

Cellulose Nanomaterials: Nanocomposite Imaging using FRET

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Introduction: Cellulose is the most abundant organic polymer on Earth, found in plants (cotton, hemp, wood), marine animals (*Tunicate*), algae (*Valonia*) bacteria (*Acetobacter xylium*) and even amoeba (*Dictyostelium discoideum*). Critical features of the structural performance of cellulose in these diverse settings are the large aspect ratio and high strength properties of the cellulose nanocrystals (CNC) and cellulose nanofibers (CNF), which provides nano-scale reinforcement. The isolation of CNC originated with Mukherjee's research in 1953.¹ Acid hydrolysis of the native cellulose is the predominant method used to prepare pure CNC and CNF. Depending on the source of the cellulose and the chemical treatment the resulting material can vary in crystalline type, surface chemistry, dimensions, and aspect ratio. This class of materials is gaining increased importance due to their novel properties (high strength, low thermal expansion, rich surface chemistry and optical transparency). Primary drivers for their use include their renewability and proven low toxicity. Consequently, several pilot plants and a number of commercial scale CNC manufacturing facilities have recently gone online worldwide utilizing wood as the raw material. The applications envisioned range from transportation to biomedical. However, recently the use of CNCs in nanocomposites has become the focus of international research efforts.² The development of measurement methods, which can characterize the structure and morphology of cellulose nanocomposites over many length scales, are needed to enable successful manufacturing and product development of cellulose nanomaterials.³ A project at NIST is developing fluorescence imaging methods to measure interface properties in cellulose nanocomposites.

Methodology¹: As a proof-of-concept system nanofibrillated cellulose (NFC) fluorescently labeled with 5-(4,6-dichlorotriazinyl)aminofluorescein (the acceptor dye) and dispersed into polyethylene (PE), doped with Coumarin 30 (the donor dye) was used to explore the use of Forster resonance energy transfer (FRET) as shown in Fig 1.⁴ Our application of laser scanning confocal microscope (LSCM) imaging combined with FRET enabled multi-scale characterization of nanofibrillated cellulose fibers in the PE matrix.

Results: The LSCM-FRET encodes nano-scale information, about the quality of the interface derived from the FRET efficiency data, and simultaneously conveys information on the homogeneity of the dispersion of the CNF in the polymer matrix on the micron-scale as shown in Fig 2. This method will be developed further to explore structure property relations in these materials by evaluating the effect of structural parameters, of a variety of sources of CNCs and CNFs, on the properties of polymer-CNC/CNF nanocomposites.

References:

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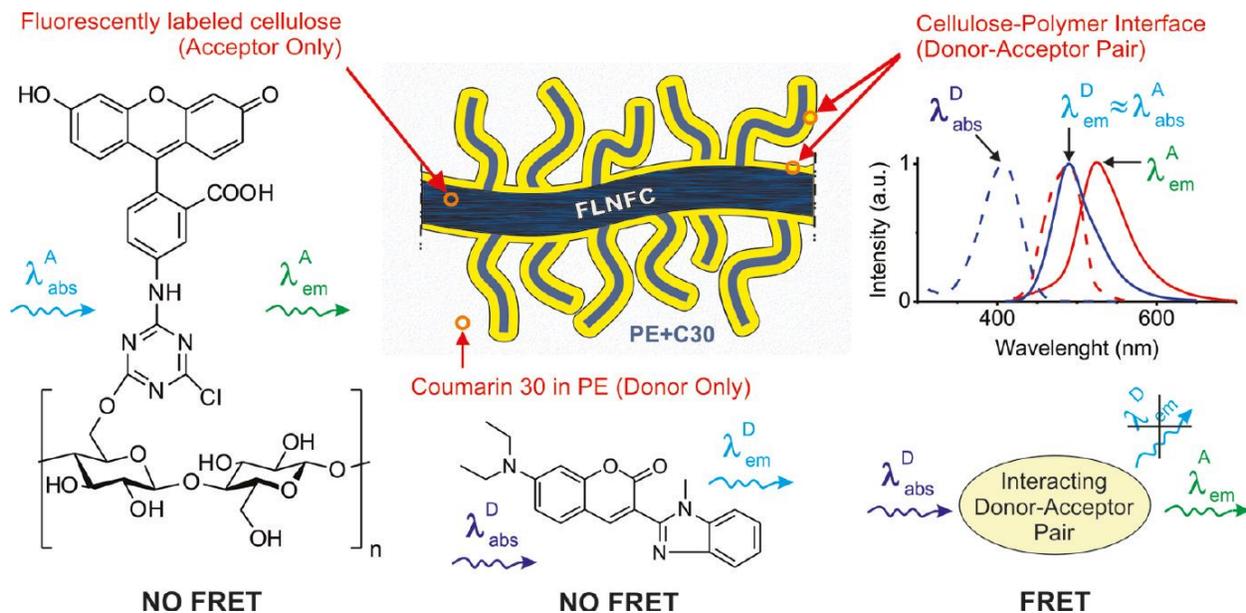


Figure 1. Schematic, illustrating the use of FRET for imaging the interface in polymer composites. FRET occurs only at the cellulose-polymer interphase where interacting donor and acceptor dyes are both present. The normalized spectra of the absorption (dashed line) and the emission (solid line) for the acceptor and donor are also shown.

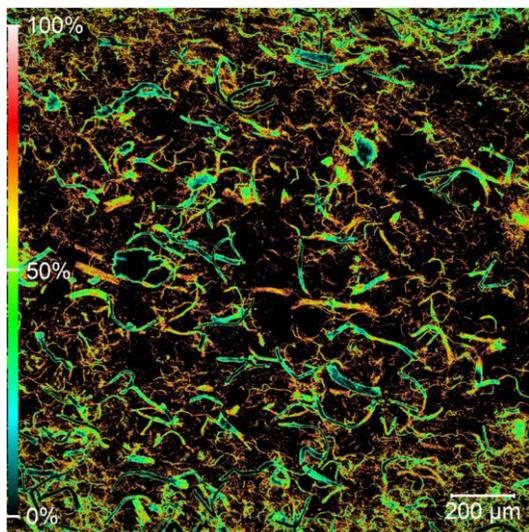


Figure 2. Laser scanning confocal microscope (LSCM) image showing color-coded FRET efficiency map.

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