Art and Science: The Role of SiliconCarbide in Developing High Temperature Crater Ceramic Glaze Recipes

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Abstract:

It is widely recognized that smooth and glossy glazes are often used by both ceramic makers and artists. However, in contrast, rarely do artists use techniques to develop the crater and foam glazes for decorating artistic artwork. Most students of ceramic art schools depend on readymade smooth and glossy glazes, which cause more traditional artistic results. This experimental study aims to develop some applicable crater and foam recipes for ceramic glazes by using an amount of Silicon Carbide (SiC). This study has helped to elevate sculpture ceramics artwork quality by providing a variety of glazing textures and decorative recipes.

Keywords*:* *Silicon Carbide, Crater Glazes, Ceramics.*

I. INTRODUCTION: SiCAPPLICATIONS IN CERAMICS

According to Frank and Janet Hamer (2004), SiCis a synthetic compound of silicon and carbon made from baked sand and coke, which isan extremely hard material (harder than aluminum oxide but less hard than diamond).Historically, the term ‘Silicon Carbide’ has been used to describe a range of products that must perform in thermally demanding applications;therefore, most ceramicists employ SiC in refractories (high heat duty kiln shelves) for its resistance to heat and low thermal expansion (Hansen,2015). There are two basic applications of SiC currently being used in the ceramics industry and art. One is using this artificial compound in refractory industries, including making kilns and electrical elements, and the second is developing craters and foam glazes for decorating artistic work. This research paper focuses on the second application.

There is a growing body of literature that recognizes the importance of using craters and foam glazes for ceramic artwork. SiC plays a vital role in creating craters and foam effects on high temperature clay bodies (stoneware or porcelain). The silicon takes up available oxygen to make SiO_2, while the carbon combines with oxygen to make the CO_2 that creates the bubbles on glaze surface (Hansen,2015). Typically, cratering or foaming are achieved with SiC, which works at a wide range of temperatures because it doesn't break down and generate carbon dioxide until it comes in contact withthe molten glaze (Almamari, 2015).

II. EXPERMINTALRESEARCH AT SQU GLAZING LAB

Several methods currently exist for the measurement of ceramic glaze quality. Many researchers have created glaze tests to explore the quality of chemical materials in the ceramic arts and industry(Almamari, 2016). One of the most well-known ways to assess the quality of SiC in making new craters and foam glazes is creating recipes in the laboratory. By using laboratory tests at Sultan Qaboos University’s ceramics glazing lab, this study has revealed that by adding between 2% to 4% SiC to each glaze recipe can significantly contribute to ceramicists by providinga variety of crater glazes used to create special artistic effects on ceramic surfaces. Aside from being traditional, these glazes are also more aesthetically pleasing than ordinary commercial glazes.

The ceramic tiles used for the experiments in this research were made of white clay (white stoneware clays) and bisquette fired at a low temperature (1000 Ċ) to guarantee the absorption of the glaze sample. There are a number of instruments available for classifying the quality of composed glaze recipes;however, to meet the main research objectives, the researcher designed a special table (1) to compare all results according to their general appearance, foam and crater effects, shivering, crawling, blisters, and pitting and pin-holing.

After weighing all materials using an accurate digital scale, all materials were placed in the container to mix and store the glaze (each test included 100 g of dry materials). The addition of 1%-2% of SiCwas been added to each recipe. The researcher then added enough water (nearly100 ml of water per 100 g of dry materials) to make a mixture the consistency of milk. As soon as the test glaze recipe was properly mixed with water, it was ready for sieving.The researcher placed a sieve supported by two wooden sticks on top of another mixing container. By using a stiff brush to force the glaze mixture through the sieve, and to ensure a smooth mixture, double sieving became very important for each slip.

To ensure accurate documentation for the slip recipes and their percentages, the researcher made a waterproof label for each glaze recipe and placed it on the container. In this stage, all test recipes were ready for application by dipping on white stoneware test tiles (5 cm x 10 cm). All test tiles were bisquette-fired at a low temperature (1000 Ċ), and after the application of the slips (43 tests), they were fired in an electric kiln at a high temperature (1290 Ċ) to allow the SiC to give more attractive artistic results. After nearly 24 hours, all test tiles were extracted from the kiln and became ready for documentation and analysis.

