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Technological Processes and Characteristics of Lighting Products Made of Ceramic Materials

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Abstract
The study examines the main stages and technological processes in the manufacture of lighting products from ceramic materials that can be implemented in industrial production. The technological stages include the possibilities of molding and several examples of molding by means of traditional and modern technologies are traced. Temperature regimes for glazing and decorative firing, possibilities for coloring both the glaze and the ceramic mass, auxiliary materials and technological techniques in the production stages are considered. Prescription compositions suitable for the production of utilitarian lighting items are considered. Examples reflecting the applicability of the considered technological techniques are given.

Keywords: Ceramic technology, ceramic molding, instrumental equipment

1. Introduction

The widespread use of lighting objects is largely determined by the psychological nature of their function. This depends mainly on the type and source of light, as well as on the environment in which it is used. In an article published in the Electrical Contractor Magazine, Kraig DiLouie notes that it is very important at what stage of our everyday functions and for what purpose we use an artificial light source, where it should be positioned, and what color the light should be [1]. In this regard, the materials from which the lighting fixtures are made are of great importance. It has been found that a direct light source without diffuse scattering leads to irritation in the cornea of the eye and to an imbalance in a person's mental state. For this purpose, the materials from which the lighting objects are made must be sufficiently transparent to transmit diffusely reflected rather than direct light. Of course, the best material for this is glass, but nowadays we find lighting objects made of a number of other silicate materials [2]. The present study considers the molding technological processes of ceramic materials used in the manufacture of lighting objects [3]. This favors the rapid progress of their implementation in the production of lighting products.

2. Experiments

All available technological processes, both traditional and modern, are used in the molding of ceramic lighting products. The traditional stages include preparation of technical documentation, production of appropriate tooling according to the selected composition and molding process, molding of the finished product, and temperature synthesis according to the selected mass and method. In modern technological processes, all robotic and digital software technologies are applicable, with additive production being used for direct molding. The experimental part includes an overview of several basic technological foundations. The main stages of manual construction, pressing, slip casting and additive production are considered.

Each stage begins with mass preparation in line with the principle illustrated in Figure 1. Sample compositions of three types of used masses are presented in Tables 1 [3].

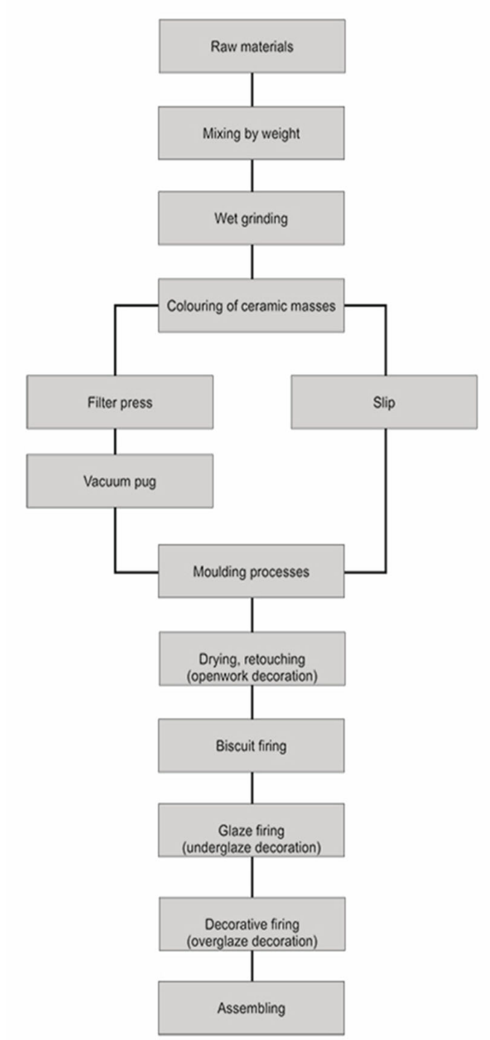


Fig. 1. Schematic diagram of mass preparation for the formation of lighting products by slip casting and plastic building.

All masses, regardless of their composition, temperature synthesis and molding method, can be colored with coloring agents during the mass preparation process. Both pure oxides and pigments comprising a combination of several coloring oxides are used as coloring components. In addition to the mass, the glazes applicable to the specific composition can also be colored, which excludes the stage of underglaze decoration. The methods of coloring the glaze are similar to those of coloring the mass, the main differences being in the amount of coloring agents and the basis of the glaze used. Blurred (roofing) glazes are used to obtain pastel colors, mostly with the addition of ZrO_2. When clear tones must be obtained, coloring additives are imported in nonturbidity (transparent) glaze. For best results, different ratios of dry matter coloring agents to glaze are used. Examples of coloring agents for coloring masses and glazes are presented in Table 5.

Plastic molding, which is a method still applicable today, includes manual and mechanical molding. This type of building can be achieved by means of mechanized devices such as a forming wheel, extruder or press, or by the free building of the form. All possibilities, alone or in combination, are used in the modern production of lighting objects. The choice of plastic masses is wide: they can be coarse or fine ceramic masses, with low or high melting temperature depending on the different operational requirements for lighting objects. The temperature synthesis of sample ceramic masses (masses 1, 2 and 3) are presented in Table 3. Table 1 presents the recipe composition of masses 1 and 2. Table 4 shows comparative indicators of the three types of ceramic materials. Depending on their chemical amount and temperature synthesis the masses have different indicators such as compressibility, water absorption and color [3,4].

