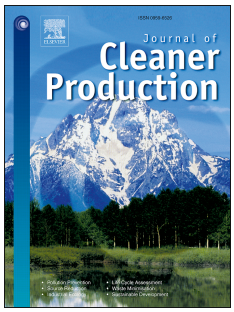
Accepted Manuscript



Examining regeneration technologies for etching solutions: a critical analysis of the characteristics and potentials

Miao Yu, Xianlai Zeng, Qingbin Song, Lili Liu, Jinhui Li

PII: S0959-6526(15)01603-0

DOI: 10.1016/j.jclepro.2015.10.131

Reference: JCLP 6362

To appear in: *Journal of Cleaner Production*

Received Date: 15 December 2014

Revised Date: 30 October 2015

Accepted Date: 30 October 2015

Please cite this article as: Yu M, Zeng X, Song Q, Liu L, Li J, Examining regeneration technologies for etching solutions: a critical analysis of the characteristics and potentials, *Journal of Cleaner Production* (2015), doi: 10.1016/j.jclepro.2015.10.131.

Examining regeneration technologies for etching solutions: a critical analysis of the characteristics and potentials

Miao Yu, Xianlai Zeng, Qingbin Song, Lili Liu, Jinhui Li

State Key Joint Laboratory of Environment Simulation and Pollution Control, School of Environment, Tsinghua University, Beijing 100084, China

Abstract: Globally, more than one billion cubic meters of waste etchants from printed circuit board industry have been generated annually with an increase of 15-18%. Nowadays, the approach of adding extra chemicals has been utilized to treat a large number of waste etchants, which could obtain low-pure products, but seriously pollute the environment. Furthermore, the processing enterprise cannot gain so much value that is affecting sustainable development. In the previous studies, the regeneration technologies of etching solution have not been studied comprehensively and systematically, so it is of extreme necessity to examine and choose the suitable technology towards a closed-loop supply chain. The results showed that previous etching solution (e.g. ammonium persulfate, sulfur/chromic acid, sulfuric acid/hydrogen peroxide, sodium chloride, ferric chloride) caused severe pollution without proper disposal, but most of the current etchants (e.g. cupric chloride, alkaline etching solution) can be renewable after substantially recycling heavy metals from the etchants. Regarding the latest emerging solution, the used oxidant such as chlorine is regarded as the major risk sources even if it has extraordinary etching ability. The current etching solutions could meet the goal of sustainable development of resources and the environment. For the copper chloride etching solutions that are now widely applied, there are various regeneration approaches, but only two are more favorable than the others. Among all the regeneration technologies, the electrolytic process and membrane technology not only get more pure products, but the residue solution can be renewable. Finally, we employed the analytic hierarchy process to compare the regeneration techniques and found that the electrolytic method and membrane technology are superior to other methods in the economic and environmental performance. The two methods can replace the chemical precipitation, which will sustain the printed circuit board industry.

Keywords: printed circuit boards; etching solution; regeneration technology; potential; comparison

1. Introduction

Printed circuit boards (PCBs) are fundamental components of all types of electronic and electrical equipment (Chen et al., 2015; Ghosh et al., 2015; Li et al., 2014). During the years, 2006 - 2010, the average growth of PCB production was 2.5% in the world annually. And in 2009, the total production of household appliances (e.g. computers, televisions, washing machines, refrigerators, air conditioners, etc.) has grown to one billion. In 2014, the total production of electronic and electrical equipment in Africa was 19 tons, the Americas 117 tons, Asia 160 tons and Oceania 6 tons. And in each region, the most quantity of domestic production per country are as follows: Egypt produced 3 tons, the United States of America 70 tons, China 60 tons and Australia 4 tons (Baldé et al., 2015).

The production of PCBs per square meter generates an average of 1.5-3.5L etchant (Allen and Almond, 2004; Peng and Chen, 2007), and in total it has yielded about one billion cubic meters around the world annually. Waste etching solutions are either acid or alkaline, and they contain a large number of copper (Jung et al., 2012). More than 70 thousand tons of copper are existed in waste etching solution each year. Arbitrary processing of the spent