"Photo-etching" Technique in Metal Decoration (Focusing on Aluminum Surface)

Indera Irawan B. Mohd Rawi Chandran
Lecturer
Department of Industrial Design
Universiti Teknologi Mara
Malaysia

Abstract

Photo-etching is a metal plate, usually copper, is coated with a light sensitive emulsion. This is then put into contact with photographic negative and exposed to light, which harden the clean parts of design. When processed the hardened parts of the coating act as an acid resist and the plate is then etched often with the addition of aquatint to create tonal contrasts. However, in this study, the researcher uses aluminum in place of copper as it is easily accessible and costs savy The researcher carries out twenty seven samplings to arrive to a hypothesis that photo-etching technique is an application in making decoration on the aluminum surface. Time is set from two minutes to about ten minutes using seven types of chemicals such as nitric acid, ferric chloride, hydrochloric acid, copper salt, sodium suphite, zinc chloride and sulfuric acid as corrosive agent at different trials or experiment. The findings depict that ferric chloride and hydrochloric acid are found to be the most appropriate corrosive agents to obtain the texture. Beside that, this study also explores the effects of corrosive agents on the aluminum and it is evident that chemicals like zinc chloride and sulfuric acid though a cleaner solution, is corrosive enough to destroy the photo-resist, which sticks on aluminum surface. Last but not least, this research will highlight the uniqueness of photo-etching and extend adequate knowledge on the craftwork. As this technique is rarely used and possessed high artistic value, it has potential to achieve recognition and popularity if given the opportunity.

1. Introduction

The number of products made of metal especially aluminum continues to grow significantly year after year. The material is well known and it can be of further use if people know how to explore its fullest potential of it especially in art technology. The researcher would like to take the opportunity to introduce the technique which is called "photo-etching". Most of the applications from this technique are used for making art decorations on metal. In Malaysia, aluminum and "photo-etching" technique are used in various areas including people's home, farm, transportation, industry, construction and home utensils. The "photo-etching" technique on aluminum surface will attract people because of its unique artistic appearance and most of these products will exist in signage, souvenir and the electronic accessories.

1.1 Problem statement

Photo-etching technique is useful in producing designs that are desirable, marketable and is equally essential for the commercial and metal industry. However, there are some irrefutable weaknesses that are very obvious in this research as listed below:

- Lack of resources through the Internet and books especially in "photo-etching" technique on aluminum.
- Lack of knowledge on "photo-etching" technique and the aluminum among art student in local colleges and a universities.

1.2 Research objectives

- To contribute and share knowledge of the technique and material in the colleges in terms of academic level and practical training at colleges and universities.
- To improve and educate on the technique and the material.
- To produce a design and product that unique, attractive and marketable to consumers.

1.3 Hypothesis

There is one hypothesis in this study:

- This "photo-etching" technique is applicable in making decoration on the aluminum surface.

1.4 Research methodology

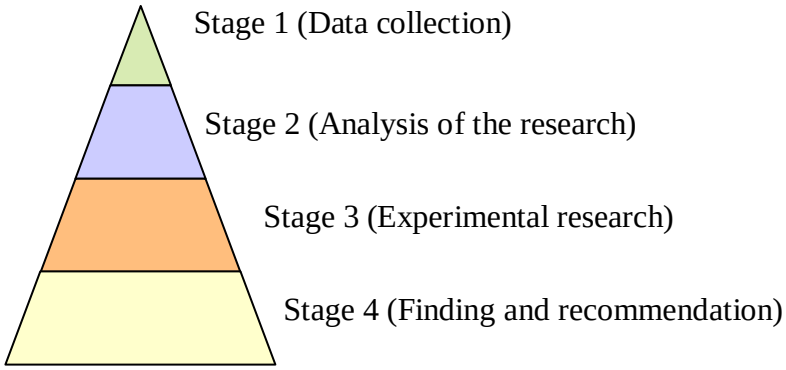


Diagram 1 Stage of the research methodology

In this research, several exploratory approaches will be adopted. The main approach is to collect some basic understanding on the issue from different perspectives and develop some testable hypothesis for future research in this subject. This research will be in the form of various experiments and an observational research. Based on the fundamental knowledge on "photo-etching" technique, this study will trace the development of aluminum as a background material in order to understand the changes in today's metal design industry. This would also involve the collection of sample from the experiment, so as to get in depth understanding of the research.

