Innovational Design of Taiwan's Jiao-zhi Pottery

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Abstract: There are two main objectives for the innovative design of Taiwan's Jiao-zhi pottery (low-temperature glaze): (1) using recycled glass to make frit and then grinding the frit and adding stain to produce the color glazes used in Taiwan's Jiao-zhi pottery, which can achieve the sustainable design desired by science and technology, (2) to create a new contemporary Taiwan Jiao-zhi pottery based on Chinese ceramic culture and modern design techniques. Jiao-zhi pottery is a branch of Chinese ceramics. Chinese ceramics has a long history from green glazed pottery in the Han dynasty, tricolored pottery in the Tang dynasty, stunning decorative porcelains from the Ming and Qing dynasties to Taiwan's Jiao-zhi pottery. The innovation and development of Taiwan Jiao-zhi pottery, color ceramics and enamel ceramics have to depend on the application of frit. In this study, both leaded and lead-free frit made from recycled glass were used in the production of innovative Taiwanese Jiao-zhi pottery. The production of frit can reduce waste glass and increase the value of waste glass in industry. The innovative design of the "Eight Immortals of color pottery dolls" and ceramic plates were used as the samples for the experiment of color frit, glaze firing, kiln atmosphere, and the overall effect of the final colors. The "Eight Immortals pottery dolls" were also used to promote socio-cultural communication and the recognition of local cultural identity, and was then applied to academic education, and to the mass production of professional workshops.

Relevance to industry:

Frit is of consequence to sustainable design, as it can provide glass recycling plants with an outlet for the recycled glass used in the manufacturing of various types of colored potteries, painted potteries, ceramic tiles, enamel ceramics as a medium flux to use, and to enhance the high added-value of product frit. The "Eight Immortals colored pottery dolls," as the model of innovative design and cultural discourse can be used for academic educational purposes; this innovative design also contributes to professional workshops and the mass production of pottery, and social cultural communication.

Key words: Taiwan Jiao-zhi pottery, sustainable design, frit.

1. Introduction

Taiwan's Jiao-zhi professional pottery workshops and mass production factories are engaged in two areas of work: (1) contracted projects of traditional temple decoration Jiao-zhi potteries, and (2) the production of contemporary crafts. The main Jiao-zhi pottery craftsmen, professional workshops and ceramic factories are concentrated in Taiwan's Chiayi County. The core technology of the Jiao-zhi pottery production are as follows: (1) science and technology including the deployment of clay , preparation of color glazes and kiln firing technology, and (2) the production of Jiao-zhi pottery dolls, including themes, and the shape of the creative process in technology which should be used in pottery dolls, to make rich colors, excellent sintering technology, which is all necessary to meet the requirements of temple projects as well as other buyers. [1] Taiwan's Jiao-zhi factories have not yet produced self-made frit and stain for use, so it has been mostly imported Jiao-zhi pottery that has relatively weak socio-cultural communicative qualities with buyers and users. Therefore, this study researches and develops the science and technology of pottery frit and works on the innovation design and cultural discourses of Jiao-zhi pottery dolls. In frit development, the high-brightness of leaded and lead-free frit with transparent, semi- transparent, opaque, and mat, from low-temperature to medium temperature (780 ℃ ~ 1220 ℃) firing were made for the various demands. In the innovative design and cultural discourses of Jiao-zhi pottery dolls, the "Eight Immortals collored dolls" were used to construct the socio-cultural communication and the recognition of local cultural identity.

The sustainable design principles of frit can be achieved by using recycled waste glass; and thus also reducing this waste product and turning it into high value-added products. In this aspect of innovativeon design, based on the design principles of social care and communication, the "Eight Immortals colored pottery dolls" were used as a medium of cultural heritage. [2] [3] The roles of the Eight Immortals are Lan Caihe (boy), Han Zhongli (beer belly), Zhang Guolao (Taoist), He Xiangu (beauty), Cao Guojiu (senior), Hau Xiangzi (youth), Li Tiegai (disabled compatriot), and Lü Dongbin (handsome) and these represent the roles of people in the world , and Jiao-zhi pottery uses them in auspicious designs evoking the protection of tightly-knit immortals. The results of this study will provide its application for academic education, as well as for professional pottery workshops and factory production.

2. Material and methods

2.1 Material

2.1.1 The source of recycling glass

The largest quantity of recycled glass comes from Taiwan beer bottles, LCD television panels, windshields of junked cars and various other waste glass etc. The recycling glass factory will first clean the glass, remove plastic parts and then classify the glass according to color, as well as potassium glass, and sodium glass. In this study, the glass for the basic material of making frit was purchased from the recycling factory. The obtained recycled glass was normal glass or potassium glass ground to 100 mesh.

