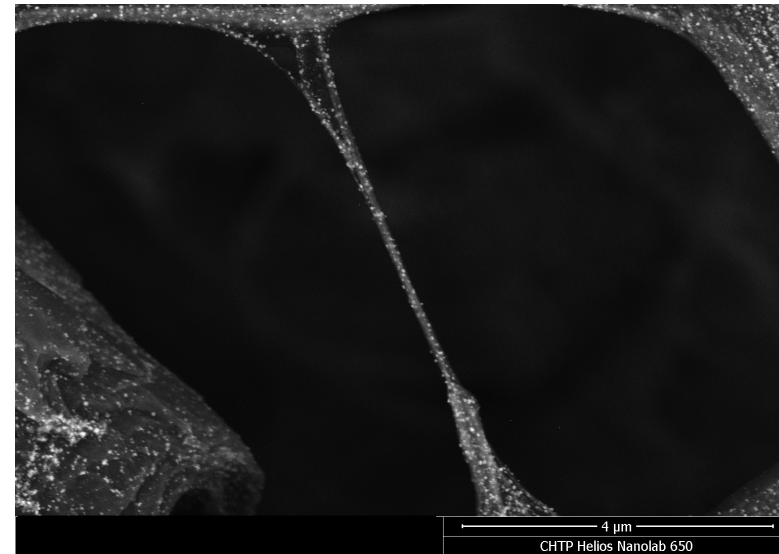


Bottom surface





Enveloped the fibers



Thread-like, strong enough to form a narrow bridge between two fibers.

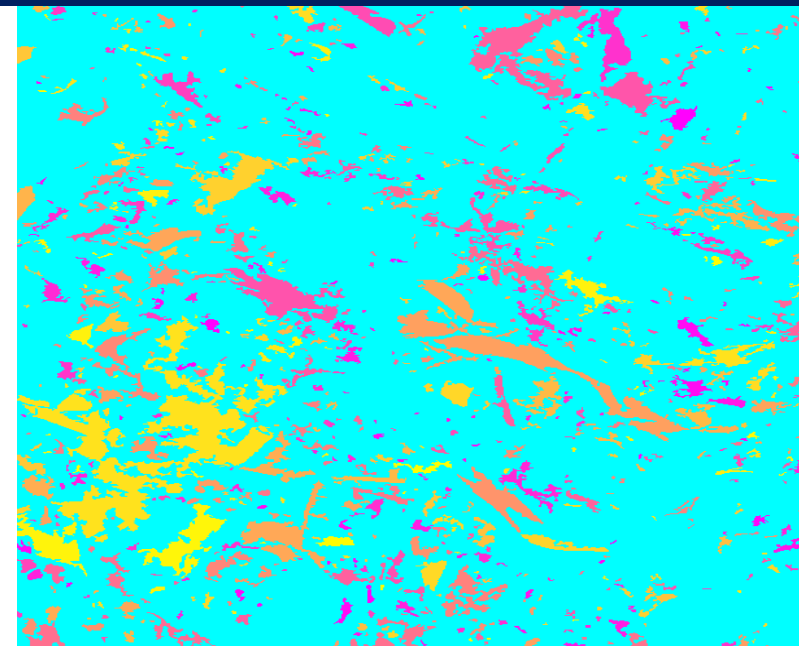
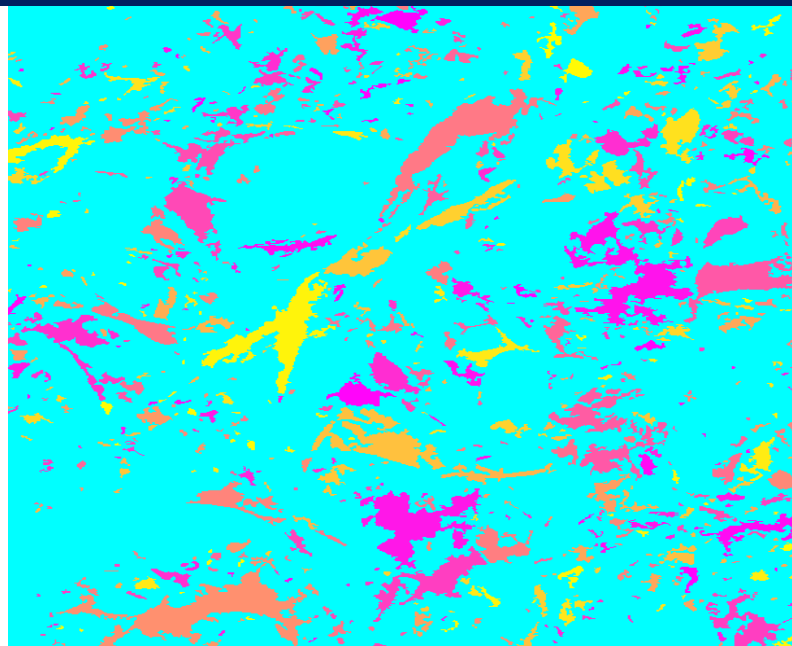
LABELLED MFC