This study will explain the principle of the aluminum and "photo-etching" technique, which existed in a design and the technology applied. All the samples and the photo shot for the presentation and paperwork would be provided. This research will compile and analyze information about the "photo-etching" on aluminum surface, such as:-

- Design and texture
- Procedure (including the chemical used and its reaction)
- Result and finding

1.5 Significance of the study

This significant experiment is to educate and create awareness among art and design student on the importance of aluminum in "photo-etching" technique. Besides, this scenario will guide and act as reference in terms of education for art and design student and those involved in the industry.

- This research is carried out away aluminum into the metal industry and create beneficial satisfaction to those involved; to provide opportunities in career advancement and to import pertinent knowledge and skill in order to become a good designer or manufacturer.
- New methods and findings are used as reference based on local needs which would be beneficial to those interested in this technique and material.
- Manual reference for young designers to learn how to apply aluminum in "photo-etching" technique, create new design and produce marketable products.

1.6 Literature review of research

In this literature review, there are a few references have been used to further elaborate this topic and discuss the research of view.

*"**Photo-etching** gives the ability to have a literal use of text and photography and **"photo- etching"** gives texture and shadow. (Marty, 2003)"*

Marty also discussed the importance of **"photo-etching"** because this technique could create and make interesting and make texture and shadow on the metal surface.

Another review is from the Craft Journal written by Jan Janeiro According to Janeiro (2001), John Garrett, a reknowed artist from Mexico uses almost aluminum on all his artwork. John Garrett is said to have been working simultaneously with two or three-dimensional formats, using thin strips of aluminum and painting it. Aluminum was not only used for industry, but it can also be used for craft and artwork, *(Jan Janeiro, 2001)*.

The third review is from the Frostburg University Photo Etching Workshop written by Calvin Custen (2001) which is about the demonstration of photo etching. Calvin Custen is the person who shows a demonstration known as the Maryland Print Maker. He gave some background details about the film and how it has been used in the printed circuit board industry for over 20 years and many of the students enjoyed the demonstration and were interested in the technique introduced by him *(Calvin Custen, 2001)*.

The three statements above demonstrate the importance of the photo-etching technique and the aluminum. This technique is quite interesting and have been used and developed in college and university abroad. But in local education scenario, there is still lack of adequate knowledge perhaps due to insufficient exposure and participation from students.

2. Research methodology

The researcher aims to conduct various tests using corrosive media and designs in order to investigate and determine the best solution method which can effectively corrode aluminum surfaces. There are seven types of corrosive media used in these experiments but the researcher has discovered that ferric chloride is the best chemical element. However, the researcher seeks to experiment with other corrosive media to investigate new method and solutions to improve the 'photo-etching' technique. Some of the samples are done manually and this is known as bath technique as plastic tray is used during the manual etching process. The researcher would only use etching machine when ferric chloride is added in the experiment samples as it more time consuming and it is easier to use the machine rather than soaking the samples in the tray. The researcher did **twenty seven** experiment samples include using **nitric acid, ferric chloride, hydrochloric acid, copper salt, sodium suphite, zinc chloride and sulfuric acid** in order to obtain reliable results as these tests were done using different corrosive media which combined with metal produces etching designs.

All these experiments use a 2mm (thickness) aluminum plate and before commencing with the etching process, the aluminum plate must be cleaned using detergent as is this chemical can be used to clean the metal surface.

Experiment 1

In this first test, researcher used rubber cement gum as the resist and starts to create abstract design on the metal surface. Then, the researcher added two parts of water and one part of **nitric acid** in which the metal plate would be soaked in the tray for one minute. However, no reaction was detected between the mordant and aluminum plate as there were no bubble and the solution did not corrode. Due to this, researcher concluded that one minute was too brief for corrosion to react on aluminum surface.

