

## **Research Article**

# Preventing Color Fading in Artist's Oil Paintings Based on Nano-PZT Ferroelectric Thin Film

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Due to the excellent electrical properties, stable temperature characteristics, and abundant material systems of ferroelectric thin film materials, in recent years, ferroelectric devices based on silicon technology have been used in microelectronic mechanical systems, new energy photovoltaics, especially nonvolatile memory and other fields. During the preservation of the artist's oil painting works, the temperature change will directly cause the physical effects of thermal expansion and contraction of the oil painting and the chemical reaction speed of the material in nature. Therefore, it is of great significance to introduce the technology of nano-PZT ferroelectric thin film into oil paintings to prevent fading. This article aims to study the research on preventing fading of the artist's oil paintings based on nano-PZT ferroelectric thin films and analyze the characteristics of ferroelectric materials, the application of ferroelectric films, the preparation methods of ferroelectric films, and the basis of the main environmental factors that affect the fading of oil paintings. In the above, we studied the fading process of different concentrations of oil paints under simulated sunlight aging and the effect of different concentrations and thicknesses of PZT ferroelectric thin films coated with nano-TiO2 coatings on the color stability of oil paints. The experimental results show that after five times of simulated solar aging for the four concentrations, the total color difference  $\Delta E: 0.05\%$  group is the largest, 0.4% group is the smallest, the higher the oil paint concentration, the smaller the color difference, the better the color stability, and the antisimulation of sunlight fading.

## 1. Introduction

Oil paintings are often aging due to light and heat during the preservation process, which will cause the pigments to change or fade and eventually lose their value. For this reason, domestic and foreign researchers have tested various methods to improve the discoloration resistance of oil paints, and conducted a lot of research, such as mixing ultraviolet absorbers, light stabilizers, and sunscreens, to improve the discoloration resistance of oil paintings. But no obvious effect was seen [1, 2].

Due to its special structural characteristics, the perovskite PZT material has excellent properties such as iron, piezoelectric, dielectric, and thermoelectric. In recent decades, it has attracted great attention from domestic and foreign designers and has become a new type of functional material in the world [3, 4]. Widely used in energy, intelligence, military, and other high-tech fields. Traditional ferroelectric and piezoelectric materials and their process size are limited, and it is difficult to adapt to the miniaturization, miniaturization, and integration requirements of modern electronic devices. Since the 1950s, researchers have been exploring the preparation, properties, and applications of iron PZT films.

In recent years, many researchers at home and abroad have conducted research on improving the discoloration resistance of pigments and preventing the fading of oil paintings, and have achieved good results. Choosing color matching pigments with high discoloration resistance and various aging resistance is an important way to improve the discoloration resistance of oil paintings, and it is also the development trend of oil paints [5, 6]. Some scholars have studied the resistance to discoloration of silicone rubber SY-1 colored with oil paints (after special treatment), inorganic dyes and gouache dyes under ozone aging, thermal oxidation aging, natural aging, and dark aging. The results show that among the pigments, oil paints have excellent heat resistance, ozone aging resistance, light resistance, and weather resistance, as well as better color stability [7, 8]. Some scholars believe that the fading of pigments exposed to the sun is not a process of gradual disappearance of colored substances, but a chemical change caused by ultraviolet rays. The ultraviolet light reacts with the dye or stimulates the dye. Air, water vapor, and pigments become colorless or light-colored compounds, causing macrofading of oil painting [9, 10]. Some researchers have tested the discoloration resistance of five kinds of pigments in oil paintings, indicating that the initial color change of oil paintings may be caused by the fading of ultraviolet-sensitive pigments, and the color change is long term [11, 12]. Since photo-oxidation aging plays an important role in the fading of oil paintings, researchers are trying to add light stabilizers to oil paintings to delay the fading of oil paintings. According to the mechanism of action, light stabilizers can be divided into shielding agents, ultraviolet absorbers, quenchers, and free radical scavengers (mainly inhibitory amine derivatives) [13, 14]. At present, the major research in foreign countries is UV absorbers. The main functional principle of light stabilizers can be determined by their chemical structure and form. Some can shield, reflect, or absorb ultraviolet light to form harmless light energy [15, 16]. In the research on enhancing the discoloration resistance of paints, some researchers have carried out in-depth research on the antitarnish performance of three oil paintings (sticky gray ocher, ocher oil paint, inorganic salt pigment) under natural aging conditions and concealment of oil paintings [17, 18]. Looking at the literature at home and abroad, it can be seen that a large number of scholars have conducted research on improving the color stability of oil paints, and there has been some progress. However, there have been few studies on the prevention of fading in artists' oil paintings based on nano-PZT ferroelectric films for many years, so it is necessary explore it in depth. The analysis of the aging phenomenon has certain practical significance for solving the aging phenomenon of polymers [19].

