Final Report

Project acronym: *Cellcolor*

Project number*: 4227*

M-ERA.NET Call 20*16*

Period covered: 1/7/2017 to 31/10/2020

2. Publishable project summary

The aim of the project was to develop original, environmentally friendly, nano-structured surfaces and coatings with engineered optical functionality for coloration and reflection of light. The surfaces and coatings were to be fabricated from cost effective natural materials such as cellulose or clays, which will allow for environmentally friendly colored surfaces with improved energy efficiency, thus providing innovative technology for design or architecture.

During 2017-18 the project mainly focused on fabricating structural colored films based on nanocellulose and nanoclays. It was known that cellulose nano crystals (CNCs) present iridescence and selective reflection of left circularly polarized (LCP) light. It is also well known that aqueous suspensions of clay biaxial platelets can form a nematic uniaxial liquid crystalline phases. In the project we have dissolved different quantities of cellulose nanorods in clay nematic liquid crystalline suspensions. Above a certain critical concentration of cellulose the suspensions are iridescent with a left handed chiral structure. Solid films were prepared from the solutions. We have demonstrated that not only iridescent films can be produced but also their selective reflection of LCP light channel is preserved. The colors reflected by the films can vary from blue to red depending on the amount of CNCs added to the system. This demonstrates that the chirality-transfer, at the nano scale, translates into the photonic characteristics of solid films produced from aqueous CNCs/clay suspensions. The precursor suspensions and the solid films have been investigated by using different techniques such as SEM, AFM and POM. Cellulose nanocrystals (CNCs) rods were successfully prepared from acid hydrolysis, with sulfuric acid, derived from different cotton base sources, as cellulose microcrystalline (Avicel® Ph 101) and filter paper. In these set of reactions different experimental hydrolysis conditions were used, as for instance reaction time. Suspensions of the cellulose nanocrystals were prepared in order to promote the nanocellulose self-assembly into a cholesteric liquid crystalline phase and extensive optical characterization was done in order to attain the liquid crystal phase diagram. A set of techniques were used to characterize the starting and the produced materials, as FTIR, XRD, SEM, AFM, wlemental analysis, as well as TGA/DSC. Photonic structures derived from CNCs aqueous suspensions by solvent casting technique were produced and characterized by means of optical characterization, SEM, UV-VIS-NIR spectrometry.

Photonic structures from CNCs suspensions were produced under a strong magnetic field of 7T and also helices and nonwoven mats by electrospinning techniques.

The clay nano particles tested were hectorite synthetic nanoclays (sodium and lithium), commercial laponite nanoclays and natural vermiculite. Suspensions with different contents of solid content were prepared and characterized by means of optical microscopy, AFM, SEM, DSC and TGA. The most promising photonic materials produced were obtained from 2% by weight of sodium fluorohectorite (NaFh) with CNCs.

During 2019-20 the main objectives of the project "Fabricating cellulose nanocomposites for structural coloration" were achieved. Three photonic systems were prepared from cellulose nanocrystals (CNCs), CNCs and Nano clays, and cellulose derivatives. The systems prepared were studied in solution and as casted solid films. Following the work described in the tasks of the project preparation, characterization and development of cellulose-based photonic structures was performed. Linked to this a manuscript dedicated to cellulose-based biomimetics and applications was written. The description of structures found in Nature are based on general design principles, which are an inspiration to cellulose-based synthetic materials. Wrinkled surfaces are obtained in which the surface topographies are tuned enabling the existence of hierarchical periodic structures. Natural as well as synthetic cellulose-based films with photonic structures are used to illustrate the use of cellulose nematic chiral liquid crystalline structures as a mean to precisely control the structural colors of the films. After plant and cellulose-based water responsive systems are addressed being highlight the role of anisotropic structures, built up from cellulose motifs, on the control of the shape changes of the material in the presence of moisture. Cellulose-based fibers produced from anisotropic solutions are made on demand at the micro/nano scale mimicking the shapes of natural fibers found in plants and spider webs. Natural and cellulose composite systems with optical characteristics sensitive to external fields have been studied.