Before

After

Figure 1: The researcher uses rubber cement gum as the resist and .

Experiment 2

As in the second experiment, researcher used the same material, resist and design. The only difference was in the time allowed for the etching process to react. However, its result was similar to the first test and this has proven that 5 minutes was too brief for corrosion to react.

Experiment 3

By using the same procedures in experiment two, researcher decided to add more acid to determine chemical strength and whether it would corrode the metal surface.

But it was discovered that the result was still similar to the first and second experiments and the conclusion was that 5 minutes was too short a time for any corrode effect

Experiment 4

Researcher progressed to experiment 4 and decided to increase the timing from 5-minute to 10-minute using the same materials. There was slight reaction but the effect was not really obvious. Researcher then decided to increase the acid quantity and the experiment time in order to create significant etching on the metal surface.

Experiment 5

As slight reaction was detected in experiment 4, researcher decided to stretch the timing from 10-minute to 30-minute using the same material and resist. The only changes were the media used whereby researcher experiments using one part water,three parts acid to make a stronger mordant and pa glue as the resist . However, only mild reaction and slight etching effect was noted as in experiment 4. Therefore, researcher concluded that even by increasing the quantity of nitric acid the aluminum surface would not corrode. Hence, researcher decided to try using ferric chloride for the next experiment.

Before After

Figure 2: The researcher use pa glue as the resist.

Experiment 6

In this experiment, same material was used using three parts of **ferric chloride** and one part of water with no resist. Researcher's timing was at 3 minutes and this resulted in proper reaction as this chemical could corrode the aluminum surface and change in texture and colour was noted on the aluminum surface. The conclusion was that ferric chloride is suitable for aluminum in etching technique. In the next experiment, researcher will try different resist and using varying timing before commencing with the 'photo-etching' technique.

Figure 3: Effect from using the ferric chloride without resist

Figure 4: Effects of the rubber cement gum as the resist for ferric chloride.

Experiment 7

In this experiment, researcher used same material and corrosive media. The only difference was that researcher uses permanent marker as resist and trying to create dotted designs in 3 minutes. The result was that chemical corrodes the metal surface and there were textures on the aluminum surface.

Therefore, it was concluded that although the timing was appropriate, the etching was not significant. As a result the duration of etching process needs to be increased.

Figure 5: (Experiment 7) Effects on use of the permanent marker as the resist for ferric chloride.

Experiment 8

Researcher uses the same material combined with gloss black to act as resist and ferric chloride as it is a corrosive media. Researcher wanted to etch a line as the etching design and by conducting the 3-minute test on the surface. It was noted that the chemical corroded the aluminum surface as there were line textures appearing on the metal. The conclusion was that this method is not really suitable and the timing needs to be increase in order to develop good and significant etching technique on metal surfaces.

Figure 6: (Experiment 8) Effects from a 3-minute corrosion and uses the gloss black paint as the resist for ferric chloride

Experiment 9

In this experiment, researcher conducted test using the same material combined with gloss black to act as resist and ferric chloride as it is a corrosive media. However, researcher decided to increase the time trial to 5 minutes in order to create a deep etching line on the metal surface. Again, it was noted that the chemical corroded the aluminum surface as there were line textures appearing on the metal but this method was not really suitable and timing needs to be increased in order to create good and deep etching technique on the metal.

Figure 7: (Experiment 9) Effects from a 5-minute corrosion and uses the gloss black paint as the resist for ferric chloride

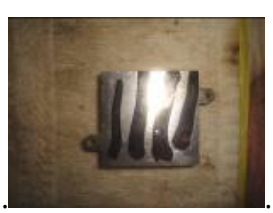
Experiment 10

For the next test, researcher still used same material, resist and corrosive media. The only difference was the time trial which has been increased to 10 minutes. Same results as the previous experiments were detected whereby the aluminum was corroded by chemical used and line design appeared. Hence, it was concluded that 10 minutes was suitable to obtain deep etching design as this depended on the strength of the acid used in the experiment. But then, researcher deems this trial as unsatisfactory as the etching does not effectively carve distinct design on the metal surface. For next experiment, researcher would use a different kind of material known as coated aluminum.