III. EVALUATING GLAZE RECIPES

This study set out to assess the importance of using SiC in developing crater effects on ceramic glazes. A strong relationship has been seen between adding SiC to glaze recipes and developing craters and foam textures in the glaze recipe results. It is interesting to note that in all 43 glaze tests of this study, the variety of glassmakers used in this project included quartz, silica, or flint showed varying results (glaze textures). The difference between using stain colorants and oxides in coloring ceramic tests was significant. In this project, the researcher aimed to use an oxidation firing environment because by using SiC, the reduction textures will appear in oxidation firing(Almamari, 2017). To ensure the SiC will develop crater textures, the firing for this project reached 1290 C. To assess the quality of the crater glaze's appearance, a bisquette-fired 50 cm² tile were used, and three coats of slips were applied on each test tile.

The results, as shown in tests 40 and 41 in Appendix (1), indicate that when a small quantity of glassmakers (silica, flint, or quartz) used in any slip recipe, the texture of tests appeared less glossy (matt). Interestingly, there were also differences in the levels of textures between fired tests. For example, as showed in tests 20 and 21 in Appendix (1), crater and foam textures appeared marginally because of SiC resistance when added to a recipe that included a high percentage of potash feldspar and quartz together. Moreover, a comparison of all 43 tests using feldspars revealed that using a high percentage of soda feldspar in a recipe [i.e., test 23 in Appendix (1)]gives a smooth texture and very beautiful overlapping colors. In fact, in this research, the most common feldspar used was potash feldspar, as shown in all tests in Appendix (1).

Because of its sodium content, high Nepheline Syenite glazes tend to craze (Hansen, 2015). In this project, the researcher expected crazing would contribute to developing craters and foaming textures; therefore, Nepheline Syenite was introduced with high percentages in tests 10, 27, 30, 31, and 42 in Appendix (1). However, unfortunately, no significant artistic textures were identified in these recipes.

The most striking observations to emerge from the project's overall test comparisons were the following four results. First, when about 5 g of iron oxide spangles are used in glaze recipes, it can help to develop very attractive artistic results, however, the artist must control this item when applied on a ceramic object [see test 15 in Appendix (1)]. Second, in contrast to iron oxide spangles, introducing 5 g of lead oxide produced negative results regarding the development of crater glaze textures, where test 20 in Appendix (1) was a smooth dark blue, and no foaming appeared. Third, the researcher saw very dutiful results that met the research main objectives, such as tests 5, 17, and 35 in Appendix (1); however, unfortunately, the crater and foam textures were fragile bubbles that were easily broken when test tiles were touched by hand, and that was one of the most disappointing results of this project. Finally, developing very complicated recipes (using high numbers of items introduced in one test recipe) can produce crater glazes that met the research's main objective. For example, in test 18 in Appendix (1), the recipe contained four oxides, including zinc, titanium dioxide, tin, and SiC, and the texture was very artistic, especially for ceramic sculpture artwork.

In summary, of the 43 tests (glaze recipes) accomplished in this project, more than 31 indicated that adding between 1%-2% of SiC can create successful attractive textured glazes and met the research main objectives. The results showed that 19 tests out of 43 tests were glossy and 24 were matt textures. Moreover, regarding the level of crater and foaming (texture), the final results of this project showed that 20 glaze tests had high texture, 11 tests had medium, and only 12 glazes failed to create any texture (smooth texture). Thus, the total of high (H) and medium (M) levels of textured tests were 31 out of 43. Finally, it is important to note that six glaze tests out of 43 showed a crawling defect, yet,none of the tested recipes showed shivering or blistering defects. For complete details, Table (1) below shows therubric usedto assess the final results

TABLEI:

Rubric to Assess the Final Results

Test No. in Appendix (1)	General Appearance		Foam and Crater Effects			Common Ceramic Glaze Defects		
	Glossy	Matt	H	M	L	Shivering	Crawling	Blisters
1		●		●				
2	●			●				
3		●		●				
4		●		●				
5		●	●					
6		●		●				
7	●				●			
8		●		●				
9		●			●			
10	●				●			
11		●	●					
12		●		●				
13	●			●				
14	●				●			
15	●		●					
16		●	●					
17		●	●					
18		●	●					
19		●		●			●	
20	●				●			
21	●				●		●	
22		●	●					
23	●		●					
24	●		●					
25		●		●			●	
26		●	●				●	
27	●				●			
28	●		●					
29		●	●					
30	●		●					
31		●			●		●	
32	●		●					
33		●	●					
34		●	●					
35		●	●					
36	●				●		●	
37	●			●				
38	●				●			
39		●	●					
40		●	●					
41		●	●					
42	●				●			
43	●				●			

