

INTERACTION FORCES BETWEEN INK PARTICLES, CELLULOSE FIBERS AND MINERAL FILLERS AS DETERMINED BY AFM

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Introduction

Recycling of wastepaper is an important industrial activity for the conservation of our natural resources. Wastepaper is mostly generated from newspaper and office waste (from photocopiers and laser printers) [1]. One important step in wastepaper recycling is the separation of ink from cellulose fibers and fillers. The efficiency of ink separation from wastepaper depends on the type of printing process, the type of ink, and the type of paper. For example, it is relatively easy to separate ink from newspaper waste; whereas, the separation of electrophotographic toners from office waste is more difficult mostly because the ink particles are fused during the printing process [2] and their surface properties change.

Typically, the de-inking of wastepaper is a two-step process where organic ink and inorganic mineral fillers (kaolinite, calcite, anatase, etc.) must be detached from cellulose fibers and next washed away from the fiber and/or removed by flotation with dispersed gas bubbles. The efficiency of separation of ink and fillers from cellulose fibers depends upon the solution chemistry of the process water, the surface chemistry of the particles to be separated, and adhesion interactions between cellulose fibers, ink, and mineral fillers. Unfortunately, the surface and solution chemistry for wastepaper de-inking technology is not completely understood. Up until now, selection of chemical reagents for promoting the detachment of ink and mineral particles from cellulose fibers and for improving their separation by flotation, has been based on trial-and-error experiments of pulping and flotation [1].

In this regard, interaction forces play an important role in the selective separation of ink particles from cellulose and filler materials. Determination of these interaction forces should lead to the development of an improved surface chemistry understanding which will provide a fundamental basis for the optimization of reagent use and experimental conditions for de-inking processes technology.

In this work, atomic force microscopy (AFM) has been used for the measurement of interaction forces between the toner inks, cellulose fibers, and mineral fillers and preliminary results are presented. For these experiments a Digital Nanoscope E (Digital Instruments, Inc.) atomic force microscope was used.

Experimental Procedures

Electrophotographic toner particles (~ 10 μm) were glued to the AFM cantilevers with a spring constant of 0.12 N/m and the interaction forces were measured between these toner particles and different substrates that are involved in de-inking flotation.

For the ink/ink system, the substrate used was a paper sheet (double printed by a laser printer). In the case of the ink/cellulose system, the cellulose fibers were pressed at high pressure (20,000 pounds) to make pellets. Before each experiment, the cellulose pellets were immersed in solution (10^{-3} M KCl) for 24 hours to allow for fiber swelling and avoid any instability of the surface during the AFM measurements. For the ink/filler system, the filler used was a single crystal of calcite (CaCO_3). Force measurements were repeated several times for each system in order to assess the reproducibility of the experiment. The error in the reproducibility was found to be within 5%.

Results and Discussion

Figure 1 shows the force/radius versus separation distance curves (approach curves) for the ink/ink, ink/cellulose and ink/calcite systems under acidic conditions. Repulsive forces were observed in the ink/ink and ink/cellulose systems as expected since both ink particles and cellulose fibers are negatively charged at most pH values. On

the other hand, an attractive force was observed for the ink/calcite system indicating that these surfaces are oppositely charged at pH 5.9. The magnitude of the attractive force measured is comparable to that observed in other systems such as the $\text{SiO}_2/\text{Al}_2\text{O}_3$ and $\text{SiO}_2/\text{polymer}$ systems [3].

For alkaline pH values, repulsive forces were observed in all three systems mentioned above as shown in Figure 2.

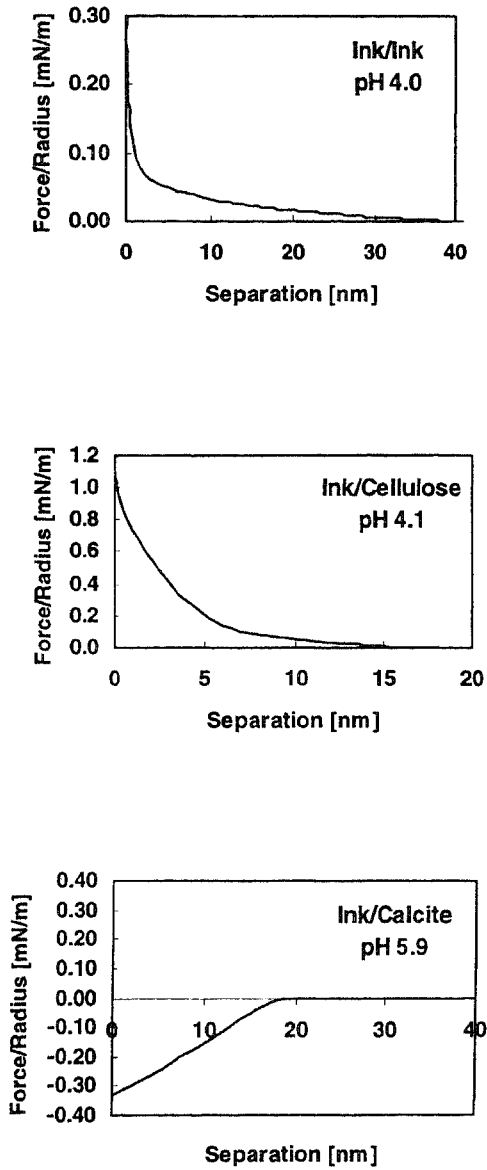


Figure 1 - Force/Radius versus separation curves (approach curves) for ink/ink, ink/cellulose and ink/filler systems under acidic conditions.