Figure 8: (Experiment 10) Effects from a 10-minute corrosion and uses the gloss black paint as the resist for ferric chloride.

Experiment 11

By using coated aluminum and same element of resist and corrosive media, the researcher tries to determine whether this combination could corrode the surface in a 5-minute trial duration. The result was that the chemical did not corrode the metal as there was no visible design appearing on the surface at all. Therefore, it was concluded that coated aluminum was not suitable to use for etching technique. Researcher will conduct next experiment using photo-resist on aluminum surface in order to get good photo etching technique. Researcher would also examine two kinds of line film, both the positive and negative sides of the design throughout the testing.



Before

After

Figure 9: (Experiment 11) Apply the gloss black paint as the resist on the coated aluminum

Experiment 12

This experiment was done by applying photo-resist on aluminum surface to generate etching reaction on the positive side of the film. Researcher conducted a 10-minute trial and it was found that the chemical corroded the metal and there were letter form and geometrical shape was released on the surface as a result of the reaction. Hence, the existence of the release form and geometrical shape through the use of the positive film proved that this technique do take effect and create reaction. However, a black spot that appeared on the metal seed to alter the design of a supposedly logo on the aluminum surface.

Figure 10: Coated aluminum plate with the photo-resist chemical before exposure under the UV light

Figure 11: (Experiment 12) Coated aluminum plate with the photo-resist chemical before exposure under the UV light.

Experiment 13

As in experiment 12, same material, resist and corrosive media were used and the trial time remained for 10-minute. The only difference was that these solutions were applied on the negative side of the film. The etching reaction happening was noted and this proved that the chemical corroded the metal as logo used depicting alphabets and geometric shape burnt the engraving and appears distinctively on surface. The conclusion was that by using negative film, it could effectively assist in photo etching technique as an engraving style was seen materialising on the metal.

Figure 12: (Experiment 13) the effect of using the negative line film.

Experiment 14

In this test, researcher tried again to determine the effectiveness of the combined solution as in experiment 13 to create the best photo etching technique. It was noted that the chemical did corrode the metal after 10 minutes and there were typographic designs released from the aluminum surface. However, since the researcher applied inaccurate procedure whilst sticking off the line film on the metal surface and position of design was wrongly placed, therefore etching reaction was unsatisfactory and results of this experiment was to be considered invalid.

Figure 13: (Experiment 14) The effect of using typographic design and positive line film

Experiment 15

As part of test and error process, the researcher is still experimenting using the same material, resist and corrosive media to create typographic design as in the previous experiment. This time, researcher used the negative side of the film for 10 minutes and it was noted that the chemical corroded as deep etching design appeared on the metal surface. However, as the line film was not properly used and applied on the aluminum metal, therefore it has spoiled the surface after etching process.

Figure 14: (Experiment 15) The effect of using typographic design and negative line film.

Experiment 16

In this experiment researcher maintained the use of material, resist and corrosive as in previous tests. This time the positive side of the film was used in order to produce etching logo designs in 10 minutes. Researcher noted reaction as the chemical corroded the metal badly and spoiled the surface. As a result, there was no definite etching that defined the designs as the metal surface was badly damaged during this process.

The conclusion derived from this experiment, was that due to lack of quantity in photo-resist on the aluminum metal could not be visibly seen small letter form logo as distinctive as duplicating the exact word size from the template.

Figure 15: (Experiment 16) The effect of using of logo design and positive line film.

Experiment 17

For this experiment, same material, resist and corrosive were used and trial time remained for 10-minute. However, researcher decided to conduct this test using negative film to create logo design. The metal corroded and it seeds that deep etching took place on the surface and it was noted during the experiment that negative film was suitable to use for logos containing small alphabet form because its end result looks just like real engraving technique. However, researcher deed this experiment to be slightly spoiled as black spots appeared distinctively on the metal due to these two factors:

i. The corrosive media used was too strong
ii. Inadequate coating was used on the metal surface with photo-resist.