On the basis of consulting a large number of domestic and foreign references related to the antifading of oil paintings, this paper found that the temperature stability of the PZT ferroelectric thin film has a certain effect on the protection of oil paintings from fading [20]. Therefore, this article combines the characteristics of ferroelectric materials, the application of ferroelectric thin films, the preparation method of ferroelectric thin films, and the main environmental factors that affect the fading of oil paintings. The color stability of oil paints was studied experimentally by covering with nano-TiO2 film.

## 2. Preventing Color Fading in Artist's Oil Paintings Based on Nano-PZT Ferroelectric Thin Film

#### 2.1. Characteristics of Ferroelectric Materials

2.1.1. Spontaneous Polarization. Spontaneous polarization refers to the inherent characteristics of ferroelectrics, whose polarization tendency changes under the influence

of electric charges. As shown in Figure 1, the virtual model of the ferroelectric crystal is introduced and its dielectric behavior is explained [21, 22]. In the virtual model of the ferroelectric crystal, various coupling modes between the body and the body are considered at the same time [23].

At a certain temperature, all Z and P ions are adjacent, so as shown in Figure 1(a), adjacent Z and P ions form a dipole, and the polarization directions of these dipoles are the same. This is the spontaneous polarization phenomenon of the aforementioned crystal, as shown in the top three rows of Figure 1(b). The ferroelectric crystals have the same layout rules of ferroelectric dipoles, as shown in Figure 1(b), but the layout rules in adjacent places are different. In direct proportion to the characteristics of ferromagnetic chips, the spontaneously polarized regions in the same direction in these places are strong electric fields [24].

2.1.2. Electric Hysteresis Loop. One of the most important characteristics of ferroelectric materials is that they have an electrical group. At the same time, as shown in Figure 2, another main criterion for judging the properties of ferroelectric materials is the electrical group. That is, when the external charge changes, the electrode vector changes. Therefore, the degree of polarization of ferroelectric materials increases as the charge increases. When the total charge exceeds the extreme point B line, due to the continuous increase of the total charge, the increase in the polarization of the crystal changes very little [25, 26]. However, due to the existence of induced polarization, once the total charge continues to increase, the voltage change of the total polarization responds to the continuous increase of the BC line. So the electrode current reaches the saturation value from point C. After point C, due to the continuous weakening of the total charge, the polarization current changes along the CBD curve. Therefore, when the total charge intensity is zero, the total polarization of the crystal is not zero.

*2.1.3. Dielectricity.* Studying the dielectric properties of ferrous materials is the most basic and important task in the research of ferrous materials. Parallel plate capacitor formula:

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}.$$
 (1)

In the formula,  $\varepsilon_0$ ,  $\varepsilon_r$  represent the vacuum dielectric Changshu and the dielectric constant to be calculated. If the relative area of the parallel plates of the two capacitor parallel plates is equal to the distance between the parallel plates, the capacitance is *C* when the medium is full; if there is a gap between the plates, the capacitance is  $C_0$ . It can be obtained by

$$\varepsilon_r = \frac{C}{C_0}.$$
 (2)



FIGURE 1: Schematic diagram of two-dimensional ferroelectric crystal structure. (a) PZT relative position. (b) Electric dipole sequencing.



FIGURE 2: Schematic diagram of hysteresis loop of ferroelectric materials.