~5% MFC

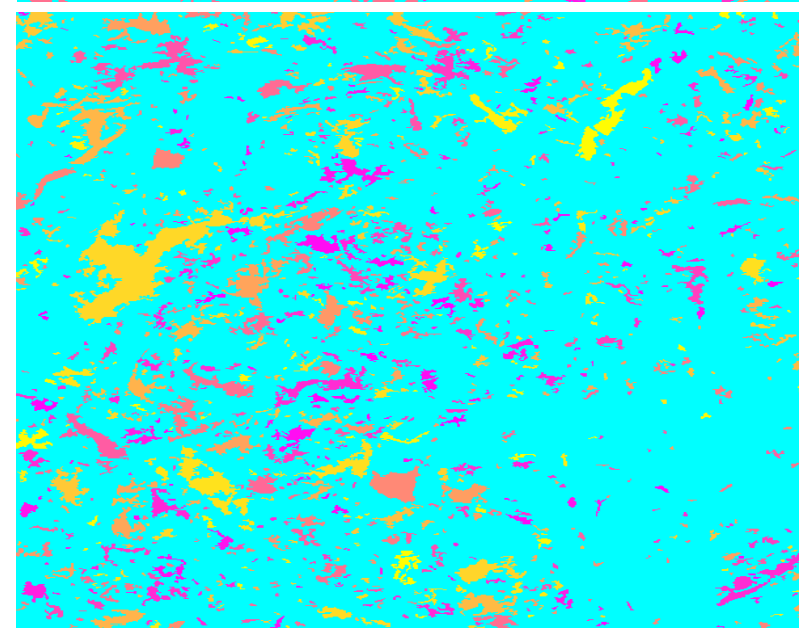
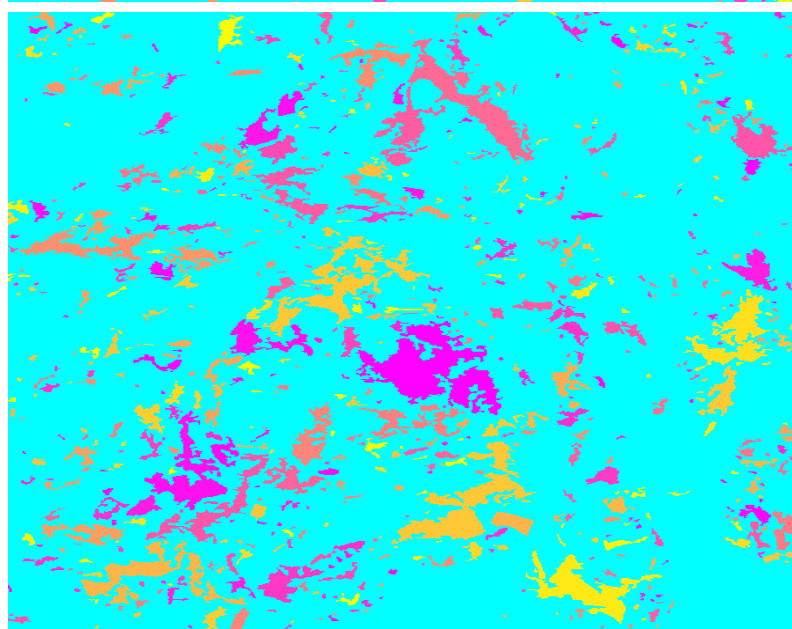
25% MFC