IV. RESEARCH SUMMARY

This project was undertaken to evaluate the ability of SiC to create crater glazes, which will elevate sculpture ceramic artwork quality by providing a variety of glazing textures and decorative recipes. Because 31 out of 43 glaze tests met the research objectives, we can show that by adding between

1%-2% of SiC, an artist can develop applicable glazes for artistic artwork in their studios. Taken together, these findings suggest a role for artists and ceramic makers in promoting their artworks' quality.More experimental tests using SiC in making crater glaze recipes help us to establish a greater degree of accuracy on formulating textured ceramic recipes. Because there are few published studies on the use of SiC for artists and art teachers, the issue of developing crater glazes is an intriguing one which could be usefully explored in further research.

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Appendix (1): Documentation of Glazes' Tests

Chemical item	Percentage (%)
Cornish stone	25
Quartz	25
Dolomite	13
Whitening	11
China clay	17
Bone ash	9
Titanium oxide	2
Chrome oxide	2
Silicon carbide	2
100%	

Recipe No. (1)

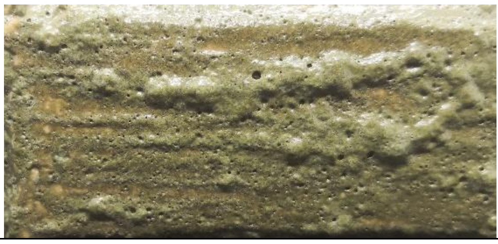
Chemical item	Percentage (%)
Cornish stone	23
Quartz	15
Dolomite	13
Whitening	16
China clay	17
Bone ash	9
Tin oxide	7
Manganese Oxide	4
Silicon carbide	2
100%	

Recipe No. (2)

Chemical item	Percentage (%)
Potash Feldspar	50
Dolomite	25
Silica	15
China clay	10
Stain (pink)	3
Silicon carbide	1
100%	

Recipe No. (3)

Chemical item	Percentage (%)
Silica	45
Potash feldspar	36
Whiting	10
China clay	9
Nickel oxide	10
Silicon carbide	2
100%	



Recipe No. (4)

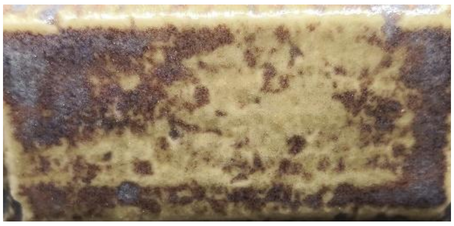
Chemical item	Percentage (%)
Potash feldspar	28
Talc	16
Quartz	16
China clay	20
Whiting	3
Zinc oxide	8
Titanium oxide	4
Red iron oxide	3
Silicon carbide	2
100%	

Recipe No. (5)

Chemical item	Percentage (%)
Potash feldspar	50
Dolomite	25
Quartz	22
China clay	3
Rutile oxide	3
Cobalt oxide	2
Silicon carbide	2
100%	

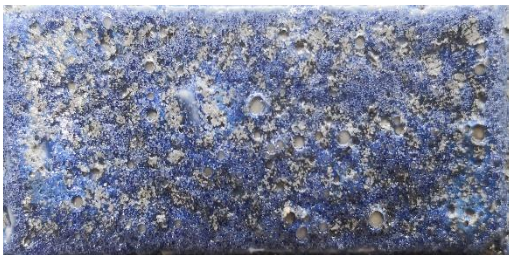
Recipe No. (6)

Chemical item	Percentage (%)
Potash feldspar	29
Quartz	23
Whiting	19
Cornish stone	8
Borax frit	9
China clay	7
Bone ash	3.5
Rutile	0.5
Red iron oxide	0.5
Copper oxide	0.5
Silicon carbide	1
100%	



Recipe No. (7)

Chemical item	Percentage (%)
Potash feldspar	50
Dolomite	26
Silica	19
China clay	5
Rutile	4
Cobalt oxide	2
Silicon carbide	2
100%	