It can be seen from formulas (1) and (2) that when there is a dielectric between the two plates instead of a vacuum, the capacitance of the plate capacitor increases. The relative dielectric constant can be used to express the multiple of the increase in capacitance, and the multiple of increase is the value of  $C/C_0 \varepsilon_r$  is the relative permittivity; permeability is usually called relative permeability, which is a dimensionless number (its value is greater than 1). For simplicity, the relative permeability is generally reduced to the dielectric constant. It can be found that when the relative area of the parallel plates of the parallel plate capacitor is equal to the distance between the parallel plates, the greater the dielectric constant of the dielectric, and therefore the greater the capacitance of the capacitor. Therefore, when manufacturing a capacitor with a relatively constant capacitance, choosing a dielectric with a higher dielectric constant will reduce the size and thickness of the electrode, which will help to make a smaller capacitor. There are many factors that affect ironbased materials, such as the chemical composition, crystal structure, and manufacturing process of the material.

2.1.4. Pyroelectricity. The characteristic that the polarization state of a crystal changes with temperature is called the pyroelectric effect [27]. The change of spontaneous polarization is  $\Delta P_s$ , the temperature change of the crystal is  $\Delta T$ , and the pyroelectric coefficient p is expressed by

$$p = \frac{\Delta P_s}{\Delta T}.$$
(3)

At a constant temperature, the single-field ferroelectric protects its combined charge through the action of free charge, so the charge generated at both ends, that is, the external electrical effect, will not appear. As the external temperature increases or decreases, the internal polarization of the crystal will be redirected, so that the combined load generated by the spontaneous polarization of the crystal cannot be fully protected. Therefore, if the crystal is connected to an external circuit, the current in the circuit can be detected. When the temperature changes, a current is generated in the crystal, and when the temperature increases or decreases, a current is generated in the opposite direction. Due to the pyroelectric effect, temperature is an important factor for changing the spontaneous polarization of the crystal. In the case of piezoelectric materials, the main factor for the spontaneous polarization is the applied voltage.

#### 2.2. Application of Ferroelectric Thin Film

2.2.1. Memory. Memory is one of the main applications of thin-film iron films, and its commonly used types mainly include nonvolatile random access memory (FRAM), dynamic random access memory (DRAM), and ferroelectric field effect transistor (FFET).

FRAM is widely used based on the principle of residual polarization after polarization of iron-based materials. The storage process must use the "0" and "1" bits. These correspond to the remaining two polarizations in the iron ring. The positive and negative are opposite. The zero electric field of the remaining polarization stabilizes the stored information and is not easy to lose. Therefore, it can be known that this type of memory requires iron materials with higher residual polarization and lower leakage current to store more information. The coercivity must also be small enough and fatigue-resistant enough to ensure that after repeated storage can still maintain performance. RAM is now widely used in the fields of information, transportation, and consumer electronics.

The gate material between the source and drain of the FFET is made of iron film instead of conventional materials. It varies greatly, and the current between source and drain can be used to represent "1" and "0" in the binary system. There is no need to reverse the polarization of the gate material. This read state behavior is nondestructive and is very suitable for creating electrically erasable read-only programmable memories. FFET has the advantages of nonvolatile, simple structure, nondestructive reading, and high integration and is a very ideal storage device.

2.2.2. Miniature Piezoelectric Driver. When a certain external electric field acts on the piezoelectric material, the piezoelectric material changes under the influence of the electric field, and the piezoelectric material acts as a driving function through the inverse piezoelectric effect of the piezoelectric material. Small piezoelectric actuators are now used in applications such as microelectronics engineering and high-precision machining because of their small size, low noise, and high displacement resolution.

#### 2.3. Preparation Method of Ferroelectric Thin Film

2.3.1. Sol-Gel Method. The basic principle of the Sol-Gel method is to dissolve the alkoxide of each membrane component in a specific solvent to react to form a double alkoxide, add a catalyst and water to make it hydrolyzed, and then converted into a solution and gel, spin-coated, dried, and sintered to produce the desired film. Due to the solution reaction step, it is easy to dope some trace elements uniformly and quantitatively to achieve uniform doping at the molecular level. The basic chemical reactions include hydrolysis and polymerization. The Sol-Gel method can be divided into two categories. One is the conventional dimetal alkoxide method, which mainly utilizes the reaction of metals and alcohols to form alkoxides, which are then hydrolyzed and polymerized to form gels. The other is metalloid alkoxide. The alkoxide method uses titanium alkoxide and strontium inorganic salt as raw materials, which are hydrolyzed and polymerized in a specific system to form a gel. The advantages of the Sol-Gel method are low preparation temperature, precise control of the chemical composition ratio of the film, uniform molecular level of the film, convenient doping changes, simple equipment, low cost, easy preparation of large surfaces, microelectricity, and compatibility.