In other words, these black spots have tarnished the layout of the metal surface. Hence, it was concluded that this method is not suitable and researcher will decrease the etching time from 10-minute to 8-minute in order to obtain another result.

Figure 16: (Experiment 17) The effect of using of logo design and negative line film.

Experiment 18

In this experiment, researcher maintained the use of material, resist, corrosive media and positive film for a 10-minute trial. Researcher used floral design as template and as a result, distinctive etching was detected on the metal surface immediately. It was noted that this test produced good release and there was no damages around the surface and researcher concluded that there was adequate photo-resist coated on the metal surface. This test was deemed satisfactory by researcher as the end product test demonstrates suitable photo etching technique.

Figure 17: (Experiment 18) The floral designs using the positive line film.

Experiment 19

In this experiment the same material, resist and corrosive were used and trial time remained for 10-minute. Researcher then proceeded to conduct this test using negative film to create floral design on the template.

Then, it was noted that etching happened but it was uncontrollable as the chemical corroded and totally spoiled the sides of its metal surface. The problem was maybe due to researcher's fault in not sticking the negative line film properly on to the aluminum surface during UV exposure. Therefore, extra care has to be taken throughout the execution of the experiment in order to ensure good results.

Figure 18: (Experiment 19) The floral designs using the negative line film.

Experiment 20

Researcher maintained the use of same chemical combination in this experiment on positive film for a 10-minute trial. An animal design template was used for the etching process and researcher discovered that reaction happened effectively as deep etching appeared on the metal. The end product was distinctively clear and contained detailed etching as this method proved to be suitable in etching technique. Researcher was satisfied with the outcome of this experiment but would still be conducting further tests in effort to come up with the best photo etching technique.

Figure 19: (Experiment 20) The animal symbol designs using the positive line film.

Experiment 21

For this experiment, the same material, resist and corrosive media were used as in previous test. The difference was that researcher conducted this test by applying negative film at a trial time of 10 minutes. Animal template was again being used in the experiment and researcher proceeded to conduct this test. It was noted that deep etching happened and design on the surface appeared. The conclusion of this experiment was that this method proved to be an applicable etching technique and satisfactory as the design appeared distinctively.

Figure 20: (Experiment 21) The animal symbol designs using the negative line film.

Experiment 22

In this experiment, researcher used the same resist and started using **hydrochloric acid** as it's a corrosive media. By conducting the test on 3-minute trial, it was noted that the chemical corrodes the metal. But the timing is not suitable as the metal surface was spoiled due to time of etching process. Thus, there is a need to decrease timing of the etching process because this mordant is too strong to etch on aluminum surface.

Before After

Figure 21: (Experiment 22) Etching with hydrochloric acid

Experiment 23

For the next test, researcher used same material and resist. Researcher added **copper salt** with **hydrochloric acid** as corrosive media. Researcher already stopped this etching process after 2-minute because the mordant was too strong and corroded the resist and metal surface. Researcher noted the reaction and concluded that chemical corroded the metal badly and spoiled the surface.

Before After

Figure 22: (Experiment 23) Etching with hydrochloric and copper salt

Experiment 24

In this experiment, researcher used **copper salt** with plain water as its corrosive media. By conducting the test on 10-minute trial it was noted that the chemical did not corrode the metal. This chemical was found unsuitable for the deep etching on aluminum surface.

Before After

Figure 23: (Experiment 24) Etching with copper salt

Experiment 25

As part of test and error process, researcher tried experimenting another different corrosive media. Researcher used **sodium suphite** with plain water. It was noted that the chemical also did not corrode the metal surface after trial for 10-minute. Researcher hypothesized that sodium suphite a weak acid and is not suitable for aluminum.

Before After

Figure 24: (Experiment 25) Etching with sodium suphite.

Experiment 26

In this experiment, researcher used **zinc chloride** with plain water. Researcher conducted a 10-minute trial and there was no reaction. Then researcher increased the time trial to 20- minute. The chemical changed to brown colour. It was noted the chemical corroded the resist and cleansed up the metal surface. This chemical was found that to be unsuitable for deep etching on aluminum surface.