Recipe No. (8)

Chemical item	Percentage (%)
Silica	40
Potash feldspar	25
Whiting	10
China clay	15
Yellow Ochre	7
Chrome oxide	2
Nickle oxide	1
Silicon carbide	2
100%	

Recipe No. (9)

Chemical item	Percentage (%)
Barium carbonite	30
Nepheline syenite	70
Bentonite	3
Nickel oxide	1
Silicon carbide	2
100%	

Recipe No. (10)

Chemical item	Percentage (%)
Manganese dioxide	35
China clay	60
Copper oxide	5
Silicon carbide	2
100%	

Recipe No. (11)

Chemical item	Percentage (%)
Manganese dioxide	10
China clay	50
Silica	34
Copper oxide	3
Cobalt oxide	3
Silicon carbide	2
100%	

Recipe No. (12)

Chemical item	Percentage (%)
Potash feldspar	50
Dolomite	25
Quartz	15
China clay	10
Rutile	4
Silicon carbide	2
100%	

Recipe No. (13)

Chemical item	Percentage (%)
Cornish stone	33
Quartz	25
Dolomite	13
Whiting	11
China clay	12
Bone ash	6
Tin oxide	3
Silicon carbide	2
100%	

Recipe No. (14)

Chemical item	Percentage (%)
Potash feldspar	48
Quartz	20
Bone ash	10
China clay	12
Talc	10
Iron oxide spangles	5

Silicon carbide	**2**
100%	

Recipe No. (15)

Chemical item	Percentage (%)
Potash feldspar	**50**
Silica	**25**
Whiting	**5**
China clay	**20**
Manganese dioxide	**4**
Silicon carbide	**2**
100%	

Recipe No. (16)

Chemical item	Percentage (%)
Potash feldspar	**50**
Dolomite	**25**
Quartz	**10**
China clay	**15**
Rutile	**4**
Silicon carbide	**2**
100%	

Recipe No. (17)

Chemical item	Percentage (%)
Potash feldspar	**28**
Talc	**26**
Silica	**21**
China clay	**10**
Whiting	**9**
Zinc oxide	**6**
Titanium dioxide	**7**
Tin oxide	**2**
Silicon carbide	**2**
100%	

Recipe No. (18)

Chemical item	Percentage (%)
Potash feldspar	**48**
Quartz	**23**
Bone ash	**13**
China clay	**13**
Talc	**3**
Manganese oxide	**5**
Silicon carbide	**2**
100%	

Recipe No. (19)

Chemical item	Percentage (%)
Potash feldspar	40
Quartz	25
Whiting	15
China clay	10
Lead Oxide	5
Silicon carbide	2
100%	

Recipe No. (20)

Chemical item	Percentage (%)
Quartz	36
Potash feldspar	39
Whiting	11
China clay	14
Cobalt carbonite	3
Silicon carbide	2
100%	

Recipe No. (21)

Chemical item	Percentage (%)
Potash feldspar	50
Dolomite	33
Quartz	11
China clay	6
Chrome Oxide	1
Silicon carbide	2
100%	

Recipe No. (22)

Chemical item	Percentage (%)
Soda feldspar	50
Whiting	40
China clay	10
Tin oxide	3
Copper carbonite	2
Silicon carbide	2
100%	

Recipe No. (23)

Chemical item	Percentage (%)
Potash feldspar	68
Whiting	18
Borax	14
Tin oxide	4
Copper oxide	2
Silicon carbide	2
100%	

Recipe No. (24)

Chemical item	Percentage (%)
Cornwall stone	67
China clay	16
Waiting	17
Purple Irion oxide	3

Silicon carbide	**2**
100%	

Recipe No. (25)

Chemical item	Percentage (%)
Potash feldspar	**40**
Quartz	**30**
Waiting	**15**
China clay	**8**
Bone ash	**4**
Dolomite	**3**
Red iron oxide	**1**
Silicon carbide	**2**
100%	

Recipe No. (26)

Chemical item	Percentage (%)
Nepheline syenite	**60**
Dolomite	**5**
Quartz	**21**
China clay	**2**
Whiting	**12**
Zinc oxide	**2**
Copper oxide	**0.5**
Silicon carbide	**2**
100%	

Recipe No. (27)