2.3.2. Magnetron Sputtering Method. Sputtering is a complex scattering process on the target. After the incident particles collide with the target molecule, a part of the momentum is transmitted to the target molecule. After the target atom collides with another target molecule, a cascade process occurs. In this scaling process, the target molecules near the specific surface move outward to acquire the corresponding momentum and release the target, thereby producing the film.

The specific mechanism of sputtering is as follows: When the accelerated gas incident light molecules collide with the surface of the target substance (cathode), an electron is released. The gas molecules collide to form the molecules needed for self-sustained flash discharge. The so-called mean free path of the initial electron increases with the increase of the electron capacity, and decreases with the increase of the pressure. At low temperature, high-temperature wall damage is caused by ions generated away from the cathode. As the electrons move, the ion efficiency is very low, and even the ions required for self-sustaining flash discharge cannot be obtained. Although the mean free path of electrons increases with the acceleration trend, it still cannot effectively increase the ion efficiency.

2.3.3. Pulsed Laser Deposition Method. Pulsed laser deposition is a relatively new and rapidly developing coating method. The basic principle is that the high-power pulsed laser generated by the pulsed laser concentrates on the target surface to form a high-temperature removal zone, generates high-temperature and high-pressure plasma, locally guides and expands the plasma, and the thin film is deposited on the substrate.

Compared with sputtering technology that must use working gas such as argon, molecular beam excitation technology can only operate under high vacuum, while pulsed laser deposition systems can operate under relatively high-purity experimental atmospheric pressure to prepare oxide films. At the same time, the pulsed laser deposition system technology can accurately transfer the ceramic components of the composite target to the film according to the stoichiometric ratio by controlling the plume and deposition process generated by the laser stripping target.

#### 2.4. The Main Environmental Factors Affecting the Fading of Oil Paintings

2.4.1. Light. Light is a kind of energy, which is very dangerous to all organic compounds. It can damage the objects it irradiates. Ultraviolet rays can destroy most of the C-C and C-O chemical bonds in organic substances and reduce the strength of the material. The photodegradation reaction self-oxidizes in the presence of oxygen molecules to generate peroxide free radicals, triggering a new chain reaction, accelerating the aging process of the material, causing the destruction of oil paints and reducing the strength of the canvas. The oil painting is composed of a variety of colors. Some coatings can absorb more near-infrared rays than others, which can cause fragmentation and damage caused by local heating, which can change the size of the image and be accompanied by cracks, cracks and discoloration. Under the action of light, long-term use of natural triterpene resins, dama resins, and frankincense

resins that restore oil color will be more prone to aging and yellowing. The copper with acid resin commonly used in oil paintings is initially transparent green, but under the influence of light, it turns into an opaque brown. Pigments such as carmine and eosin, which are used as flesh-colored shades, are also easy to change color.

2.4.2. Temperature. Temperature changes can directly cause the natural effects of thermal expansion and contraction of oil paints and the chemical reaction rate of materials in nature; oil paintings are composed of multiple materials, and the physical properties (expansion coefficients) of different materials are different, and temperature changes can cause catastrophic. Effects such as temperature rise, the moisture content in solid oil paintings increase, material degradation, oxidation, hydrolysis and other reactions accelerate, oil painting materials are damaged and look dry. Discoloration accelerates the relative aging process and fragility of oil paintings. When the temperature reaches 40°C, the bituminous pigment in the paint layer will dissolve, forming dark brown spots and polluting the picture.

