December 4th, 2020

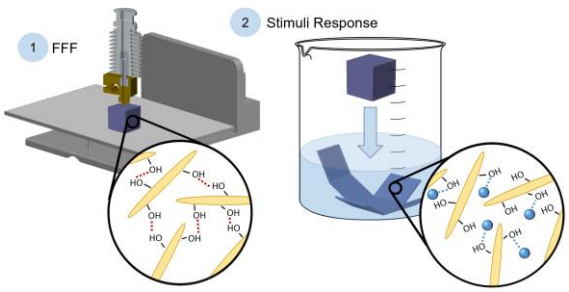
4D-Printing with Cellulose Nanocrystals: Mechanical Adaptivity and Thermal Influence

Tyler W. Seguine[1], Jacob F. Fallon[3], Arit Das[2,3], Emily A. Holz[1], Mindy R. Bracco[1], Justin E. Yon[1], E. Johan Foster[1,3], Michael J. Bortner[2,3]

[1]Materials Science and Engineering, Virginia Tech, Blacksburg, VA, 24061, USA
[2]Department of Chemical Engineering, Virginia Tech, Blacksburg, VA 24061
[3]Macromolecules Innovation Institute, Virginia Tech, Blacksburg, VA, 24061, USA

Abstract

Additive manufacturing, specifically 4D-printing, of cellulose nanocrystals (CNCs) is continuing to gain interest. CNC thermoplastic nanocomposites have been demonstrated as a water responsive, mechanically adaptive material that have the capability of being printed with fused filament fabrication (FFF). In this study, a 10wt% CNC thermoplastic polyurethane (TPU) nanocomposite filament is printed using FFF. A processing window for the nanocomposite was established to highlight the effects of thermal energy input on printed part mechanical adaptivity in its dry and wet state. Increasing temperatures and slower speeds within the processing window resulted in thermal energies that induce significant degradation of the CNC/TPU network and reduced storage moduli values for both the dry and wet state. However, the mechanical adaptation persisted for all the printed samples. Additional research is being conducted to determine the effect thermal degradation has on the rheology of the nanocomposite. From preliminary rotational rheometry experiments, it was determined that shear storage moduli and complex viscosity were increasing at the printing temperatures, indicating potential changes in chemical structure. Further potential changes were highlighted with FTIR-ATR. The wavenumbers corresponding with specific bonds related to crosslinking were evident for pieces of nanocomposite filament aged at the respective printing temperatures. These results illustrate significant promise for CNC/TPU nanocomposites in 4D-printed, shape adaptable structures and gives preliminary insight into the kinetics of thermal degradation.



Flow Chart depicting concept of 4D-prinitng, specifically for CNCs. CNCs can form a percolating network within a thermoplastic matrix and then disassociate when immersed in water. Jacob Fallon helped with this figure.

Biography

Tyler Seguine is a Master of Science Student in the department of Materials Science and Engineering at Virginia Tech. He is expected to defend in the Spring of 2021. Tyler also received his Bachelor's in Materials Science and Engineering at Virginia Tech. He works with Dr. Michael Bortner, investigating the use of fused filament fabrication (FFF) to 3D-print mechanically adaptive cellulose nanocrystal (CNC) and thermoplastic polyurethane (TPU) structures. Tyler's main goal is to determine not only the optimized parameters for said nanocomposite, but also to examine the effects elevated temperatures have on the thermal stability of the CNC/TPU nanocomposites during printing.