Supporting Information

Synergistic Cross-linking and Reinforcing Enhancement of Rubber Latex with Cellulose Nanocrystals for Thin Film Glove Applications

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S1. Morphological Analysis of CNCs

Transmission Electron and Atomic Force Microscopic Imaging Analysis

A 200 kV field emission transmission electron microscopy (FEI Tecnai G2 F20 TEM) was used to analyze the morphology of the CNCs. For Atomic Force Microscopy (AFM) imaging, clean silicon wafers were spin coated (3800 rpm for 45 s) with a 0.001 wt % CNC suspension and dried overnight at 70 °C. The sample was then imaged in tapping mode using an AFM (Agilent 5500 AFM).

The morphology and interactions of individual CNC were studied using atomic force microscopy (AFM) and transmission electron microscopy (TEM). The AFM image in Figure S1a of the dry CNC dispersed on a silicon wafer shows individual spindle-like shaped crystals, tightly packed with the highlighted color revealing the diameter and length to be ca. 8 and 170 nm, respectively. measurement of the physical properties in tapping mode revealed the stiffness and strength of the CNCs was determined to be in the order of approximately 155 and 9.8 GPa, respectively. Already dispersed CNCs gel in aqueous solution containing 8 wt % of CNCs was further diluted and dropped on a grid for TEM analysis. Upon drying, the CNCs were stained with uranium to contrast it from the carbon base background.

The TEM image in Figure S1b revealed very interesting results. The length of the CNCs seem to be typically long that the average determined from the AFM analysis. Upon closer examination, it was realized that the CNCs formed a network of individual crystals when in solution, leading to self assembled structure upon removal of the water medium. On the nanoscale, particles can interact depending on their shape, size and charge. CNCs have been known to form liquid crystals, where they self assemble to form an ordered phase of domain[19]. Hence, leading to observations of long fiber-like spindles with dimensions well over 500 nm long as observed in Figure S1b.

Likewise, the packing ability of the individual crystals aid the formation of networks, leading to structures with interlocking and tight packing in the same direction. When applied as a reinforcing material in latex rubber suspending in an aqueous medium, similar behavior and characteristics are expected to occur which is beneficial towards enhancing the physical properties of the latex upon drying.

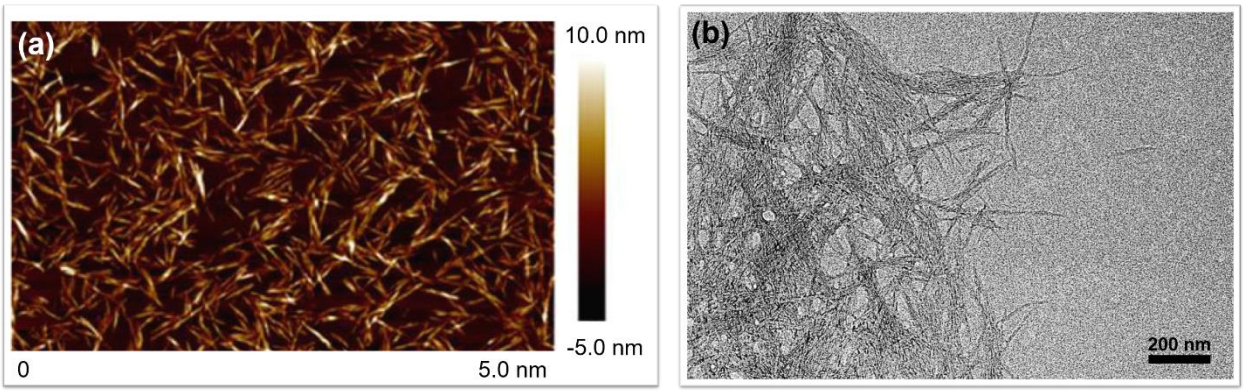

Figure S1. (a) AFM and (b) TEM morphological analysis of dry and water dispersed CNCs, respectively.

S2. Enhanced Zinc Oxide Dispersion with CNC in Water

To investigate the dispersibility and dispersion stability of ZnO in water with and without the aid of CNC, ZnO, CNC and a combination of ZnO and CNC (ZnO:CNC ratios of 1:1, 1:2 and 1:3) were dispersed in deionized water at a total concentration of 1 wt %. Each sample was sonicated for 10 min to allow for proper dispersion of the particulates of each component. The vials containing the dispersed samples were left to sit for a period of 96 h while observing the changes over time.

