

# Investigation of the Micro- and Nano-structural Elements of Biocomposites based on Canadian Flax Fibres

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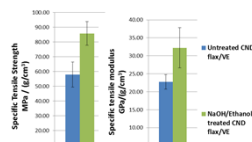
The performance of a fibre as a reinforcement in a composite material is dependent on the ability to transfer force from the matrix to the structural fibre. Weak interface regions will prevent the force transfer reaching the fibre's capacity, resulting in a lower performance than what could be achieved. **To create consistent biocomposite products, an improved understanding of the interface region between biofibres and matrices is needed.**

## Macroscopic Characterization

NaOH/ethanol treatment cleans the fiber surface, partially removing non-cellulose chemicals on the flax fiber surface and separates larger fiber bundles into smaller bundles. **After alkaline treatment, both the contact area and the mechanical interlocking between fiber and VE matrix are increased, which lead to stronger interfacial adhesion** inside NaOH/ethanol treated Canadian flax fiber/VE composites



The specific tensile strength of treated flax/VE shows dramatic increase compared to untreated flax composites, which is because **better interfacial adhesion leads to better load transfer between the matrix and the fiber.** In addition, the alkaline treatment can change the crystallinity of cellulose, which can improve the tensile properties of treated flax composites.



## Next Steps

Both pre-treatment and the selected resin mixture affect the resin-fibre interface chemistry. Work is ongoing to systematically understand their effects **at the molecular level.** This provides a chemical understanding of the results from macroscopic tests. Ultimately, this work will identify the best pretreatment for flax fibres, and produce a resin with better bonding potential for biocomposite material production.

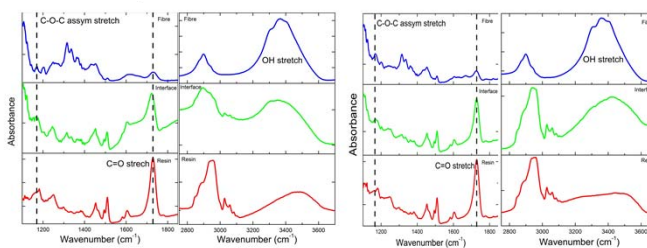
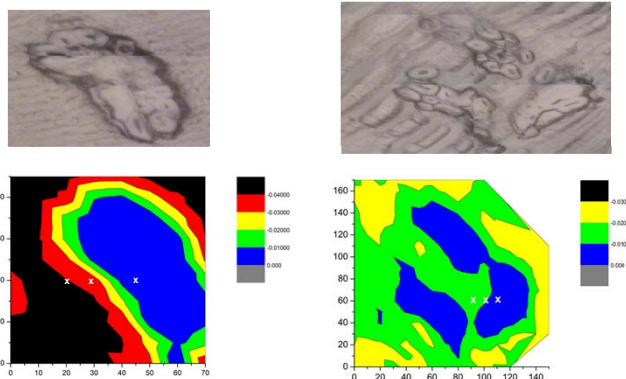
Operating Funding Partners

## Synchrotron Infrared Mapping of Fibre Bundles

Fibre bundles of even thickness surrounded by resin were selected for mapping. A complete FTIR spectrum was collected at each (x,y) coordinate. The sharp C=O stretch was used to identify the presence of resin.

Untreated Canadian flax with vinyl ester resin

NaOH/Ethanol treated Canadian flax with vinyl ester resin



- The Fibre spectra show few differences as a result of the NaOH/Ethanol treatment.
- In the NaOH/Ethanol treated Interface spectrum, the broader OH stretch may indicate **Hydrogen bonding between the fibre and resin.**
- The lack of a sharp C=O stretch, or aromatic C-H stretching in the Fibre spectra suggest that **the resin does not penetrate the fibre bundles.**
- It is unclear why the untreated Interface spectrum C=O peak maximum is shifted relative to that in the Resin spectrum.

## Soft X-ray Spectromicroscopy

All soft X-ray spectromicroscopy data were collected using the Scanning Transmission X-ray Microscope (STXM) at the CLS soft X-ray Spectromicroscopy (SM) beamline. Biocomposite samples cut to 90 nm thin sections and mounted on Si<sub>3</sub>N<sub>4</sub> windows were used to record absorption spectromicroscopy data at the C 1s region (280 to 320 eV) using the STXM. Figure 3.1 shows the X-ray images (average of few images recorded at the C 1s region) of two fibre bundles from the biocomposite sample used in the study. The difference in contrast in the images show that different components are present between the fibre bundles. The lumen is also visible in a few places in the fibre bundles (red arrows). At few places, there are void spaces between the fibre bundles or between the fibre bundles and the vinyl ester (no contact of the fibre bundle with the vinyl ester as indicated by the red arrows).

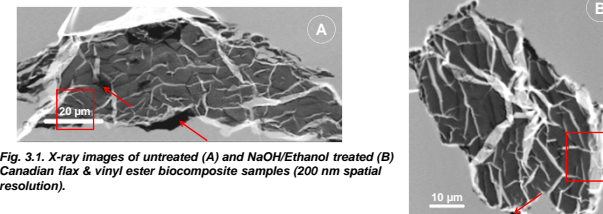


Fig. 3.1. X-ray images of untreated (A) and NaOH/Ethanol treated (B) Canadian flax & vinyl ester biocomposite samples (200 nm spatial resolution).

The marked region (in red) in the above samples were used in the detailed study at a higher resolution (~80 nm) to determine the interaction of fibre bundles with the vinyl ester resin. Figures 3.2 (untreated flax) and 3.3 (NaOH/ethanol treated flax) show the X-ray images of the samples recorded at a single X-ray energy (A), the cluster spectra (B) extracted from different regions using the principle component analysis (PCA), and the pseudo-colour composite image (C) of all cluster spectra mapped on the samples. The different absorption contrast of X-ray images (Fig 3.2A & Fig 3.3A) recorded just near the absorption energy of the vinyl ester resin indicates that the resin has penetrated well into the sample and has filled some void spaces in between the fibre bundles. The cluster spectra (Fig 3.2B and 3.3B) show the absorption peaks of pure fibre and pure fibre (C-OH 289.3 eV) and vinyl ester (aromatic C=C 285.2 eV & COOR 288.6 eV). All other four spectra marked as interfaces have different contributions from fibre and vinyl ester to the spectra.

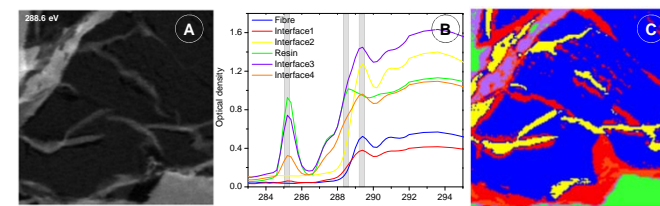


Fig. 3.2. X-ray image (A), cluster spectra (B) and composite image (C) of untreated Canadian flax & vinyl ester biocomposite.

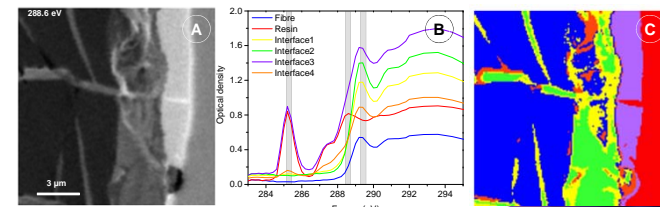


Fig. 3.3. X-ray image (A), cluster spectra (B) and composite image (C) of NaOH/Ethanol treated Canadian flax & vinyl ester biocomposite.