Table 1. Quantitative analysis in percentages of the used masses.

Major components	Mass 1	Mass 2	Mass 3
SiO_2	66.39	73.04	69.1
Al_2O_3	20.74	18.22	23.0
TiO_2	-	-	2.1
Fe_2O_3	1.19	2.59	4.2
CaO	3.64	1.43	0.2
MgO	3.60	1.58	0.3
Na_2O	-	-	0.1
K_2O	3.39	2.56	1.0

Table 3. Temperature synthesis with isothermal retention in minutes at final temperature: 1180°C for mass 1, 1050°C for mass 2, and 1250°C for mass 3.

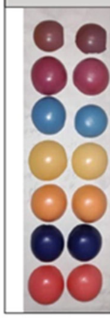
t°C	Mass 1	Mass 2	Mass3
150°C	40	30	60
650°C	60	60	40
860/950°C	5	40	5
High t°C	20	40	20

Table 4. Comparative indicators of the three types of ceramic materials.

Index	Mass 1	Mass 2	Mass 3
Firing temperature	1180°C	1050°C	1250°C
Firing shrinkage	11 %	8 %	4.5%
Water absorption	0.4 %	10 %	6 %
Color	White	Red	Yellow

Of fundamental importance for each mass is the temperature synthesis, which must be performed so that all the processes of decarbonization and crystallization are performed.

Table 5. Percent ratio of coloring oxides added to mass and glaze.

Color	Major components	Percentages % in mass	Percentages % in glaze
	Fe Cr Zn	8	3
	Zr Si Cd S	10	5
	Zr Si V	12	5
	Zr Si Pr	8	3
	Zr Si Pr	12	5
	Co Si	10	3
	Zr Si Cd S	13	8

The possibilities for coloring the mass and the glaze are wide. The coloring pigments contained in the overglaze paints are mainly synthesized coloring oxides. Overglaze paints also include large amounts of low-melting glass, as well as organic-based solutions. Table 6 shows the temperature regimes at overglaze decoration.

Table 6. Temperature regime at the decorative firing of overglaze paints at $750^{o}C$ and $850^{o}C$.

$t^{o}C$	Retention/min	Retention/min
$150^{o}C$	30	30
$750^{o}C$	5	-
$850^{o}C$	-	5

In decorative firing, the final temperature is essential. Isothermal retention is performed mainly at low temperatures in order to evaporate the water content of auxiliary components such as water-soluble carriers.

One of the most common techniques in the formation and reproduction of all kinds of products, including lighting, is the casting of ceramic masses. Different compositions lend the product different appearances and the choice of material mainly depends on the specific project. Decorative approaches are also various and may include underglaze and overglaze decoration, embossed or printed images, and openwork. For masses with low light transmittance, appropriate decoration of the form is achieved by openwork decorations. In the case of glass materials with a high light transmission coefficient and refractive index, such an approach is not necessary due to their transparency and translucency. Figure 2 shows a detail of a lighting product made of hard porcelain with a refractive index of 1.5 approximately equal to the glass [5,6].

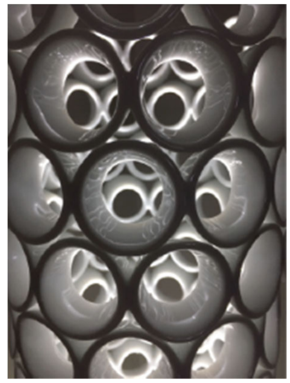


Fig. 2. Lighting object made of porcelain by French moldmaker Guy Maynard.

Table 7 reveals the mineral phases which are obtained after high-temperature synthesis. Quartz and Mullite are obtained in Mass 1 (soft porcelain); Anorthite, Wollastonite, Quartz and Almandine are achieved in Mass 2 (red-fired ceramics); and Quartz, Magnesium calcite, Albite, Gypsum, Kaolinite and Orthoclase are observed in Mass 3 (pale-fired ceramics).

Table 7. Mineral phase analysis of the synthesized samples.

Samples	Mineral phases
Mass 1	SiO_2 $3Al_2O_32SiO_2$
Mass 2	$CaAl_2Si_2O_8$ $CaSiO_3$ SiO_2 $Fe_3Al_2(SiO_4)_3$
Mass 3	SiO_2 $CaMg(CO3\ )_2$ $KAl_2(AlSi_3O_{10})(F,OH)_2$ $NaAlSi_3O_8$ $CaSO_42H_2O$ $Al_2O_32SiO_22H_2O$ $Al_2O_3K_2O6SiO_2$

3. Conclusion

The examples in the study show the use of a wide range of ceramic compositions used in the manufacture of lighting products. Forming techniques can also be varied depending on the specifics and objectives of the particular project. The type of material chosen mainly depends on the purpose of the lighting product. From this point of view, the decisive factor is the environment it is intended for. Objects made of unglazed ceramic masses with low water absorption are suitable for both indoor and outdoor environments. The possibilities of decorative techniques without the presence of a glaze layer are also wide. The masses can be decorated using embossing and openwork techniques and by coloring the composition with a rich palette of oxides and pigments. All ceramic materials are suitable for interior use, regardless of their physical and mechanical properties, mainly due to the lack of sudden temperature changes in the environment. This, in turn, allows the use of a wide range of technological and decorative processes for the manufacture of lighting products from ceramic materials.

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