2.1.2 The other materials of frit

The other added materials of frit are related to glass manufacturing and glass clarifying agents, such as the following: borax, boric acid, potassium carbonate, sodium carbonate, and Glauber's salt, lead oxide, lead carbonate, feldspar, silica, calcium carbonate, bone ashes, lithium carbonate, tin oxide, and zirconium silicate.

2.1.3 The preparation of pottery clay

Taiwan's Jiao-zhi pottery workshops and the pottery factories directly purchase the clay from the pottery clay factories. The clay includes hand building clay and casting clay. In this study, the clay is self-prepared according to the percentage of the deployment, the sintering temperature and the required whiteness. The main raw materials are porcelain clay, ball clay, bentonite, and grog. The self-prepared clays were tested for their viscosity, sintering temperature and whiteness effects. The reference formulas are as follows:

Table 1. White Casting Body

Firing Result	Fomula	Percentage(%)
Cone 08-06 (950℃-1015℃) Shrinkage 6%, glaze rating 12	Kentucky ball clay ＃4	40.0
	Silica 2	8.0
	Kaolin 1	6.0
	Cornwall stone	14.7
	Sodium carbonate	0.3
Cone 06-04 (1015℃-1060℃) Shrinkage 3%, glaze rating 12	Kentucky ball clay ＃4	45.0
	Talc 4	0.0
	Kaolin 1	5.0
	Sodium carbonate	0.3
	Bisque Firing: Fire to cone 06 Fired Results：This body fires to a pure white at cone 06- 04（1015℃-1060℃）	

(James Chappell, 1977) [4]

2.2 Methods

2.2.1 The leaded frit development of recycled glass

In this study, the recovery glass was obtained from Chun-Chi recycling factory in Hsinchu, Taiwan. The cleaned recovery glass was crushed to a size of 100 mesh. Using the multi-factor experimental design method, the potassium glass, sodium glass, colored glass, and colorless glass were added to potassium carbonate, sodium carbonate, potassium nitrate, sodium nitrate, lead oxide, and lead carbonate to make the various frits according to the different percentages. The color of green and brown in leaded color frit was significantly reduced. This leaded frit can be applied for glaze needing iron addition, which can then reduce the use of iron oxide (Fe_2O_3), and black iron oxide (Fe_3O_4). To remove the green color of iron oxide, mirabilite can be added.

According to the glaze view, the general water-soluble materials, such as potassium carbonate, sodium carbonate, potassium nitrate, sodium nitrate, borax, boric acid etc. are not suitable for use in the raw glaze directly as the water-soluble materials will permeate to the clay base and cause damage. In order to overcome this problem and to reduce lead toxicity, it is necessary to make frit before any application.

In the leaded frit made from the recycled glass, the lead levels are from 20% to 40%, and can be bright and transparent. This leaded frit also can help iron, copper, cobalt to form color. This frit has been used to produce lead glaze and has been tested by glazed tile factories. There is no difference in brightness between the new product and the high-lead glaze. The frit made in this study can be used for color in ceramics, and for over and under glazing, and for sintering from 780 ℃ ~ 1220 ℃ to form a product with better brightness and color.

2.2.2 In this study, the reference formula of the frit is as follows:

Table 2. Lead Frit Formula-1

Type	Material	Percentage(%)
1	red lead (Pb_3O_4) 10	-60
	quartz (SiO_2) 5	-30
	recycling glass grain	15-90
2	white lead ($2PbCO_3 \cdot Pb(OH)2$)	10-60
	quartz (SiO_2) 2	-30
	recycling glass grain	15-90

The Compounds used in this formula include $2PbO \cdot SiO_2$, or PbO: SiO_2=81:82 in weight percentage, which is the best for melting (96.01% solubility), and has the lowest low-melting-point (complete melting) temperature (764 ℃) (J. H. Koenig. 1937; Shirakiacris Yoichi , 1981). [5] [6]

2.2.3 The second design leaded frit formula for reference is as follows,

Table 3. Lead Frit Formula-2

Metirial	Percentage(%)
red lead	65.01
recycling glass grain	100
Quartz (SiO_2) 3	4
Borax 12	
lithium carbonate	3
potassium feldspar	5

Table 4. lead frit formula (Shirakiacris Yoichi , 1981) [5]

The reference formula of glaze with lead frit- type 1

$$\left.\begin{matrix}0.06\ Na_2O\\0.12\ K_2O\\0.43\ CaO\\0.13\ ZnO\\0.26\ PbO\end{matrix}\right\} \left\{\begin{matrix}0.31\ B_2O_3\\0.27\ Al_2O_3\end{matrix}\right\} 2.60\ SiO_2$$

