Emerging Issue in a Proper Recycling Technology for the Non-Metallic Portion Separated from Printed Circuit Board Scrap: A Pyrolysis Based Recycling Approach

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INTRODUCTION

Nowadays, E-waste is one of the fastest growing waste streams worldwide. In 2009 alone, approximately 53 million tonnes of e-waste were generated. It is continuing to grow up by 3-5 % per Annum or approximately three times faster than other individual waste stream in solid waste sector (Schwarzer et al., 2005). Printed circuit board (PCB) is an essential component of electric and electronic equipment thus this resulting a significant increased number of PCB waste generated per year. Recycling is becoming an essential part to be considered due to the material diversity, and its complex structure. Although, the development of newer technologies and methods to recycle PCB have been investigated for decades. The recycling process in many developing regions are still primitive, and they are based on the separation of the precious element from PCB waste and reused it as material utilization.
Many of the material in PCB waste are able to be recovered and reused. However, the separation process is a key process for the successful of the further material recovery process. Amongst other things, the metals can be gather and recover to a like new material whilst plastics and other non metallic materials can also be recovered in some way. Non- metallic material after the precious metal separation process are not coped with the proper treatment such as landfill or combustion. Landfilling can seriously harm the environment by heavy metals leaching into the soil and ground water. Whilst, combustion of these products can release large quantities of hazardous chemical to surroundings. The ashes from combustion are often contaminated with toxicant element such as lead and other heavy metals. Although recently some hazardous chemicals, including flame retardants and heavy metals such as lead, mercury, chromium and cadmium have been banned from PCB industry. Still a vast amount of older PCB waste once they are discarded. The important constraints of these composite materials are how to be recovered correctly. Typically, thermosetting plastic can not be treated with the normal heating in order to be reformed. This resulting that the proper techniques shall be with other distinctive heating process. The crucial point is that thermoset plastic would be the ignition under oxygen atmosphere. However, there is a technique known as pyrolysis. It is the process with the capability to convert organic compound into gas and liquid within the reactor where heated and absence of oxygen. The aim of this paper is to provide an overview of an alternative proper treatment for this emerging issue and given its current approach techniques and comparisons. The paper will address the issue of using pyrolysis method for PCB waste recycling and, will explore the initiative as it is a proper recycling process of this waste stream. Throughout the paper, the emphasis will be on comparing the current available treatment which have been using worldwide and the pyrolysis method applied for recycling.

PCB material recycling method

Recycling of PCB is a serious concern not only of the environment but also the recovery of valuable materials. A successful recycling approach of PCB should take into consideration of recycled items support in order to compensate for the recycling cost, the investment and the environmental impacts. Recycling of PCB in particular is still a challenging task due to the diversity of these materials and the evolution of toxic substances. In the past, recovering of precious metal from PCB such as copper (Cu) was carried out on a large scale for a positive economic revenue and in terms of material utilization, whilst the non metallic material were treated with traditional process such as landfilling, combustion and reused as filler material. The environmental awareness pushed now toward a more comprehensive processes which includes recovering and recycling of ceramics and organic fractions in substitution to not eco-efficient disposal in this traditional pathway. Pyrolysis recycling is attractive because it allows recovering organic products in flammable gas, oil, and carbon solid residue. However, there

are additional controls needed to be considered in terms of flame retardants and toxic substances included in non metallic fraction can pollute the environment. In normal PCB recycling process required several steps such as disassemble of components (for printed circuit board assembled (PCBA) if necessary), physical recycling and then chemical recycling. Metal recovery can be performed by pyrometallurgical process. Crushing and separation are the key point for the successful improvement of further treatment. Non metallic fraction (NMF) after precious metal separation are now needed to be considered. In general, NMF consists of ceramics, short length glass fiber and thermoset plastic. From aforementioned data detailing that pyrolysis is suitable with organic products including plastics whiling thermoset plastics requires exceptional heating without oxygen, thus pyrolysis seems to be suitable for these materials. However the toxicant substances generation need to be investigated.

Problems associated with current PCB disposal treatment

Landfilling
As the non-metallic powder containing heavy metals, landfill may cause potential danger to the environment and security, for the leachate would penetrate to groundwater. On the other hand, it increases the scarcity of land, and it is a serious resource wasting (W. Li et al., 2012).

Combustion
Incineration, non-metallic powders carry a large number of low calorific value composite, such as glass fibers and other inorganic constituents. As a result, the heat generated in the incineration is not high enough. Meanwhile, it may produce large amounts of dioxins and other carcinogens, causing serious environmental contamination (W. Li et al., 2012).