50% MFC

Top surface



Bottom surface

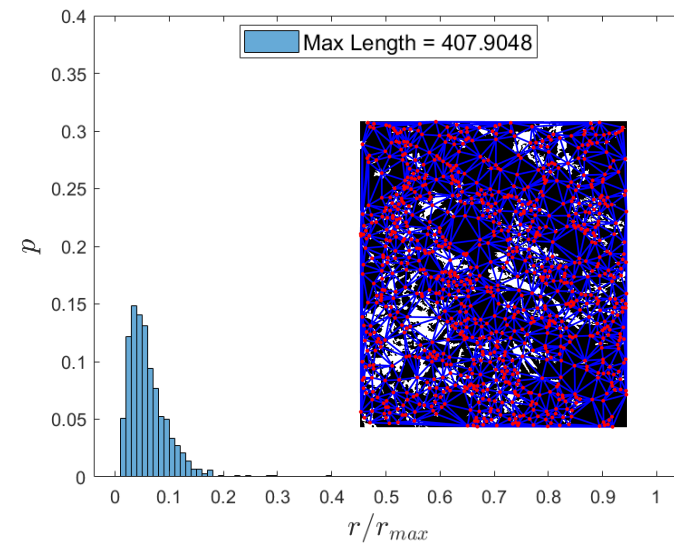
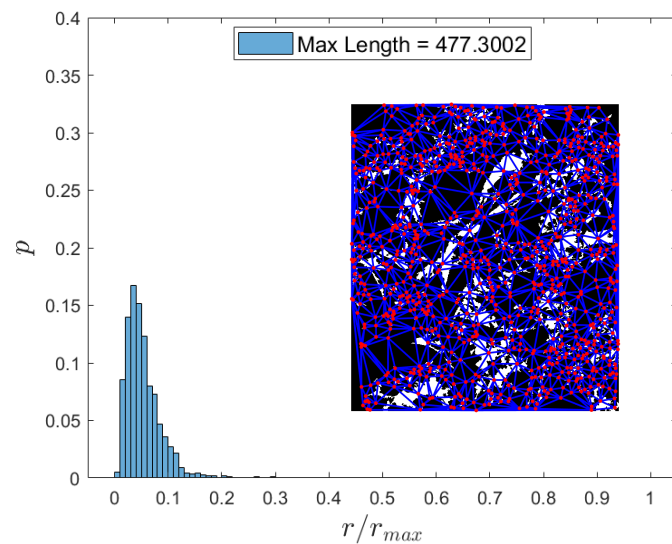
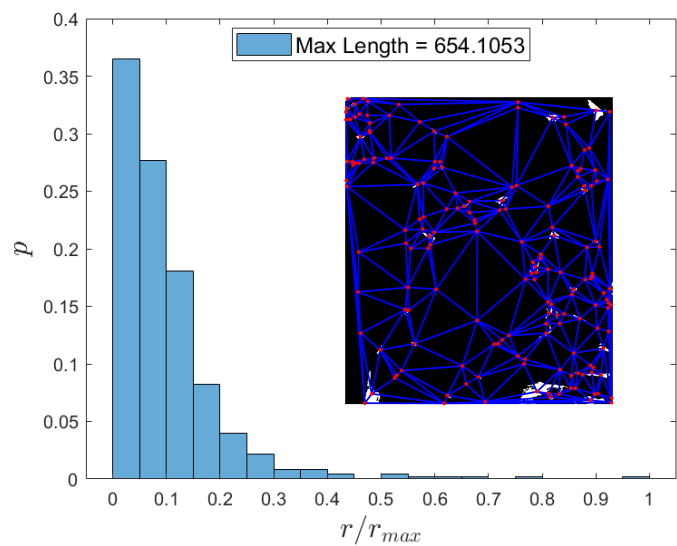