2.4.3. Humidity. Changes in humidity levels are obvious during the expansion or compression of the oil painting. Because the base materials of linen, wood board, and paint generally have high water absorption, especially the fabric base materials, which are particularly sensitive to dry and wet reactions, the chemical reaction between the base material and the paint layer is relatively slow. The canvas will expand shortly after being damp, or shrink again when the relative humidity drops. At this time, the tension on the back side rises sharply, but the tension on the front color layer does not change much, resulting in uneven stress. The base and color layers are due to Partial bulge after separation, small cracks on the picture, deformation or shedding of oil paint; moisture promotes the corrosive effect of light, and promotes the oxidation of metal pigments, such as cadmium, strontium, titanium, and lead, making the painting surface oily yellow or whitish, making the painting discoloration; it also breeds mold growth and reproduction. Humidity will also affect the internal and external crates of the oil painting, which will become softer and longer (shortened when dry) and deformed by traction after being absorbed. Due to the extrusion and deformation of the canvas, the deformation of the crate will also damage the canvas.

2.4.4. Air Pollutants. The air contains gaseous pollutants and dust in the form of particles and dust. Most gaseous pollutants are caused by fuel combustion in power plants, factories, residential areas, and automobiles. Today, the most important gaseous pollutants in the world are sulfur dioxide, nitrogen dioxide, and ozone, and the main components of powder are acid, alkali, and salt. Sulfur dioxide has a bleaching effect. In addition, it easily reacts with oxygen to form sulfur trioxide. Sulfur trioxide can quickly combine with water to form sulfuric acid. Sulfuric acid is a strong acid that is very corrosive to canvas and paint. 2.4.5. Mold. The particles fall on the surface of the oil painting, attach and absorb water, provide a way for the growth and growth of mold, and provide a place and food for the microorganisms in the air to multiply and multiply in the oil painting. When the environment is suitable, the mold will grow rapidly, and the fibers in the oil painting vegetables and organic matter are decomposed and used as nutrients, causing immediate damage. The organic acid produced by the mold in the metabolic process causes acid corrosion on the oil painting, and the pigment produced by the mold colony contaminates the oil painting in various ways, forming mildew spots. The heat generated by the mold in the metabolic process accelerates the destruction of the painting.

#### 3. Experiment

3.1. Preparation of PZT Ferroelectric Thin Film. At present, there are many methods for preparing PZT ferroelectric thin film materials, such as sputtering method, hydrothermal synthesis method, pulsed laser deposition method, molecular beam epitaxy method, sol-gel method (Sol-Gel method), and metal organic chemical vapor phase deposition method (MOCVD method). This paper chooses the Sol-Gel method to prepare ferroelectric thin films. Table 1 shows the experimental raw materials for the preparation of PZT films.

Figure 3 is the overall process of preparing PZT thin films. The composition of PZT is selected as  $Pb_{1,1} (Zr_{0.51}Ti_{0.47})O_3$ , and the Pb excess is 10%. The preparation process of PZT ferroelectric thin film is as follows:

- (1) Weighing: According to the stoichiometric ratio of the amount of material n(Pb):n(Zr):n(Ti) = 1.1: 0.51:0.47, weigh an appropriate amount of lead acetate and zirconium nitrate.
- (2) Dissolution: When the temperature reaches 40°C, add appropriate amount of glycol methyl ether to lead acetate, stir while heating, seal with plastic wrap, add appropriate amount of glycol methyl ether to zirconium nitrate, and place in a constant temperature water bath.
- (3) Mixing: first add the dissolved zirconium nitrate solution to the lead acetate solution, then slowly add an appropriate amount of acetic acid and acetylacetone, stirring constantly during the dissolution process.
- (4) Weighing of tetrabutyl titanate: Because tetrabutyl titanate easily reacts with moisture in the air, use a needle to weigh tetrabutyl titanate and ethylene glycol methyl ether, and add them to the mixture as a chelating agent. In the middle, the mixture is thoroughly mixed and stirred.
- (5) Standing: Put the prepared mixture in an environment below room temperature 20°C (so that it can be used for a long time after storage) for 3 days.
- (6) Film spin-off: First, filter the 0.2 mol/L PZT static precursor twice, coat the PZT solution on the Pt/Ti/ SiO2/Si substrate with a homogenizer, and then put it into a rapid annealing furnace under O2. After

TABLE 1: Table of raw materials for PZT film preparation.

