Colloids and Surfaces A: Physicochem. Eng. Aspects 480 (2015) 398–404

Contents lists available at ScienceDirect

Colloids and Surfaces A: Physicochemical and Engineering Aspects

journal homepage: www.elsevier.com/locate/colsurfa

Investigation of an improved deinking process of waste paper – The influence of surface tension and charge in suspension on ink removal

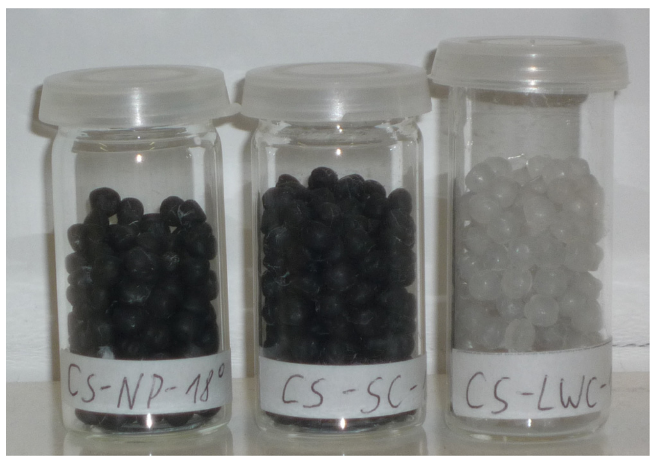
Gudrun Petzold*, Simona Schwarz

Leibniz-Institut für Polymerforschung Dresden e.V., Hohe Straße 6, D-01069 Dresden, Germany

HIGHLIGHTS

- We present a concept for ink removal using polymer particles instead of air bubbles.
- The process is characterized by the properties in suspension.
- Dynamic surface tension can represent possible interactions.
- The efficiency is strongly influenced by the properties of paper.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 31 July 2014
Received in revised form 30 January 2015
Accepted 31 January 2015
Available online 11 February 2015

Keywords:
Cellulose
Surfactant mixture
Deinking
Charge
Surface tension

ABSTRACT

"Adsorption deinking" is a new concept for ink removal from suspensions using polymer particles instead of air bubbles (flotation) in a process with high efficiency, concerning the consumption of energy and water. We studied the influence of different papers and inks, of the deinking solution (compared with water), and of the duration of deinking. The process is characterized not only by the colour of polymer particles, but also by the properties in suspension such as charge, turbidity or particle size. Further it is shown, that dynamic surface tension is a useful tool to characterize not only the surfactant in suspension, but also its interaction with other substances (cellulose and ink). The efficiency of adsorption deinking is strongly influenced by the properties in suspension which depend on the type of paper.

1. Introduction

Recycling of papers by flotation deinking is a very important process, especially in Germany or Western Europe. In Germany about 80% of produced paper will be recycled. A conventional deinking process can be divided into three processes: ink detachment from the fibres, using surfactants and additives, ink agglomeration or ink dispersion and removal of ink by air flotation [1]. Different aspects of this process, such as the effect of process parameters [2], or the influence of deinking chemistry [3–8], pH or types of prints [9,10] on flotation were carefully investigated. The results were also summarized in reviews, for instance by Dorris [9], by

* Corresponding author. Tel.: +49 351 4658 243.
E-mail address: petzold@ipfdd.de (G. Petzold).

http://dx.doi.org/10.1016/j.colsurfa.2015.01.084
0927-7757/

Somasundaran [11], or Borchardt [12], whereas various aspects of newsprint deinking are discussed in [13,14].

But, already in 1976 Sparks and Puddington [15] described "a novel variation of the spherical agglomeration technique" and found that hydrophobic particles, such as polyethylene, or the same material, plasticized with wax, dispersed in pulp suspension, are capable of collecting ink particles. Compared to "deinking by flotation" this technique is said to be more efficient due to a higher pulp consistency and a lower extent of fibre loss [16].

Wasmund and Pelton [17] mentioned as an advantage of Sparks and Puddington's work, that the size and surface chemistry of plastic pellets can be controlled. So plastic pellets coated either with silicone or paraffin oil were used to remove carbon black in water. Ink can be effectively removed by adsorption on polymer surfaces too. Muvundamina [18] showed the benefit of keeping plastic contaminants in the furnish and using them as attributes in deinking. He found that polystyrene displays a more pronounced change in grey level after adsorption of ink than polyethylene.