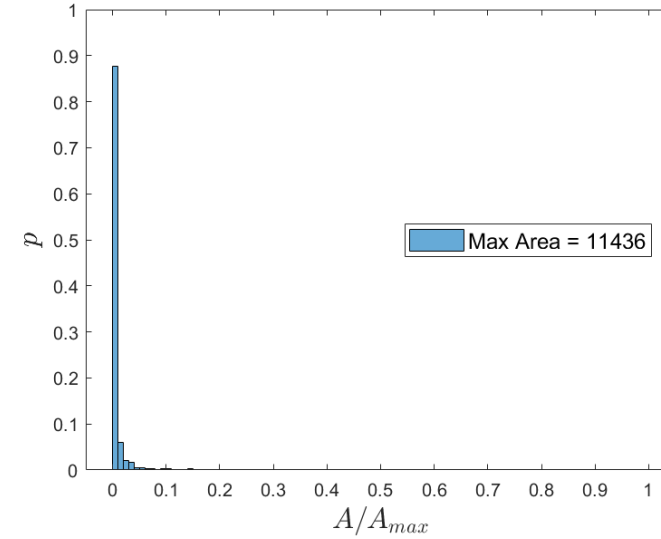
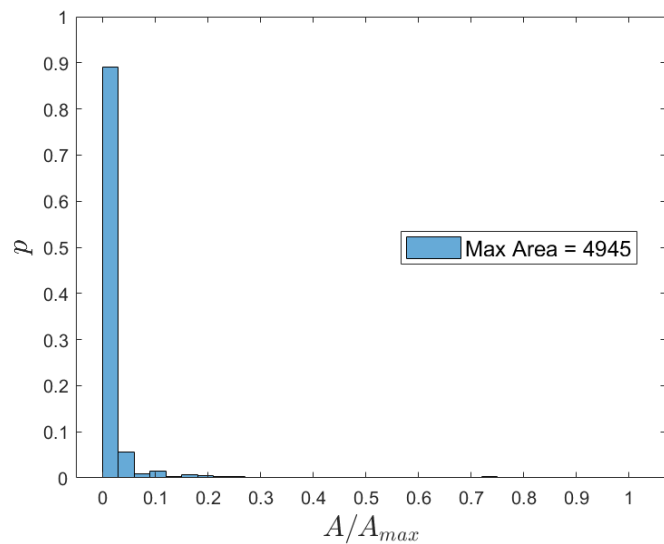
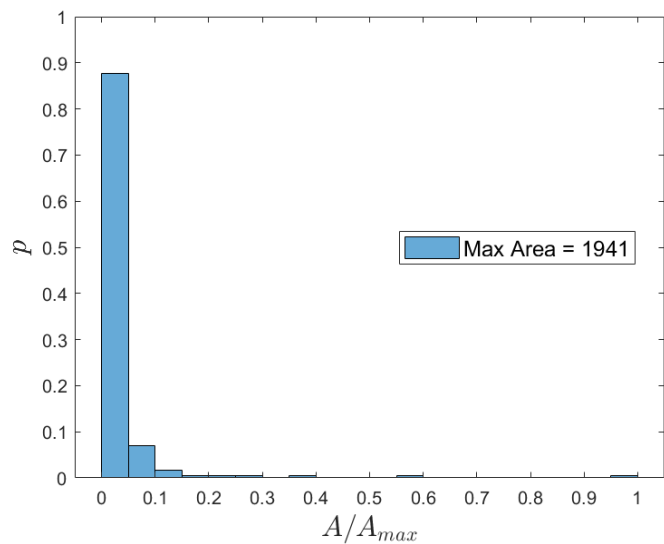


