1. Introduction

With the development of the textile industry and the improvement of people's living standards, people's requirements for the quality of textiles are getting higher and higher, and they are also paying more and more attention to the requirements of environmental protection and functionality. Traditional textiles can no longer meet the latest requirements for modern industrial use, clothing, and decoration. The development of modern textiles has been towards diversification and functionalization. Nano-TiO₂ has attracted much attention due to its advantages of low cost and nontoxicity, small particle size, large specific surface area, strong magnetic properties, high catalytic activity, good absorption performance, strong ability to absorb ultraviolet rays, high surface activity, good thermal conductivity, good dispersibility, and good stability. At present, nano-TiO₂ mainly has the main advantages of antiultraviolet, antibacterial, antistatic, extinction, antiaging, self-cleaning, and heat insulation in textiles. However, the biological effects of nanomaterials and their impact on the environment and health have also attracted more and more attention. Whether nanomaterials are suitable for clothing fabrics remains to be considered.

In this paper, by analyzing the photocatalytic mechanism and UV shielding performance of nano-TiO₂ materials, combined with the method of molecular dynamics, the application of functional nanomaterials in clothing design engineering is explored, and the safety performance of nanomaterials in the field of clothing is studied. The experiment found that nano-TiO₂ material has excellent antiultraviolet ability and self-cleaning ability. Through the toxicological experiments of nano-TiO₂, it was found that although nano-TiO₂ material itself has toxic reactions, the inert nature of nano-TiO₂ determines the difficulty of reacting with organisms. The toxic reaction of nano-TiO₂ is
directly related to the time and dose of nano-TiO$_2$. The longer the time and the larger the dose, the greater the toxic reaction.

As the application scope of nanomaterials becomes wider, more and more research has been done in this area. Rosario et al. complicate engineering design through statistical uncertainty confounding normative design methods and degrading performance for reliability work. The easiest way to address this uncertainty is a two-loop simulation, a nested Monte Carlo method, that is, intractable for practical problems. In this work, a flexible and general approximation technique is introduced that avoids double loops. This approximation is constructed in the context of a new theory of reliability design under statistical uncertainty. It introduces metrics to measure the effectiveness of RBDO strategies (effective margin and effective reliability), a minimum condition to control uncertainty reliability (accuracy margin), and tighter conditions to ensure that all desired required reliability. Numerous open-source code examples are provided to demonstrate our approach in a reproducible manner [1]. Xiaojiao reported a robust porous superhydrophobic composite (PSC) based on a multilayered carbon nanotube network and a poly (ethylene-vinyl acetate) matrix for recoverable shape reconfiguration and underwater vibration detection. Solvent plasticization and capillary effect endow PSC with good shape memory properties, and skeleton deformation makes PSC suitable for detecting various underwater vibrations [2]. Wongkaew et al. answered many questions about nanomaterials used in the past 5 years (2013–2018), their inherent properties, and the role of chemicals of interest in analytical applications for the analytical systems they provide, and quantitatively assess their positive impact on the analysis. Furthermore, in order to contribute to an in-depth understanding of how functional nanomaterials can be beneficially and effectively applied to electrochemical biosensor-based lab-on-a-chip devices, some pioneering studies are comprehensively presented here to discuss important fundamentals regarding device fabrication and nanomaterials knowledge [3]. In this article, Zhong et al. reviewed the development of nanomaterial-based chloride detection strategies and their applications in biological analysis. Much progress has been made in the past decade, but most attempts are still in the proof-of-concept stage. The recent progress of nanomaterials in chloride ion detection is described, and they are divided into three categories according to their roles in detection: as sensing platforms, as signal probes, and applications in homogeneous systems. Furthermore, they discuss the key challenges they face and the future prospects of the field [4]. Wilts et al. found that the bright colors of many animals come from the physical interaction of light with nanostructured, multifunctional materials. Although their lengths are typically in the 100 nm range, the morphology of these structures can vary widely. These bio-nanostructures are obtained in a controlled manner using biological materials under ambient conditions, a natural formation process using equilibrium self-assembly, and elements away from equilibrium and growth processes. This makes not only the color itself but also the formation process highly technically and ecologically relevant. However, for many bio-nanostructured materials, little is known about their formation mechanisms due to the lack of in vivo imaging methods. In this paper, they present a toolbox of natural multifunctional nanostructures and state-of-the-art knowledge about understanding their far-from-equilibrium assembly processes [5]. Hegde improved the properties of fabrics by modifying fibers or yarns and making fabrics by nano or microtechnology during the fiber production stage or during the fabric finishing process. It includes aesthetics and functionality resulting in improved feel, drape, comfort and UV protection, self-cleaning, flame retardant, and antimicrobial properties. Self-cleaning fabrics will be popular and will revolutionize the apparel industry. Nano and microencapsulation technologies are applied to textile fibers, yarns, or fabrics to improve their end uses such as aroma, drape, hand, care and maintenance, comfort, and safety. A holistic approach to human skin can be provided by using microencapsulated fragrance garments that can be applied to multiple disciplines such as healthcare textiles and cosmo textiles. Invisible nano and microcapsules produce effects through the wearer’s sense of touch, reducing stress and increasing comfort and relaxation. Although the technology is applied to textiles, it is an interdisciplinary application in the fields of medicine, defense, aerospace, and engineering [6]. Liu et al. studied the cold shock resistance and safety performance of nano 3/SiO$_2$/C composite inorganic phase change heat storage materials at ultralow temperature and established a low-temperature cold shock test system. At 40, 60, 80, and 196°C, it was studied on composite inorganic phase-change heat storage materials with different raw material particle sizes by static cold shock and dynamic cold shock. Using balance, vernier caliper, DSC, SEM, and XRD, the surface morphology, phase composition, and thermal properties of phase change heat storage materials were analyzed respectively. The results showed that the thermal properties of phase change heat storage materials with different particle sizes are only 1.97–8.89%, especially under the low-temperature shock of 196°C, with the increase of particle size, the cold shock resistance of the material is better. The physical properties, chemical properties, and heat storage capacity of the material are basically stable under impact, and it has good cold shock resistance. The cold shock of the two methods does not affect the heat storage function of the material, does not cause a waste of heat energy, and has good safety performance [7]. These pieces of literature are very detailed in the introduction of the safety performance of nanomaterials and have a constructive role in the research of this paper.