Reagent name	Chemical formula	Purity (%)	Molecular weight
Lead acetate	$Pb(CH_3COO)_2 \cdot 3H_2O$	99.5	379.19
Zirconium nitrate	$Zr(NO_3)_4 \cdot 5H_2O$	99.5	429.32
Tetrabutyl titanate	[CH <sub>3</sub> (CH <sub>2</sub> ) <sub>3</sub> O] <sub>4</sub> Ti	98	339.86
Ethylene glycol monomethyl ether	CH <sub>3</sub> OCH <sub>2</sub> CH <sub>2</sub> OH	99.5	76.08
Acetic acid	CH <sub>3</sub> COOH	99	60.04
Formamide	CH <sub>3</sub> NO	99.5	45.03



FIGURE 3: The overall process of PZT ferroelectric thin film preparation.

drying and cracking, the process is repeated several times, and the last layer is annealed with O2 to obtain the desired thickness of PZT ferroelectric film.

In the PZT solution prepared by the sol-gel method, a hydrolysis-overcondensation reaction occurs between the raw materials to form a sol PZT containing oxygen-metal bonds Ti-O, Zr-O, and Pb-O. When mixing and stirring, the OC4H9 butoxy bond of the titanium polymer replaces the Zr-O and Pb-O bonds, and finally forms a network polymer that combines oxygen and metal elements, thereby forming a uniform PZT colloidal solution. The chemical reaction that occurs is:

(1) Hydrolysis reaction of 
$$Zr(NO_3)_45H_2O$$
 inorganic salt:  
 $Zr(NO_3)_4 + H_2O \longrightarrow Zr(NO_3)_3(OH) + HNO_3$ ,  
 $Zr(NO_3)_3(OH) + H_2O \longrightarrow ZrO(NO_3)(OH) + HNO_3$ .  
(4)

(2) Hydrolysis reaction of Pb(CH<sub>3</sub>COO)<sub>2</sub> organic salt:

$$Pb(CH_{3}COO)_{2} + H_{2}O \longrightarrow Pb(OH)(CH_{3}COO) + CH_{3}COOH.$$
(5)

 (3) Hydrolysis reaction of butyl titanate Ti(OC<sub>4</sub>H<sub>9</sub>)<sub>4</sub> metal organic salt:

$$\mathrm{Ti}(\mathrm{OC}_{4}\mathrm{H}_{9})_{4} + \mathrm{H}_{2}\mathrm{O} \longrightarrow \mathrm{Ti}(\mathrm{OC}_{4}\mathrm{H}_{9})_{3}(\mathrm{OH}) + \mathrm{C}_{4}\mathrm{H}_{9}\mathrm{OH}.$$
(6)

$$Ti(OC_{4}H_{9})_{3} - (OH) + (OH) - Ti(OC_{4}H_{9})_{3}$$

$$\longrightarrow (C_{4}H_{9}O)_{3} - Ti - O - Ti - (OC_{4}H_{9})_{3} + H_{2}O,$$

$$Ti(OC_{4}H_{9})_{3} - (OH) + Ti(OC_{4}H_{9})_{4}$$

$$\longrightarrow (C_{4}H_{9}O)_{3} - Ti - O - Ti - (OC_{4}H_{9})_{3} + C_{4}H_{9}OH$$
(7)

TABLE 2:  $L^*$  value of different concentration and different exposure times.

Concentration	0	1	2	3	4	5
0.05	$59.92\pm0.32$	$55.27 \pm 0.3$	$53.9 \pm 0.31$	$52.57\pm0.32$	$51.41 \pm 0.34$	$50.46\pm0.31$
0.1	$50.47 \pm 0.51$	$47.38 \pm 0.53$	$46.14\pm0.54$	$45.04\pm0.57$	$44.12\pm0.58$	$43.34\pm0.57$
0.2	$44.39 \pm 0.36$	$41.73\pm0.37$	$41.78\pm0.38$	$41.67\pm0.36$	$41.58\pm0.35$	$41.51\pm0.36$
0.4	$39.44 \pm 0.61$	$37.98 \pm 0.61$	$39.39 \pm 0.59$	$40.13\pm0.58$	$40.86\pm0.61$	$41.21\pm0.57$

3.2. Specimen Production. Add 0.16 g of nano-TiO<sub>2</sub> to the PZT film, stir evenly, divide into 4 parts, then add 0.01 g, 0.02 g, 0.04 g, and 0.08 g paint, respectively, mix quickly, manually stir and mix for 30 minutes, the preparation and use concentration is 0.05%, 0.1%, 0.2%, and 0.4% PZT film until the pigment is completely dispersed.