Reused by apply into new products
According to the different of the composite materials, non metallic material could be applied to make types of product. For example, asphalt, cement mortar and environmental friendly concrete members (W. Ru et al., 2011). Glass reinforced plastic materials can be used to apply with fiber reinforce plastics FRP. Non metallic material was applied in powder form with the short length glass fiber. The short has improved FRP mechanical and physical performance especially bending strength. Reused as phenolic molding compound e.g. Filler material can be improved their flexural strength, impact strength, water absorption and the heat resistance (W. Li et al., 2012).

Pyrolysis method associated with PCB

There are two scenarios of the pyrolysis associated with the PCB waste. First, in case that non metallic materials have been separated from metal portion before processed with the pyrolysis method. Otherwise, PCB waste would be processed only with pyrolysis without mechanical separation. Mechanical separation enhances the further heating process because of the increased contacting area with heat. However, size reduction from mechanical separation limits the further used of glass fiber and requires high energy consumption of crushing equipment because of the hardness and tenacity of PCB product.

Pyrolysis of thermosetting plastic in PCB
Pyrolysis is a thermochemical decomposition of organic material in the heating reactor by using elevated temperature without participation of oxygen in the chemical reaction. Thermosetting plastic is the main organic material included in PCB. The differences in thermal property of the materials in PCB are quite wide and can be ranged up from thermoset plastic, fiber glass and ceramic respectively. Hence, there is an opportunity to a total separation of this complex material for a further material utilization process. Pyrolysis technique can be used in both before or after metal separation. The pyrolysis process turns

resin plastics into flammable gas and condense into flammable liquid form. Fuel oil is the main output product from pyrolysis process. Most of the past research operated pyrolysis temperature approximately range from 400 ~ 550 C. and condense at different range of temperature. An extremely low temperature of gas compensation gave highest output yields. However, in this case the hydrogen chemical reaction may not be fully finished. As a result, the output product has become a wax form and requires a fuel distillation process. On the other hand, the condensate of pyrolysis gas with a narrow range of temperature has given a better result in the quality of flammable liquid (fuel oil) but lower in quantity yield from the pyrolysis gas condensation process.

Recycling of glass fibers from pyrolysis

After pyrolysis process, glass fiber and ceramics have been found in solid residue with carbon deposited on the surface. It can be operated with 450 C. to completely burn carbon off, and then clean up by rinsed several times with distilled water to remove ash and finally air dry (Cui et al., 2010; Guan et al., 2008).

CONCLUSIONS

As the most potential approach for PCB recycling, the pyrolysis technique still need a high level of skill and equipment. Meanwhile, these primitive treatments for the overabundant amount of PCB waste generated per year are not sustainable and eco-friendly. From past research indicated that pyrolysis process is able to recover organic part of PCB into flammable liquid and gases. This could be a potential approach for PCB recycling in the near future. However the flame retardant and product additive in PCB may influence on the quality of the output products, this aspect need to be further investigated. The current disposal treatments of non metallic material from PCB waste are totally improper. They cause secondhand pollution and resource wasting. The results of this study have pointed out that pyrolysis method can be applied for PCB recycling process and suit for using as material recycle treatment for the non-metallic fraction from PCB waste.

REFERENCES

Cui Quan, Aimin Li, Ningbo Gao, Zhang dan, 2010. Characterization of products recycling from PCB waste pyrolysis. Journal of Analytical and Applied Pyrolysis, 89(1):102-106

Guan Jie, Li Ying-Shun, Lu Mai-Xi, 2008. Product characterization of waste printed circuit board by pyrolysis. Journal of Analytical and Applied Pyrolysis, 83(2):185-189

Schwarzer,S., Bono, A.D., Peduzzi, P., Giuliani,G. & Kluser, S. (2005). E-waste, the hidden side of IT equipment's manufacturing and use. UNEP Early Warning on Emerging Environmental Threats No.5.

Wang R, Wang PM, Zhang TF. A non-metallic powders of waste printed circuit boards environmentally friendly cement mortar in China Patent No.: 201110178408.4,2011.

Wenhong Li, Yan Zhi, Qingyin Dong, Lili Liu, Jinhui Li, Shili Liu, Henghua Xie, 2012. Research progress on the recycling technology for nonmetallic materials from wasted printed circuit board.The 7th International Conference on Waste Management and Technology. Procedia Environmental Sciences 16 (2012) 569 – 575

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