Before

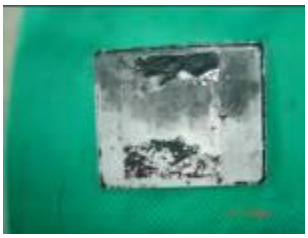
After

Figure 25: (Experiment 26) Etching with zinc chloride.

Experiment 27

For this experiment, the same material and resist were used and trial time was 10 minutes. Researcher used **sulfuric acid** with plain water as its corrosive media. The chemical changed to green colors after react with aluminum. Again, it was noted that the chemical corrodes the resist and cleansed up the metal surface. This chemical was suitable as cleaner etch on aluminum surface.

Before



After

Figure 26: (Experiment 27) Etching with sulfuric acid.

3. Results and findings

There was a certain problem with the design, in which the acid would corrode the thin line especially in relief design. The thin line of the design was spoiled and disappeared from the metal surface. It was the acid that due to corrode that line as a result of inadequate use of the photo-resist used to coat the thin line. Another result was from the material. The first material is aluminum. The researcher found that it was quite difficult to do a finishing and polishing on aluminum and it would be easily bruised compared to other metal after the etching process. There were black spots seemon the metal surface because the chemical used was too strong and it also damages the metal surface. The researcher needed to control the timing of the etching process and it was discovered that ten minutes was the maximum time for the old acid solution to react and one to two minutes for the new acid solution to give effects. The metal surface would be spoiled if the timing of the etching was not done properly.

The air circulation and room temperature were also very important in determining the activeness of acid and its effect on the aluminum. The researcher found that cold aluminum would take a longer time to etch. The result of the earlier etching experiments took only five minutes to corrode because during that time, the aluminum plate was hot and dry after it was polished with buff machine. (Please refer to experiment six and seven).

However, there has also a problem to obtain fast etching when the metal was wet after being cleaned with the photo-developer. The metal plate needed to be dried first before putting it into etching machine. The metal surface also needed to be coated again with another resist. The design of the metal surface would spoilt if the surface were not properly coated

According to the experiment, researcher found that ferric chloride and hydrochloric acid are still suitable for photo-etching technique on aluminum surface compared to nitric acid ,copper salt, sodium suphite, zinc chloride and sulfuric acid. Zinc chloride and sulfuric acid can be a cleaner solution. These two chemicals corrode and destroy the photo-resist which is sticking on metal surface.

4. Recommendation

The main objective of this research is to gain and impart knowledge on the technique of photo-etching and material used. Photo-etching is not used only in electronic accessories, but it is also useful in art craft and souvenir products. The main reasons in using aluminum because of its characteristics. It is silver white in color and it is anti rust. Aluminum is one of the most useful metal in the world but it still has problem with its polishing surface. The best way is to use the emery paper in order to get a matt finish. Buff machine is recommended on aluminum because this will make it more shiny. After etching, the metal can also be coloured and it becomes more attractive visually and looks creative.

The photo-etching on aluminum surface can be recommended for mass production because it saves cost. According to Mr. Abu Bakar Ishak, the owner of Bakarim Kreatif (the souvenir company) said
"The photo-etching technique really saves cost, time and it is indeed a profitable business. No need to buy or build master mould for the mass production. The line film is the mould (*Abu Bakar Ishak,2004)"*

Lastly, the researcher has great interest in investigating and experimenting with both material and processes. The researcher tries to explore a vast range of material and techniques associated with industrial production and technology. Information gained from these exploration and experiment have been shared freely with lecturers and colleague and in lectures and workshop. By doing this way, the researcher believes that technical skills among students will develop rapidly, resulting in increased sophistication and refinement in the handling of new materials and processes.

This research can still be done and continued by taking more variation of acid or variation of resist to do further experiments on aluminum. Apart from getting knowledge, it will also attract people to start new specialization in photo-etching techniques especially for graduates.

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