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Ultra-thin coatings of paper by tailor-made nanoparticles

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Abstract

In this study we have examined the use of nanosized precipitated calcium carbonate and silica particles for creating ultra-thin coating layer on paper. The nanoparticles were stabilized by adsorption of polyelectrolytes on the particle surface. The stabilized particles were combined either with cellulose nanofibril material to create a uniform network structure or used in a bilayer approach. Application of the constructed particle structures on paper enabled adjustable wettability of the surface.

Introduction

Due to the substantially smaller size compared to the solid particles normally used in paper coatings, nanoparticles can provide a useful tool to develop surface treatment procedures for paper (1, 2). At the moment few attempts have been made to use nanoparticles in paper coatings improving for example printing quality (3, 4). In order to utilize nanoparticles in applications, their stability and aggregation tendency has to be considered and controlled. This can be done for example by introducing functional groups on the surface (5) or via adsorption (6, 7).

In the present study nanoparticles were stabilized via adsorption and used as such, or in nanocomposite structures either combined with cellulose nanofibril material (8) or used as adsorption substrate for a hydrophobe. The hydrophobe was applied so that the particle surface was only partially hydrophobized. Such particles might be exploitable in stabilization of emulsions and foams (9, 10).

Materials

Precarb nanosized precipitated calcium carbonate (PCC) was donated by Schaefer Kalk (Diez, Germany) and the silica nanoparticle (SNP) sol (Bindzil 40/130) was produced by Eka Chemicals AB. Pectin (Fluka), poly(allylamine hydrochloride) (PAH, from Sigma-Aldrich) and polyethyleneimine (PEI, from Polysciences Inc.) were used for surface modification of the particles. The nanofibrillated cellulose (NFC) was prepared by disintegration of never dried hard wood using a Masuko supermass colloidor at 3 % consistency.

Results and Discussion

Oppositely charged polyelectrolytes were adsorbed on the nanoparticle surface so that the surface saturation point was reached. This was considered to be the point where the greatest possible amount of a substance has been adsorbed on the particle but no free polymer is present in the solution. Pectin was used for stabilization of nanoPCC particles and PAH and PEI to stabilize
SNPs. The needed concentrations of the polyelectrolytes to stabilize 1 g of nanoparticles were 100 mg, 30 mg and 50 mg of pectin, PAH and PEI, respectively.

The cationic SNPs were further modified by controlled adsorption of a hydrophobe (Fig. 1c) to create particles with only partially covered surface. This bilayer treatment of the SNPs increased the hydrophobicity of the spin coated layer notably.

![Figure 1. Schematic illustration of creating nanocomposite structure using a nanoparticle (a) which is modified with oppositely charged polyelectrolyte (b) and further combined with other substances (c) or immersed into a fibril network (d).](image)

Surface modification of the nanoPCC particles increased the dispersion stability considerably. The spin coated dispersions formed uniform layers where individual nanoparticles were observable. This was not achieved with unmodified nanoPCC particles. The stabilized nanoPCC particles were combined with NFC material, or with NFC material pretreated with PAH, to create a fibril matrix with uniformly distributed particles (Fig. 1d). Application of the fibril-nanoparticle material on paper surface did not increase the water contact angle. However, the penetration of water into paper structure was significantly decreased.

**Conclusions**

Calcium carbonate and silica nanoparticles were successfully stabilized and modified by adsorption. Depending on the chosen modification, the wettability or barrier properties of the coated substrate could be controlled.

**References**