Through the photocatalytic mechanism of nano-TiO$_2$ materials, various properties of nano-TiO$_2$ materials were found. Toxicological experiments using nano-TiO$_2$ to explore the biological effects of nanomaterials and their impact on the environment and health, whether they can be applied to clothing fabrics, and how much is appropriate.
2. Safety Performance of Clothing Design

2.1. Photocatalytic Mechanism of Nano-TiO₂

Photocatalytic technology has entered people’s lives by treating dirty water. Compared with other materials, TiO₂ is more stable and has good photocatalytic activity conditions, and photocatalysis is symbolic in the experimental process of TiO₂ [8]. Strong photocatalysis can make nanomaterials excited by long wave sunlight, improve the utilization of solar energy, and effectively inhibit the recombination rate of electrons and holes, so as to better play the role of TiO₂ photocatalyst. Some studies have found that nano-TiO₂ exhibits excellent antiwetting and water-repellent properties in the treatment of various textiles, and has self-cleaning properties for textiles [9]. The processing methods of nanomaterials used in textiles mainly include cospinning method and finishing method. The method of blending spinning is suitable for chemical fibers. Nanoparticles are added during polymerization and then spun into fibers. Its advantage is good durability. Figure 1 is the crystal structure diagram of nano-TiO₂. Nano-TiO₂ is mainly composed of three kinds of octahedral crystals. Different structures lead to different densities and quality of various nanomaterials, so the properties of nanomaterials are also different [10]. The quantum efficiency of nano-TiO₂ is low, and the recombination rate of photogenerated electron-hole pairs is high, resulting in poor photocatalytic performance. It only has photocatalytic activity under UV light sources, and the utilization rate of solar energy is not high. Therefore, the application range of nano-TiO₂ is limited. The shaped nano-TiO₂ has good photocatalytic activity [11]. Figure 2 is a schematic diagram of the photocatalytic mechanism of TiO₂.

The photocatalytic properties of nano-TiO₂ are determined by the energy band structure [12]. The energy band structure describes the forbidden or allowed energy carried by electrons, which is caused by the quantum dynamic electron wave diffraction in the periodic lattice. The energy band structure of a material determines many properties, especially its electronic and optical properties. Unshaped TiO₂ does not have photocatalytic properties. The most widely used in life is anatase TiO₂. This nanomaterial has a forbidden bandwidth of 3.2 eV at pH = 1.