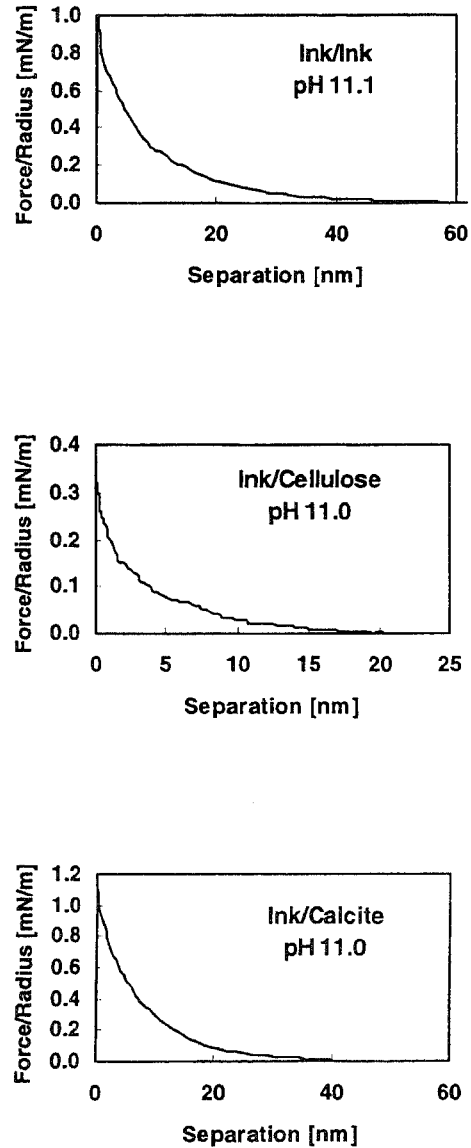


Figure 2 - Force/Radius versus separation curves (approach curves) for ink/ink, ink/cellulose and ink/filler systems under alkaline conditions.

Figure 3 shows the effect of pH on the adhesion force for the ink/calcite system. These adhesion forces were determined from the retract force curves. It can be noted from Figure 3 that the adhesion force tends to decrease as the alkalinity of the solution increases. These results suggest that separation of ink from calcite (filler material) should be facilitated under alkaline conditions. Additional measurements are being made in order to determine the adhesion force at other pH values.

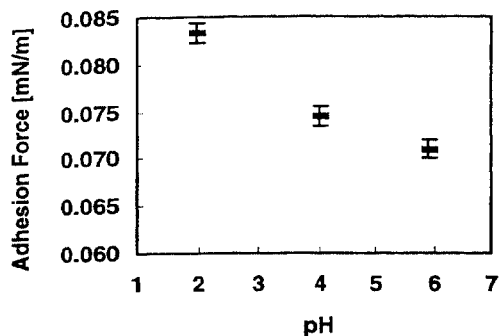


Figure 3 - Effect of pH on the adhesion force for the ink/calcite system.

Ink particles are naturally hydrophobic whereas the cellulose fibers are naturally hydrophilic. Ideally, ink particles should attach to air bubbles and be separated from cellulose fibers during flotation. However, in actual separation, there is always a certain amount of cellulose fibers (5-10%) present in the flotation concentrate along with the ink particles.

The repulsive forces observed between ink particles and cellulose fibers (Figures 1 and 2) indicate that cellulose should not be present in the flotation froth (the ink product known as the rejects). The carryover of cellulose fibers may occur not only due to incomplete release during pulping and mechanical entrapment but, also, due to the interaction force between ink particles and the mineral filler/cellulose fiber aggregates. Such a possibility is evident from the attractive forces observed for the ink/calcite system under acidic conditions. See Figures 1 and 3.

Under alkaline conditions, repulsive forces were observed for the ink/ink, ink/cellulose and the ink/filler (calcite) system. These results suggest that the interaction forces may not be a significant factor in the carryover of cellulose fibers into the ink product during the flotation separation.

Summary and Conclusions

Waste paper pulp is a complex system and consists of organic (ink, cellulose fibers, starch, etc.) and inorganic (kaolinite, calcite, antase, etc.) components. The interaction of these particulates with each other in the presence of chemical reagents is difficult to describe. Understanding the nature of the interaction forces involved will provide a basis to improve de-inking technology and develop more efficient separation processes for the recovery of clean cellulose fibers and the production of high quality recycled paper product.

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