The reference formula of glaze with lead frit- type 2

$$\left.\begin{matrix}0.07\ K_2O\\0.01\ CaO\\0.83\ PbO\end{matrix}\right\} 0.20\ Al_2O_3 \cdot 1.75\ SiO_2$$

The reference formula of glaze with lead frit-type 3

$1.0.PbO \cdot O.254Al_2O_3 \cdot 1.91SiO_2$

Material	weight
Pb_3O_4	211.88
Kaolin	65.55
SiO_2	84.08

2.2.4 The development of the lead-free frit using recycled glass

Lead-frit has been used in glazed pottery for more than a thousand years in China, and is still in use in the glazed tile factories in Taiwan. The biggest advantage of the lead glaze is its sparkling shiny appearance and having no pinholes; in the minds of temple believers in Taiwan, a brightly glazed tile is the symbol of prosperity, so lead glaze frit is still used. In this study lead-free frit can replace the lead frit. Borax, boric acid, potassium carbonate, and sodium carbonate were used to replace lead oxide in the experimental design as follows:

Table 5. American Patent Frit -（Babosil）and Development formula

Citation and Development Fomula	Material	Percentage (%)
American patent frit- type l (Babosil Frit)	borax ($Na_2O \cdot 2B_2O_3 \cdot 10H_2O$)	42.7
	barium carbonate ($BaCO_3$)	27.8
	Potash Feldspar	15.2
	quartz (SiO_2) 8	.7
	soda powder (Na_2CO_3) 5.	6
Development formula of American pat ent fri t-type 2 (Babosil Frit)	borax ($Na_2O \cdot 2B_2O3 \cdot 10H_2O$)	42.7
	barium carbonate ($BaCO_3$)	27.8
	Potash Feldspar	15.2
	quartz (SiO_2)	8.7
	soda powder (Na_2CO_3)	5.6
	recycling glass powder	3.3

Note1: The design test formula of lead-free frit using recycled glass-type
2: The type 2 test, with additive of recycling glass powder, had a successful result after firing

2.2.5 The reference formula of glaze with lead-free frit

Table 6. lead-free frit

$$\left.\begin{matrix}0.149 & Na_2O\\ 0.207 & K_2O\\ 0.644 & CaO\end{matrix}\right\} \left.\begin{matrix}0.800 & B_2O_3\\ 0.200 & Al_2O_3\end{matrix}\right\} 1.900 \quad SiO_2$$

(Shirakiacris Yoichi 1981) [5]

2.2.6 The formula of lead-free frit using recycled glass (the frit has the opaque property, better covering, and can be used for making tile glaze and brick coating) [7] [8] [9]

Table 7. Development of Lead Free Frit

Material	Percentage (%)
Potash Feldspar	20
borax ($Na2O \cdot 2B_2O_3 \cdot 10H_2O$)	30
boric acid ($B_2O \cdot 3H_2O$)	20
calcium carbonate ($CaCO_3$) 15	
quartz (SiO_2) 25	
tin oxide (SnO_2) 8	

zirconium silicate ($ZrO_2 \cdot SiO_2$)	14
bone ash (Ca_3 (PO_4) 2)	3
recycling glass powder	25

Note: the frit has been used for glazed tile, brick coating, overgraze drawing, and had good results in terms of covering property and bright saturated color.

2.3 The frit kiln for firing recycling glass

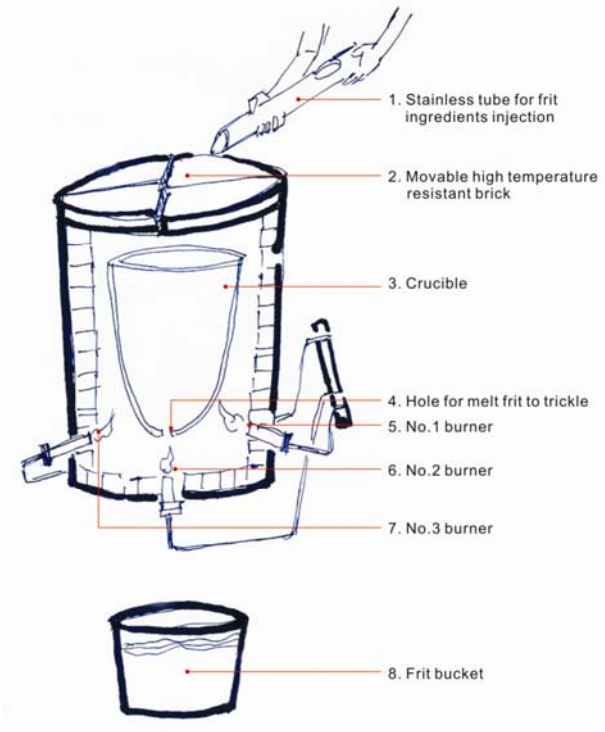
2.3.1 Manufacturing the frit kiln

The design graphics of the frit kiln are shown in Figure 1. The frit kiln design used in this study was constructed by Qi-Dun ceramic company.