BLOB AREA AND DISTANCE BETWEEN BLOBS (TOP SURFACE)

~5% MFC

25% MFC

50% MFC

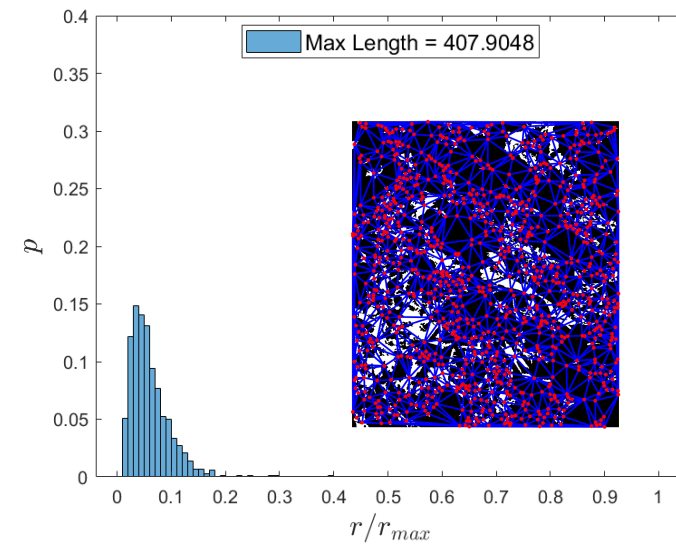
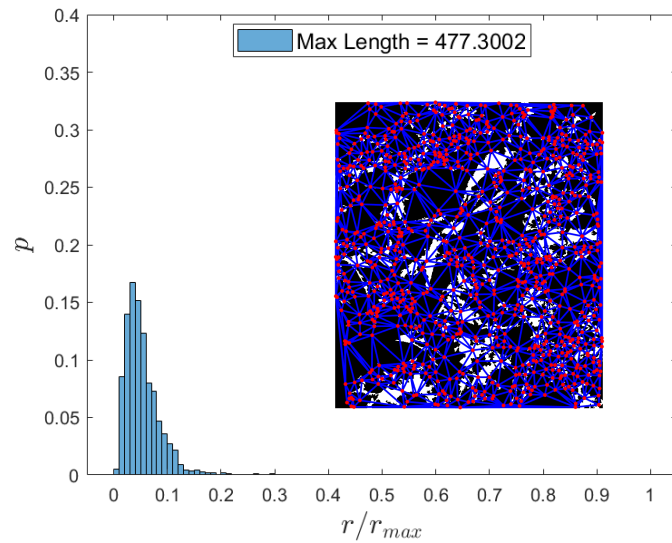
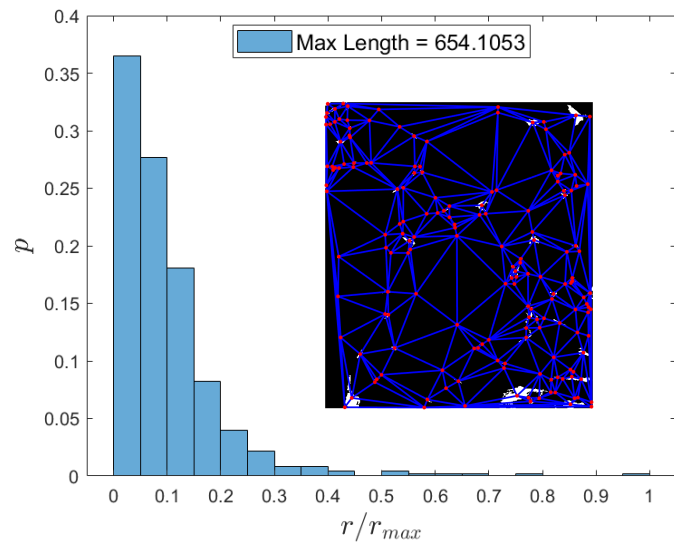