After mixing the prepared PZT colored film with the catalyst 1 : 2, use a syringe to inject a mold with a diameter of 20 mm and a thickness of 15 mm, place it in a vacuum box, and hold at -0.1 MPa for 30 minutes. Release the negative pressure to evaporate, place it in a constant temperature water bath, keep the temperature at 37°C for 24 hours, remove the edges and make a test piece with a diameter of 20 mm and a thickness of 15 mm. There are ten test pieces in each group, a total of four groups. After making it, store it in a dark place for later use.

#### 3.3. Simulated Solar Aging Method and Color Measurement

3.3.1. Simulated Solar Aging Method. After completing the test piece, measure the original spectrum data of the test piece and derive the  $L^*a^*b^*$  value. Place the sample under a simulated solar aging lamp with a temperature of about 24°C and a relative humidity of about 53%, and illuminate for about 17.14 hours (equivalent to 200 hours of sunshine at noon), and then re-measure the spectral data of the sample to derive  $L^*a^*b^*$  value, and estimate the value of  $\Delta E$ ,  $\Delta L$ ,  $\Delta a$ , and  $\Delta b$ . Then, repeat it four more times in the same way.

*3.3.2. Measurement and Calculation of Color.* The color measurement and calculation use the following formula:

Poor brightness:

$$\Delta L * = L *_{1} - L *_{2}. \tag{8}$$

Color difference:

$$\Delta a * = a * {}_{1} - a * {}_{2},$$
  
$$\Delta b * = b * {}_{1} - b * {}_{2}.$$
 (9)

Total color difference:

$$\Delta E *_{ab} = \left[ \left( \Delta L * \right)^2 + \left( \Delta a * \right)^2 + \left( \Delta b * \right)^2 \right]^{1/2}.$$
 (10)

3.4. Statistical Analysis. The data are entered and statistically analyzed by SPSS13.0 statistical software. This paper uses a two-factor analysis of variance to analyze the interaction of different concentrations, different aging times, and the interaction between concentration and aging time on  $\Delta E$ ,  $\Delta L^*$ ,

 $\Delta a^*$ , and the influence of  $\Delta b^*$ ; P < 0.05 is statistically significant.

#### 4. Discussion

In the  $L^*a^*b^*$  system,  $L^*$  in Table 2 represents the degree of brightness, a positive change in  $L^*$  value means brighter, and a negative change means darker. The difference between the brightness of the nano-PZT and the ferroelectric film after coloring of the four concentrations of oil paint is particularly obvious in the early changes.

Table 3 shows the  $a^*$  value, where  $a^*$  is the difference between red and green, positive represents red, negative represents green, and zero represents colorless. The colored nano-PZT ferroelectric coating in oil paint gradually decreases with the  $a^*$  value of the duration of solar radiation in the simulation, and the change is most obvious in the early stage. The  $a^*$  value of the color concentration of the four cadmium red oil paintings is positive and gradually decreases, that is, the color gradually becomes lighter on the whole.

The  $b^*$  value in Table 4 is yellow-blue quality difference, positive represents yellow, negative represents blue, and zero represents colorless. The nano-PZT ferroelectric film colored by the four low-concentration oil paints has a positive  $b^*$ value as the duration of simulated sunlight increases, and shows a gradual increase, that is, it turns yellow in the overall trend, but changes early. It is more obvious.

It can be seen from Figure 4 that under the simulated sunlight aging of the 0.05% oil paint group, there is a significant difference in  $\Delta E$  between the first and second aging and the other four agings (P < 0.05). The  $\Delta E$  changes of various oil paints of different concentrations are mainly concentrated in the first aging; the  $\Delta L$  of the 0.1% and 0.2% oil paint groups is negative after the first and second aging, that is, the lightness becomes darker; 0.4% oil paint group of simulating solar aging was negative for the first time and positive for the second time, and there was a significant difference between the two (P < 0.05).