The photocatalytic reaction generates chemically active free radicals. The main free radicals and reactions are shown below. After being irradiated by sunlight or ultraviolet light, nano-titania is excited to form electron-hole pairs, and the conduction band electrons and valence band holes in the excited state can be recombined [13], and the light energy will be consumed in the form of heat or other forms.

\[
\text{TiO}_2 + h\nu \rightarrow \text{TiO}_2^+ + e^- + h^+ \quad \text{(1)}
\]

\[
e^- + h^+ \rightarrow \text{reunite with } h\nu \quad \text{(2)}
\]

Hydroxyl radicals are obtained by H₂O or OH-ion reaction:

\[
\text{H}_2\text{O} + h^+ \rightarrow \text{OH} + \text{H}^+ \quad \text{(3)}
\]

\[
\text{OH}^- + h^+ \rightarrow \text{OH} \quad \text{(4)}
\]

Reaction with O₂ to generate hydroxyl radicals is

\[
e^- + \text{O}_2 \rightarrow \text{O}_2^- \quad \text{(5)}
\]

\[
\text{H}_2\text{O} + \text{O}_2^- \rightarrow \text{OOH} + \text{OH}^- \quad \text{(6)}
\]

\[
2\text{OOH} \rightarrow \text{O}_2 + \text{H}_2\text{O}_2 \quad \text{(7)}
\]
is Rayleigh’s light-scattering law. Among them, the law of rays of different wavelengths, which depend on the particle maximum scattering ability of nanoparticles to ultraviolet passing through the surface of the nanomaterials, thereby process, the ultraviolet rays will scatter outward when.

2.2. Nanometer TiO₂ UV Shielding Properties. The UV shielding performance of nano-TiO₂ is mainly attributed to the function of TiO₂ to absorb and radiate UV [15]. After research, it was found that nano-TiO₂ is a wide-bandgap semiconductor structure, and the following formula is obtained:

\[ TiO_2 e^- + h^+ \] (11).

According to the wavelength of ultraviolet rays is greater than the length of the nanoparticles, in this performance process, the ultraviolet rays will scatter outward when passing through the surface of the nanomaterials, thereby reducing the intensity of the concentrated ultraviolet rays [16]. There is an optimal original particle size for the maximum scattering ability of nanoparticles to ultraviolet rays of different wavelengths, which depends on the particle shape, original particle size, and secondary particle size. This is Rayleigh’s light-scattering law. Among them, the law of nano-TiO₂ shielding ultraviolet rays conforms to the Rayleigh light scattering law. According to the law of light scattering, the ability of particles to scatter light is greatly affected by the refractive index and particle size. The larger the refractive index of particles, the stronger the scattering ability. The larger the particle size, the more obvious the scattering ability. The particle scattered light intensity equation is as follows:

\[ \frac{\varepsilon_s}{\varepsilon_i} = \frac{b^4}{\lambda^3} \frac{m^2 - 1}{m^2 + 2}. \] (12).

Among them, \( \varepsilon_s \) is the transmittance of ultraviolet light; \( \varepsilon_i \) is the intensity of the irradiated light during the shielding process; \( b \) is the length of the particle; \( \lambda \) is the wavelength of the light; \( m \) is the refractive index of the light.

Based on Rayleigh’s light scattering law, the optimal particle size can be further calculated. The commonly used formula is as follows:

\[ h_{best} = \frac{\lambda}{1414vb^2} \left( \frac{m^2 + 2}{m^2 - 1} \right), \] (13)

\[ d_{best} = \frac{0.91\lambda}{v_b\sigma} \left( \frac{m^2 + 2}{m^2 - 1} \right). \] (14)

The mechanism of nano-TiO₂ directly affects its particle surface activity, antibacterial properties, safety, and stability [17]. People take advantage of the properties of nano-TiO₂, to apply nano-TiO₂ to the fields of UV protection clothing, cosmetics, sewage treatment, and food packaging.

3. Molecular Dynamics Method

3.1. Basic Principles of Molecular Dynamics. Molecular dynamics is a comprehensive technology that integrates physics, chemistry, and mathematics [18]. As a simulation method, molecular dynamics works by solving the motion of samples in a structure. The motion trajectory of the sample is obtained to calculate the structural integration of the entire system, and the physical properties of the sample at the macro level are obtained [19]. In this paper, molecular dynamics is applied to the toxicological research of nanomaterials to explore whether nanomaterials can induce various pathological toxicological reactions in clothing design under a biological environment [20].

The motion characteristics of a molecular or atomic system satisfy the classical Newtonian laws of mechanics, and the equation of motion can be expressed by the following equation:

\[ g_s = \frac{b^4 r_x(t)}{bt^3} = \sum_{s<j} F_s (r_{x_s}). \] (16)

The mass of the x atom is represented by \( g_s \), \( r_x(t) \) is the position of the x atom at time t, and the force between the x atom and the j atom is represented by \( F_s (r_{x_s}) \), in order to ensure that \( x < j \) is not repeated.