(1) Crucible (using cordierite material with ball clay and rotary molding method)

(2) Drill a hole at the bottom of the crucible, so that the melt frit can trick le down to the stainless steel bucket with cold water inside

(3) The melting frit immediately cracks into small pieces, and is easier to grind.



(1) Stainless tube for frit ingredients injection
(2) Movable high temperature resistant brick
(3) Crucible
(4) Hole for melt frit to trickle
(5) No. 1 burner
(6) No. 2 burner
(7) No. 3 burner
(8) Frit bucket

Figure 1 Frit Kiln

2.3.2 Firing frit design

(1) use gas fuel, with three burners, two on both sides of the crucible, and one at the bottom of the crucible to prevent the rapid cooling of the melt frit during trickling

(2) warm up crucible temperature to 1220 ℃ before feeding test materials

(3) reduce gas pressure, and then feed the test material rapidly

(4) The melt frit starts to trickle at crucible temperatures of 1240 ℃ ~ 1260 ℃

(5) The melting frit immediately cracks into small pieces after tric kling down to the stainless steel bucket with cold water; that makes it easier to grind

2.3.3 Fast ball grinder

Put the frit fragmentation to the fast ball grinder and add the proper amount of water, grind about 45 minutes, and then pour out the liquid and dry it. The powder can be used for glaze preparation according to the percentage of the formula.

3. Result

3.1 The application of frit, stain, and color drawing test

In this study, under normal environmental stress (earthquakes, wind, rain) the traditional ceramic figures were weak. By using this new method with lower temperatures for firing the figure ceramics became strengthened. [10] We have combined frit, stain, colored glaze, and innovative design of "Eight Immortals pottery dolls", and the color drawing plates test to obtain good results in pottery products.

3.2 The firing results of color drawing plates test (frit +stain)

In the color drawing test of frit and colored glaze, use the opaque color frit glaze to paint in the convex part and sinter at 1180 ℃, and then paint lead-free frit glaze and fire at 780 ℃. resulting as in a smooth effect.

Table 7. low firing Glaze Plates

Title Pictu	re	Object	Method/Result	Method/Result
1. Frog, morning glory (Blue and white underglaze painting)		Yellow morning glory	Frit 30% -40% +yellow stain sintering at 780 ℃ producing shiny smooth result	Lead-free opaque frit + yellow underglaze stain convex part firing 1180 ℃
2. lotus and dragonfly (Blue and white underglaze painting)		Blue lotus leaf	Frit +overglaze light-blue stain sintering at 780 ℃ producing smooth and shiny result	Red lotus: lead-free opaque frit + red underglaze stain, firing 1180 ℃
		Green lotus leaf	Frit +overglaze green stain sintering at 780 ℃ producing smooth and shiny result	
3.Red fly eagle (Blu e and white underglaze painting)		Green, yellow-green mountain	Frit ＋overglaze green and yellow-green stain sintering at 780 ℃ producing smooth and shiny result	
		Red flying eagle	L	ead-free opaque frit + red underglaze stain firing at 1180 ℃
4. Landscape (Blue and white underglaze painting)		faraway Green mountain	Frit + overglaze green stain sintering at 780 ℃ producing smooth and shiny result	
		Red main mountain	Frit + red overglaze sintering at 780 ℃ producing smooth and shiny result	

3.2.1 The sintering result of "Lan Caihe", which is one of the "Eight Immortals pottery dolls" (design pottery in this study)

Table 8. Lan Caihe Pottry Doll

Picture	First Sintering	Second Sintering
	The first sintering is at 1220 ℃ producing shiny white glaze result	1. Purple overglaze stain + frit sintering at 780 ℃ producing shiny and smooth result 2. Red overglaze stain + frit sintering at 780 ℃ producing shiny and smooth result 3. Green overglaze stain + frit sintering at 780 ℃ producing shiny and smooth result 4. Yellow overglaze stain + frit sintering at 780 ℃ producing shiny and smooth result

"eight immortals pottery dolls"graphic design (design by this study) :