According to Figure 5, there is no significant difference in  $\Delta L$  between the second aging and the third aging for the 0.05% oil paint group specimens under simulated sunlight aging (P > 0.05); the 0.2% oil paint group has no significant difference in the third aging and there was no significant difference between the second aging, the fourth aging and the third aging (P > 0.05).

It can be seen from Figure 6 that the color difference  $\Delta E$  after five simulated solar aging tests with four concentrations is the highest in the 0.05% group, and the lowest in the 0.4% group; the lightness difference  $\Delta L$ : except that the 0.4% group is positive. The remaining concentrations are all

TABLE 3:  $a^*$  value of different concentration and different exposure times.

Concentration/%	0	1	2	3	4	5
0.05	$13.9\pm0.13$	$11.11 \pm 0.23$	$10.08\pm0.22$	$9.68\pm0.22$	$9.39 \pm 0.21$	$9.3 \pm 0.22$
0.1	$21.92\pm0.29$	$18.19\pm0.42$	$16.97 \pm 0.41$	$16.51 \pm 0.42$	$16.15\pm0.41$	$16.02\pm0.41$
0.2	$29.07\pm0.3$	$24.38 \pm 0.34$	$22.66\pm0.4$	$21.59 \pm 0.42$	$20.95\pm0.41$	$20.47\pm0.38$
0.4	$46.39 \pm 0.25$	$41.29\pm0.3$	$37.81 \pm 0.3$	$35.52\pm0.29$	$33.74\pm0.29$	$32.55 \pm 0.35$

TABLE 4:  $b^*$  value of different concentration and different exposure times.

Concentration/%	0	1	2	3	4	5
0.05	$-2.47\pm0.13$	$19.39\pm0.47$	$24.73\pm0.57$	$27.37 \pm 0.58$	$29.8 \pm 0.59$	$31.81 \pm 0.6$
0.1	$1.3 \pm 0.09$	$18.23\pm0.15$	$22.83 \pm 0.22$	$24.77\pm0.21$	$26.43 \pm 0.22$	$27.94 \pm 0.21$
0.2	$6.85\pm0.18$	$17.82\pm0.27$	$20.91 \pm 0.25$	$22.7\pm0.26$	$23.6\pm0.29$	$23.97\pm0.3$
0.4	$24.49 \pm 0.39$	$25.25\pm0.41$	$24.75\pm0.39$	$23.81 \pm 0.4$	$21.87 \pm 0.42$	$19.53\pm0.41$



FIGURE 4: The values of  $\Delta E$ ,  $\Delta L$ ,  $\Delta a$ , and  $\Delta b$  (a) after the first time and (b) between the first time and the second time under simulated solar aging.



FIGURE 5: The  $\Delta E$ ,  $\Delta L$ ,  $\Delta a$ , and  $\Delta b$  values (a) between the third and second time and (b) between the fourth and third time under simulated daylighting.



FIGURE 6:  $\Delta E$ ,  $\Delta L$ ,  $\Delta a$ , and  $\Delta b$  values (a) between the fifth and fourth times and (b) after the fifth time under simulated daylighting.

negative values, that is, except for the brightness of the 0.4% group, the brightness of the other concentration groups are all darkened, and the 0.05% darkening degree is the highest; the chromaticity difference  $\Delta a$  of the four concentration groups are all negative values. Among them, the 0.4% group is the highest, that is, the 0.4% group has the highest degree of color fading after the four concentrations after aging, and the 0.05% group has the lowest color fading; the chromaticity difference  $\Delta b$  of the four concentration groups is negative when divided by the 0.4% group. The others are all positive, and the highest in the 0.05% group.

#### 5. Conclusions

The paint is a necessary part of oil painting creation. The quality of the paint determines the quality and effect of the color of the picture, and also determines the long-term preservation of the painting. Oil paintings are easily affected by factors such as light in the air, temperature and humidity, and mold, which make oil paintings fade seriously. The temperature characteristics of the PZT ferroelectric film can improve the color stability of oil paints, enhance the ability to resist fading, and effectively protect the fading of oil paintings. Therefore, the method of applying PZT ferroelectric film to enhance the color stability of oil painting is an effective method.

### **Data Availability**

No data were used to support this study.

## **Conflicts of Interest**

The author declares that there are no conflicts of interest.

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