~5% MFC

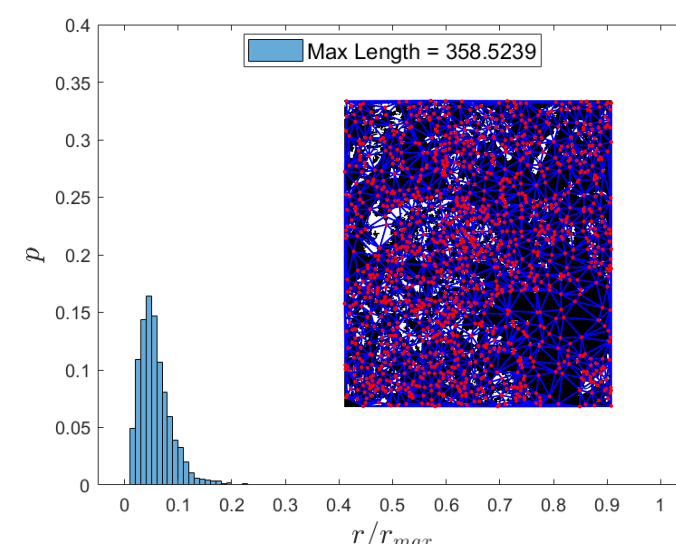
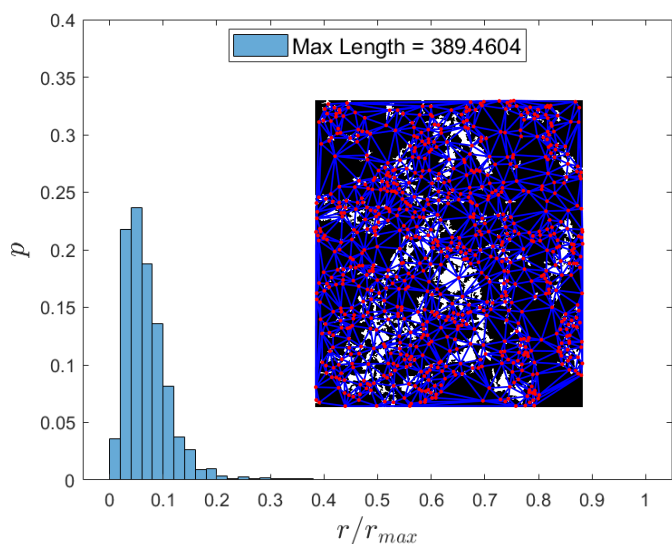
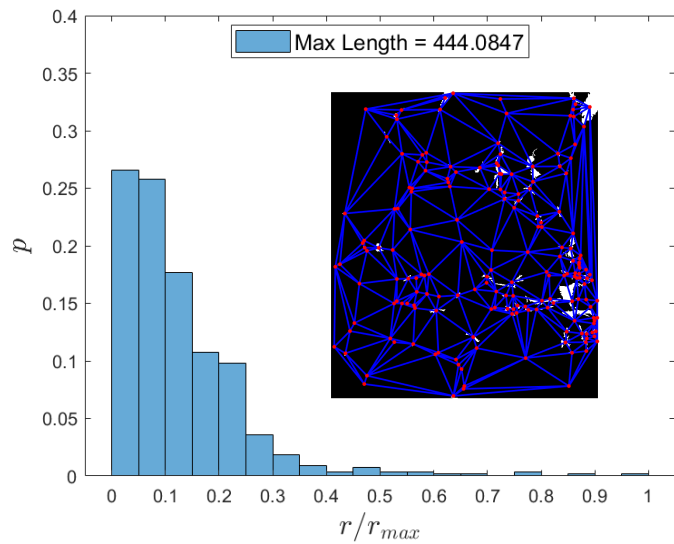
25% MFC

50% MFC

Top surface



Bottom surface



CONCLUSION

- The staining protocol developed in this study has been proven to be effective in enhancing contrast.
- The stained MFC particles are easily distinguishable within the paper structure.
- The staining materials were strongly attached to the MFC, and no stains were released.
- The developed staining protocol shows potential for studying individual fibers and new cellulosic products.

Thank you