(1) Lan Caihe (2) Han Zhongli (3) Zhang Guolao (4) He Xiangu (5) Cao Guojiu (6) Han Xiangzi (7) Li Tieguai (8) Lü Dongbin

Figure 2. Eight Immortals Pottery Dolls Graphic Design

4. Discussions

Sustainable design for applying frit in low temperature pottery has been shown in this study. Good results have been obtained with the least social, environmental and economic cost. It is the strategic use of design to meet and integrate current and future human needs without compromising the environment [11] The innovational design of Taiwan Jiao-zhi pottery has combined with the frit technology, and has been applied to the "eight immortals pottery dolls" and color drawing test. Design is a creative activity. Design is a process by which information is transformed into a tangible outcome. "Design is the conscious decision making process by which information (an idea) is transformed into an outcome, be it tangible (product) or intangible (service)" (Dr Bettina von Stamm, 2003) [12]

The frit innovation of this study has contributed to solving the waste reduction and recycling problem, and has expanded the area of frit application including Jiao-zhi low-temperature glazed pottery, stain painting, tile industry, brick coating (slip glaze, engobe, stain) and flux for enamel ceramics. The pottery sintering temperature range has been expanded from 780 ℃ to 1220 ℃. The results of this study have practical application in Taiwan's Jiao-zhi pottery industries. Of the "Eight Immortals pottery dolls" in this study attempts to achieve social communication and the description of local cultural identity. Chinese glazed pottery, including the Han green glaze, the Tang tri-colors pottery, the Ming and Qing color drawing porcelain, were the foundation of Taiwan's Jiao-zhi pottery. Taiwan's Jiao-zhi pottery is the extension and localization of Chinese glazed pottery.

[13] Henri Bergson (1859～1941) has stated that (1) duration（durée）is the motion, and the change development process itself, (2) duration（durée）has the property of time, rather than space; the duration process is carried out in a process of time without occupying space. duration is an experience of the mind, a status of activity, a kind of psychological integration, and a psychological process. The innovative design of Taiwan's Jiao-zhi pottery is the duration of Chinese glazed pottery time and temple space.

In this study, the design of the "Eight Immortals pottery dolls" attempts to provide a social cultural communication and dialogue. [14] The roles of the "Eight Immortals doll" include (1) Lan Caihe, (2) Han Zhong-li, (3) Zhang Guolao, (4) He Xian-gu, (5) Cao Guojiu (6) Han Xian-zi, (7) Li Tie-quai, and (8) Lü Dongbin. These roles are an epitome of society；Lan Caihe is a child, Han Zhong-li is a beer belly, Zhang Guolao is a Taoist, He Xian-gu is a beauty, Cao Guojiu is a senior person, Han Xian-zi is a youth, Li Tie-quai is a disabled compatriot, and Lü Dongbin is handsome man, They reflect the various types people, including you and me, and as long as we practice Taoist rules, we are likely to become an immortal god. The "dialogue theory" of Bakhtin (Mikhail Mikhailoviteh Bakhtin, 1895-1975) [15] has formed the opening characteristic and the "big dialogue" of the art of thinking. The figures of the Jiao-zhi dolls in the dialogue is the person with an idea, and becomes the man in man. All have gotten involved in the big dialogue without their ego. In this study, the role of the Eight Immortals pottery dolls in themselves have their independent personalities, and no longer just project a sense of the creator. The female He Xian-gu doll directly communicates with the buyer and user, and is not just the shadow of the author. This literary image of the He Xian-gu doll is ever-changing in time, and has the largest exposure with its openness to the real world.

The "Eight Immortals pottery dolls" has been a set of decorative elements in the temple architecture and only can be enjoyed by its sight. The 'Eight Immortals colored doll' of the innovative design has strength on the temple and has become a contemporary craft works which can be held in one's hand, and has become the craft production of play. They are not just alternative nostalgic fashion dolls, but also historical and cultural examples of Taiwan's lively creativity. They are not only a form of social dialogue of Taiwanese culture in the subconscious, but also a real presentation of Taiwan's symbol and language.[16][17] The 'Eight Immortals colored dolls' of the innovative design have become the linkage between traditional culture and modern culture as well as the recognition of contemporary Taiwan cultural identity.

5. Conclusion

The innovative design of Taiwan's Jiao-zhi pottery makes the pottery industry have their root and way out; in this study, high value-added frit was created, and at the same time the problem of environmental protection in glass recycling was solved. Through science and technological research and development, the pottery industry can produce richer color and more durable products, and reduce the problem of fragility without sintering. The results of this study also allow pottery to be applied in a broader field, and to reach the function of social and cultural dialogue. The results of this study will can be applied to academic education, professional pottery workshops and factory production.

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