Chemical item	Percentage (%)
Potash feldspar	**60**
Dolomite	**15**
Silica	**9**
China clay	**8**
Whiting	**8**
Zinc oxide	**2**
Rutile	**2**
Purple iron oxide	**1**
Copper oxide	**1**
Silicon carbide	**1**
100%	

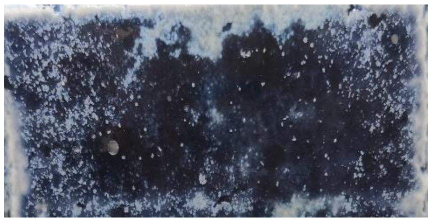
Recipe No. (28)

Chemical item	Percentage (%)
Ball clay	**34**
Potash feldspar	**24**
Quartz	**24**
Whiting	**18**
Red iron oxide	**2**
Silicon carbide	**1**

100%

Recipe No. (29)

Chemical item	Percentage (%)
Nepheline syenite	50
Dolomite	37
Silica	9
China clay	4
Rutile	7
Cobalt oxide	1
Silicon carbide	1
100%	



Recipe No. (30)

Chemical item	Percentage (%)
Nepheline syenite	60
China clay	14
Flint	17
Whiting	9
Cobalt oxide	2
Silicon carbide	1
100%	

Recipe No. (31)

Chemical item	Percentage (%)
Potash feldspar	50
Dolomite	26
Quartz	10
China clay	14
Rutile	2
Copper carbonite	2
Silicon carbide	2
100%	

Recipe No. (32)

Chemical item	Percentage (%)
Potash feldspar	48
Soda feldspar	28
Whiting	17
Gerstly borate	4
Copper carbonite	3
Silicon carbide	2
100%	

Recipe No. (33)

Chemical item	Percentage (%)
Potash feldspar	48
Barium carbonite	16
Silica	16
Dolomite	10
China clay	10
Tin oxide	2
Copper carbonite	2
Silicon carbide	2
100%	

Recipe No. (34)

Chemical item	Percentage (%)
Quartz	47
China clay	30
Whiting	33
Titanium dioxide	4
Silicon carbide	2
100%	

Recipe No. (35)

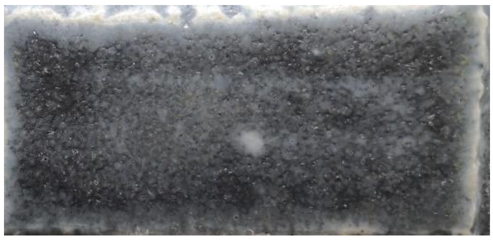
Chemical item	Percentage (%)
Potash feldspar	38
Talc	16
Quartz	21
China clay	10
Whiting	7
Zinc oxide	8
Copper oxide	4
Silicon carbide	2
100%	

Recipe No. (36)

Chemical item	Percentage (%)
Potash feldspar	50
Silica	23
Whiting	18
Talc	4
China clay	4
Gerstly borate	1
Black Irion oxide	1
Silicon carbide	2
100%	

Recipe No. (37)

Chemical item	Percentage (%)
Talc	40
Dolomite	30
China clay	20
Bone ash	10
Nickle oxide	1
Cobalt oxide	1
Silicon carbide	2
100%	



Recipe No. (38)

Chemical item	Percentage (%)
Whiting	10
Potash feldspar	26
Quartz	50
China clay	14
Red iron oxide	5
Cobalt oxide	4
Silicon carbide	2
100%	

Recipe No. (39)

Chemical item	Percentage (%)
Potash feldspar	40
Quartz	28
China clay	26
Dolomite	26
Whiting	16
Silicon carbide	2
100%	

Recipe No. (40)

Chemical item	Percentage (%)
Manganese dioxide	40
China clay	20
Copper oxide	15
Quartz	25
Silicon carbide	2
100%	

Recipe No. (41)

Chemical item	Percentage (%)
Barium carbonite	40
Nepheline syenite	40
Bentonite	3
Copper carbonite	1.5
Silica	20
Silicon carbide	1
100%	

Recipe No. (42)

Chemical item	Percentage (%)
Potash feldspar	40
Dolomite	27
Quartz	21
Wallstonite	15
China clay	11
Zinc oxide	7
Chrome oxide	6
Silicon carbide	2
100%	

Recipe No. (43)