Engineering of Chiral Phases from Cellulose Nanocrystals: Effect of CNCs Dimension and SO_3 content

V.F. Korolovych [a], V.V. Cherpak [a], R. Xiong [a], R. Ma [a], D. Nepal [b], Timothy J. Bunning [b], Vladimir V. Tsukruk [a]

[a] School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, USA

[b] Air Force Research Laboratory, Materials and Manufacturing Directorate, Wright Patterson Air Force Base, Ohio 45433, USA

One-dimensional rod-like nanostructures with high aspect ratio (10-50) and chiral surface centers such as cellulose nanocrystals (CNCs) are popular light-weight natural nanomaterials with intriguing properties, such as extraordinary mechanical performance, optical transparency and anisotropy, low thermal expansion, low density, large specific surface area, biodegradability and availability [1,2]. Furthermore, the anisotropic shape of these cigar-like nanocrystal (100-500 nm length and 3-20 nm in diameter) provides opportunities to create stimuli-responsive chiral phases at high concentrations (Fig. 1). Despite a number of recent examples on chiral nematic organization, strong chiral laminated nanocomposites, or tunable photonic crystals, some fundamental questions important for the development of novel lightweight mesophase CNC materials with unique mechanical, tunable photonic properties are still not addressed. Among critical issues to be considered are the precise control of CNCs dimension and SO_3 content at the CNCs surface in order to balance local packing and tuning of structure of chiral phase. Here we demonstrate that the size and aspect ratio of CNCs are dependent on the cellulose source. The sources based wood pulp lead to longer nanocrystals with hight aspect ratio. At the same time, sources based microcrystalline cellulose form shoter CNCs with lower aspect ratio. Thus, by selecting different CNC sources, we demonstrate that aspect ratio is an effective parameter to engineering CNC based mesophases in dry and liquid state. Namely, CNCs with a smaller aspect ratio form chiral phases with a smaller pitch value. Removing of solvent from the LC chiral phases decreases the absolute value of pitch, but the trend between aspect ratio and pitch is preserved allowing for simple tuning of structure and photonic properties of CNCs based chiral phases.

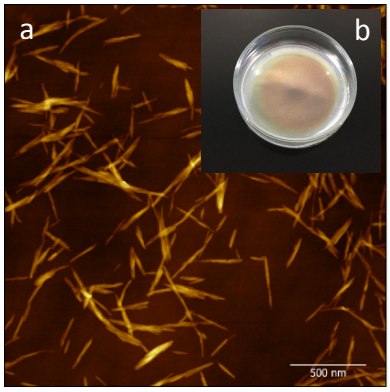

Figure 1. AFM image of CNCs (a) and their chiral phase (b).

References

[1] J.P.F Lagerwall, C. Schütz, M. Salajkova, J. Noh, J. Hyun Park, G. Scalia, L. Bergström. Cellulose nanocrystal-based materials: from liquid crystal self-assembly and glass formation to multifunctional thin films. NPG Asia Materials 2014, 6, p. 1-11.

[2] Ye, C.; Malak, S. T.; Hu, K.; Wu, W.; Tsukruk, V. V. Cellulose Nanocrystal Microcapsules as Tunable Cages for Nano- and Microparticles. ACS Nano 2015, 9, p. 10887–10895.