Handke et al. [19] recently described "adsorption deinking" as a new concept for ink removal in a process with high efficiency, concerning the consumption of energy and water. A mixture of 50% newspaper and 50% magazine paper in suspension (solid content between 3 and 20%) can be deinked by adsorption on polymer particles (granules) such as polyamide (PA) [20]. Compared to flotation deinking, this process works at significantly higher solid content. Therefore the consumption of water and energy can be drastically reduced (water by 90%) [19,20]. The novelty of adsorption deinking, described in [20], is that polymer particles with certain properties (polymer type, size of the particles) are used instead of air bubbles whereas in [15–18] it is described, that plastic contaminants (with or without hydrophobic substances such as silicon or paraffin oil) can be used as attributes in deinking. Further, used particles can be recycled after the deinking by cleaning with a surfactant solution [21].

However, despite the adsorption deinking process worked very well, there is still a lack of understanding of the true mechanism of this deinking process, especially the influence of polymer as well as the type of paper and the type of ink. The aim of the present work was hence to study the "chemistry" of adsorption deinking. At first the influence of the deinking solution (DS) (compared with pure water) and the duration time was investigated using commercial types of printed paper (newspaper and magazine paper). Then the influence of ink – type, such as offset: heat-set or cold-set, was also investigated. The deinking process was characterized not only by the degree of ink adsorption (colour of polymer granules and cellulose), but also by the properties of the DS after removal of the solid material.

2. Experimental

2.1. Polymer

In all experiments polypropylene homopolymer (Hostalen PP H 2150; PP) granules (density 0.900 g/cm^3), ISO 1183, provided by Lyondell Basell Industries, were used as particles.

2.2. Papers and inks

At first usual newspaper (NP) as well as magazine paper (MP) was used to study some aspects of the deinking process such as the influence of duration time.

Later, for a complete investigation of possible interactions, three types of inks (two offset inks, provided by Siegwerk Druckfarben AG and one rotogravure ink) according to Table 1 were used to print on three types of paper. But it is necessary to say that not all of these combinations are certainly applied in practice, for instance Heatset-Newspaper (HS-NP). The printed samples were used for model experiments and supplied by cooperation with the Technical University (TU) Dresden and industry.

2.3. Deinking procedure

Deinking experiments were made in the Institut für Holz- und Papiertechnik, TU Dresden. Each of the printed samples was deinked separately according to [19] using a Hobart-pulper. At first pieces of dry paper (size about 2 cm × 2 cm) were immersed in the "deinking solution" (DS) according to the INGEDE-method 11 [9,22], using oleic acid (0.8%), sodium hydroxide (0.6%), and sodium silicate (1.8%) at pH 8.1. The solid content in suspension is 15%. The duration of deinking was 5, 10, or 20 min. After these times it was easy to remove the coloured particles on the top of the pulper.

2.4. Properties of the suspensions and filtrates

The charge of filtrates (which is negative in all cases) was characterized by the charge compensating polyelectrolyte titration with a particle charge detector (PCD Mütek), using poly-diallyl-dimethyl-ammoniumchloride (PDADMAC, 0.001 mol/l) as polycationic standard. In a similar way the charge of the paper or cellulose (after drying) can be measured (0.1 g of dry cellulose was suspended in 10 ml of Milli-Q-water). The turbidities of the filtrates were measured with a Turbidimeter AN IS, Hach, Germany.

Further, the dynamic surface tension was determined (at 22 °C) to characterize the surface activity of the suspensions, with and without the influence of paper and ink using the bubble pressure tensiometer scienceline t 60 (SITA, Dresden, Germany) with a maximum of bubble lifetime $t = 60$ s.

For a complete characterization of the interactions the properties of the selected 3 types of papers and inks, oleic acid, polymer, and their "mixed suspensions" were investigated separately as shown in Table 2. So, for instance, E characterizes the properties of the paper (without ink) in water whereas D shows the influence of DS on this paper. The "adsorption deinking" process using polymer is simulated by B

3. Results

3.1. Influence of the duration of deinking

It was found previously, that dynamic surface tension is a useful tool to characterize not only surfactants, but also their interaction with other substances in solution such as colloidal substances (stickies) [23]. For basic research a profile analysis tensiometer (PAT; Sinterface) was used, but for this application relevant topic the surface tension was measured with a bubble pressure tensiometer with maximum bubble age of 60 s.

As we will show here, the surface tension of the DS (oleic acid and additives according to INGEDE 11) reacts very sensitive in presence of different papers. The low surface tension of the DS increases by adding printed paper as a result of the decrease of the DS concentration, demonstrating that the surfactant will be adsorbed on the ink and/or the fibre. The extent of this change depends on the properties of papers or inks (Fig. 1).

The surface tension decreases in dependence on the bubble age. For an aqueous solution of a pure surfactant (above the critical micelle concentration) the equilibrium of surface tension is reached very fast, whereas this time can be longer for a surfactant, mixed with additives. As shown in Fig. 1 the equilibrium surface tension for the deinking mixture is reached in about 1 s whereas this time can be much longer, for instance for water soluble polymers or polymer-surfactant complexes [24].