Figure S2 shows the changes in the dispersion of the suspended particles containing the CNC, ZnO, and ZnO-CNC at different ratios. It can be observed that the ZnO begins to settle after 1 h and is clearly evident after 5 h. At the 24 h mark, pictures of the bottom of the vials were captured

to observe the settled particles. It can be seen that there was a clear difference in the amount of settled particles at the bottom of the vials with the variation in the CNC concentration. A trend that displays a decreasing particle settlement with increasing amount of CNC was noted. This showed that the CNC-ZnO complex formation aids the ZnO to stay suspended in the water longer due to the high dispersibility of CNC stemming from the excellent dispersibility of CNCs in water. Without the aid of CNCs, ZnO settled rapidly due to its high density of ZnO (5.61 g/mL).

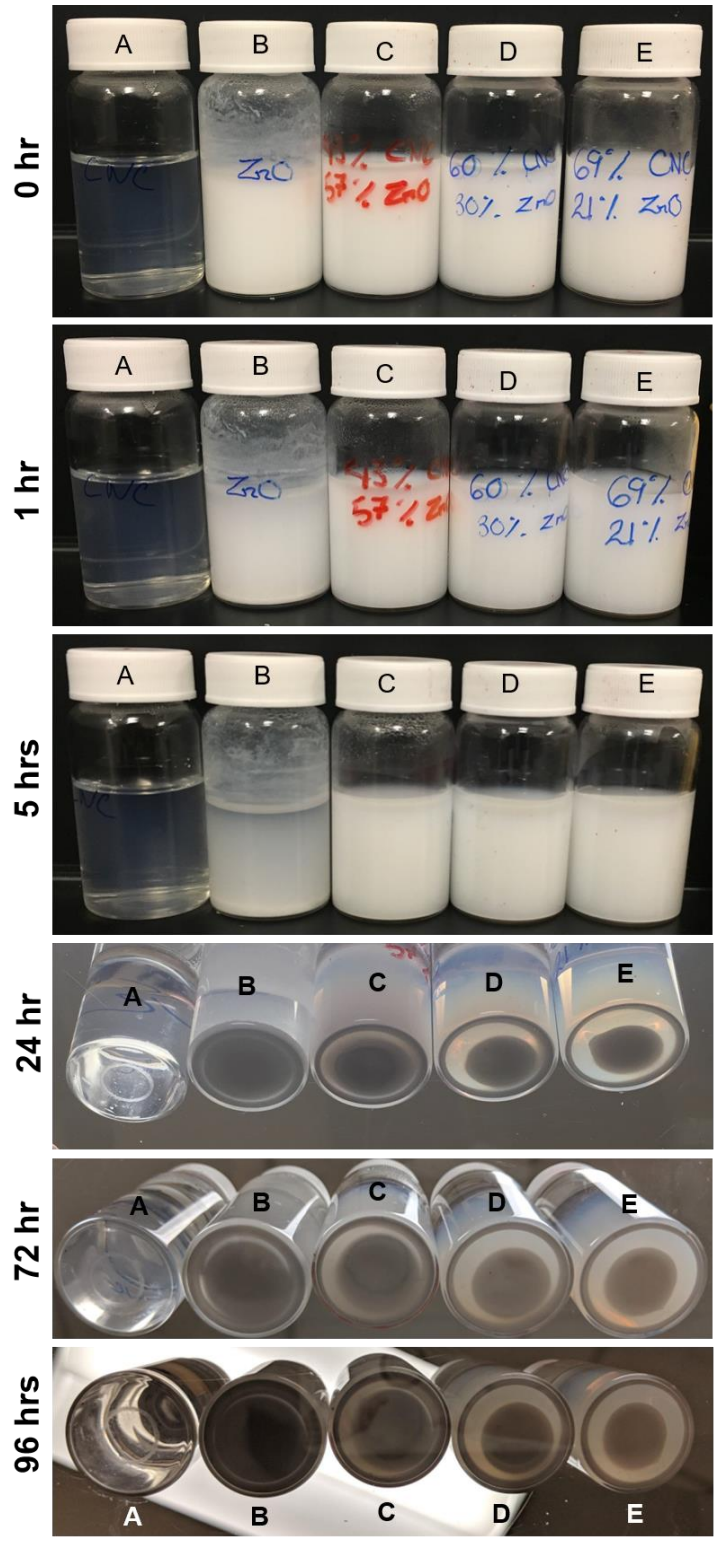

Figure S2: Vials containing sonicated particles in deionized water and left to sit for 96 h (A) CNC, (B) ZnO, (C) ZnO-CNC (1:1), (D) ZnO-CNC (1:2) and (E) ZnO-CNC (1:3).