

CHAPTER II

LITERATURE REVIEW

2.1 Ink Removal

Previous studies on surfactant-based deinking process have been carried out on surfaces of either plastic films [Gecol *et al.*, 2001, 2002, 2003] or rigid plastics [Songsiri *et al.*, 2002] in order to remove either water-based or solvent-based [Songsiri *et al.*, 2001; Gecol *et al.*, 2003] ink using an anionic surfactant [Gecol *et al.*, 2001], nonionic surfactants [Gecol *et al.*, 2001, 2002, 2003], an amphoteric surfactant [Gecol *et al.*, 2001,2003], and cationic surfactants [Gecol *et al.*, 2001, 2003; Songsiri, *et al.*, 2002]. For either water- or solvent-based ink, cationic surfactants were found to be the most effective in ink removal at concentrations well above their critical micelle concentration (CMC) and at high pH levels (generally greater than or equal to 11) [Gecol *et al.*, 2001, 2003; Songsiri *et al.*, 2002].

Deinking process involves two sequential steps of adsorption and solubilization. In the adsorption step, surfactant monomers adsorb onto the solid surfaces of both printed ink and plastic, resulting in decreasing the interfacial tensions of the liquid/ink and liquid/plastic interfaces (Rosen, 1989). If the interfacial tensions of plastic/water and ink/water is equal to or less than that of the ink/water interfaces, the printed ink can then be removed from the plastic surface (Rosen, 1989; Adamsom, 1991; Porter, 1994). In the solubilization step, molecularly dispersed ink (or ink binder) is dissolved into surfactant micelles. Hence, the existence of micellar microenvironment is necessary for the success of this step (Shan *et al.*, 1999). Generally, the adsorption of surfactant monomers maximizes in the vicinity of the critical micelle concentration (CMC), while solubilization occurs when the surfactant concentration exceeds the CMC (Rosen, 1989).

To remove solvent-based inks from polymer surfaces, epoxy resin which exists about 82.0 % (Encyclopedia of Polymer Science and Engineering vol 13, 1988) in a normal screen-printing ink formulation plays an important role in the detachment of the ink. The epoxy resin contains epoxy groups and aromatic rings in

its structure. These two components are important for ink detachment by adsorption and solubilization mechanisms.

2.2 Surfactant Adsorption

The adsorption of surfactant relates to two aspects i.e., zeta potential and wettability (Singh *et al.*, 2001; Hanna *et al.*, 1990; Koopal *et al.*, 1999).

2.2.1 Zeta Potential

Zeta potential is the electrical potential of the charged surface at the plane of shear between a particle and surrounding medium as the particle and the medium move with respect to each other (Adamsom, 1991). The electrical potential of ink particles will be changed by the adsorption of surfactant monomer through both electrostatic and van der Waal forces. Surfactant molecules adsorb onto solid surface by electrostatic force through the interaction of opposite charges of the solid surface and the surfactant head group (Shan *et al.*, 1997; Gurses *et al.*, 2003; Hanna *et al.*, 1990; Ninness *et al.*, 2002; Zhao *et al.*, 1996) and the hydrophobic force through the interaction between surfactant tail group and their neighbors or between surfactant tail group and hydrophobic surface of solid (Hanna *et al.*, 1990; Ninness *et al.*, 2002; Zhao *et al.*, 1996; Biswas *et al.*, 1997; Sarrazin-Cartalas *et al.*, 1994). The amount of surfactant molecules adsorbing on ink surface can be justified by several factors such as the area of head group and the structure of tails group of the surfactant. Both concentration and the number of carbon atoms of the hydrophobic tail group (Ajay *et al.*, 1996; Wang *et al.*, 1999) are major factors affecting the zeta potential of hydrophilic surface because they govern the number of surfactant molecules adsorbing onto a charged surface (Ajay and Sharad, 1996; Wang *et al.*, 1999). While the charge of the ink surface, which limits the number of surfactant monomers to be adsorbed onto ink surface, depends on the pH of solution (Jual *et al.*, 1996; Wang *et al.*, 1999). If the solution pH is adjusted below the point of zero charge (PZC) of the solid surface, the solid surface becomes positive. In contrary, it is negative when the solution pH is greater than the PZC.

2.2.2 Wettability

The surfactant adsorption also affects wettability, which indicates the displacement of air by liquid on solid surface, resulting from the surface tension of CnTAB solution is less than the critical surface tension of ink [Rosen,1989]. Ink detachment occurs when the sum of polymer-water and ink-water interfacial tensions are equal to or less than that of the ink-polymer interfacial tension [Rosen,1989; Broze,1994]. The decreases of ink-water interfacial tensions can be taken place when CnTAB solution attaches or spreads on ink surface or the decrease of contact angle of CnTAB solution on ink. Contact angle is the tangent between the liquid surface and the solid surface [Drelich *et al.*,1996]. The higher the wettability, the lower contact angle appears. The adsorption of surfactant on ink attributes to the decrease of ink and binder/water and HDPE/water interfacial tensions, making the detachment more thermodynamically favorable. It is the same as mechanism aiding detergency of both particulate and oily soils [Rosen,1989; Broze,1995]. The formation of a water layer between ink/binder particles and the plastic surface or wettability of surface by surfactants is important for deinking. If the deinking solution can wet on ink surface, the ink removal process will occur. Therefore, the factors affecting the adsorption such as concentration and tail chain length of surfactant also govern the wettability of liquid as well. For the effect of tail chain length, wettability on solid surface decreases with increasing carbon atoms in the tail chain length of Alkyltrimethylammonium bromides (CnTAB) ($n = 12, 14$ and 16) too [Balasuwatthi *et al.*,2004]. Moreover, it was found that the results of zeta potential and wettability of both CTAB on a non-metallic surface and DTAB on silica were found to be corresponded with each other [Gurses *et al.*,2003; Singh *et al.*,2001].

2.3 Solubilization

Solubilization is an important process for deinking when the surfactant concentration exceeds the CMC. The solubilization capacity depends upon the amount of solubilize to be solubilized into surfactant micelles. Therefore, the structures of both surfactant and solubilize are the main factors controlling the solubilization capacity. According to the study of the solubilization of amphiphilic

hemicyanine dyes in CTAB solution, the aromatic ring of the dyes is solubilized into the palisade layer of CTAB micelles while the negative charge of sulfonate group simply associates with the positive charge of the CTAB head group (Shan *et al.*, 1997). The environment in micelles such as the hydrophobicity, which results from the aggregation number of surfactant and the hydrophobic property of surfactant tail group (Rosen,1989). The parameters that affect the aggregation number are the number of carbon atom in the tail group, temperature and added salt. It has been found that adding salt into surfactant solution increases the aggregation number of surfactant (Swanson-Vethamuthu *et al.*, 1996). On the other hand, increasing temperature of surfactant solution results in a decrease in the aggregation number of surfactant (Dorrance *et al.*, 1974; Malliaris *et al.*, 1985). Moreover, the concentration of surfactant affects the amount of micelle in the solution, the number of surfactant micelle increases slightly with increasing surfactant concentration.