There are many ways to solve the above equations, generally through the integration method. The most suitable method is mainly the velocity Verlet algorithm with strong stability. The algorithm formula is as follows:

\[ w(t + \Delta t) = w(t) + m(t)\Delta t + \frac{1}{2} b(t)\Delta t^2, \] (17)

\[ m(t + \Delta t) = m(t) + \frac{1}{2} \Delta t[p(t) + b(t + \Delta t)]. \] (18)

In the formula, \( w(t), m(t), b(t) \) are used to represent the position, velocity, and acceleration of the atom at t. \( \Delta t \) is the duration of the entire process.

3.2. The Simulation Process of the Molecular Dynamics Simulation Method. (1) Select and determine the object of the simulation; (2) determine the approximate simulation duration; (3) establish the potential energy function between atoms; and (4) determine the simulation boundary conditions and the parameters of the integration algorithm, and extract useful parameters from the calculation results.

In the simulation process, the first step is to determine reasonable boundaries and to obtain information by building more subtle models [21]. Firstly, in order to reduce
the amount of calculation, it is necessary to establish a larger simulation system to ensure statistical reliability. Secondly, it is necessary to consider the coupling between volume change, stress balance, strain characteristics, and reality from the actual physical nature. The problem of the "size effect" in the simulation process of the molecular dynamics simulation method can be effectively solved by determining the boundary. During the simulation process, the number of particles should not be too large. Too many particles will easily lead to the entire simulation process taking too long, and it is difficult to grasp the accuracy of the experiment, resulting in unsatisfactory experimental results [22]. Therefore, the number of particles in the simulation experiment should be less than the real number in the system, and the number of particles in the simulation experiment process is regulated by setting boundary conditions to avoid unnecessary factors affecting the molecular dynamics simulation experiment. There are two main types of boundaries in molecular dynamics simulations: periodic and aperiodic boundary conditions. Figure 3 is a schematic diagram of periodic boundary conditions.

3.2.1. Periodic Boundary Conditions. All particle numbers are surrounded by a system in which particles interact with each other [23]. Reduce the calculation model to save calculation resources, so as to solve the problem of the limitation of computer computing power. The periodic boundary conditions can make the overflow particles return to the simulation cell from the opposite direction, which can ensure that the number of particles in the simulation system is constant. The whole system is divided into a nine-square lattice system, and the particles in each lattice of the periodic boundary can interact with each other. The particles in this system can be replicated infinitely upwards. When the force of the particles in one grid is unbalanced, the particles of other grids can go to another grid to balance the particle space, and the stability of the whole system can be adjusted. Figure 4 shows the commonly used molecular dynamics simulation methods on different time and space scales.

3.2.2. Aperiodic Boundary Conditions. These boundary conditions are used depending on whether the simulated system is in equilibrium [24]. When the particles in the simulation system are unbalanced, the aperiodic boundary conditions should play a role in balance, but the periodic boundary conditions cannot be used at this time.

3.3. Ensemble and Simulated Temperature. In the process of molecular dynamics simulation, the system is prone to drift during the equilibrium process due to the problems of stage processing, integration error, and the existence of external force and friction force when calculating the force. Therefore, it is necessary to strictly control the temperature and pressure of the system to prevent the collapse of the entire system [25]. Before the calculation simulation, it is necessary to select the appropriate ensemble according to the different characteristics of the simulation research object. The ensemble can reflect the physical state of the particles during the experiment, and the corresponding ensemble is selected according to the experimental object. The isothermal and isobaric ensemble is a widely used ensemble. Commonly used ensembles mainly include pressure ensembles, microcanonical ensembles, canonical ensembles, and so on.

The microcanonical ensemble has made outstanding contributions to the research on the safety performance of nanomaterials, and the microcanonical ensemble is applied to molecular dynamics simulations. The heat generated during the experiment increases the temperature of the ensemble. Therefore, during the simulation experiment, to keep the temperature of the whole system constant, it is necessary to dissipate this excess heat. According to the relationship between the temperature of the ensemble and the kinetic energy of the molecules, the following formula can be obtained:
Among them, $D$ refers to the kinetic energy, $G$ refers to the number of atoms in the system; $G_H$ refers to the constraint number; $D_C$ refers to the Boltzmann constant; $f_i$ refers to the atomic mass; $v_i$ refers to the velocity of atom $i$; $C(t)$ refers to the temperature of the system. Molecular dynamics simulation system mainly uses velocity calibration method and Berendsen method to control system temperature. Under hydrothermal conditions, particle nucleation and growth will occur, and ultrafine powders with controllable morphology and size will be generated. The powders with complete grain development, small particle size, uniform distribution, and less agglomeration need not be calcined.

The speed calibration method is to multiply the correction coefficient, and its formula is as follows:

$$\delta = \frac{C_{\text{eq}}}{C(t)}.$$  

(20)

It can be seen from the above formula that the theory of the speed calibration method is relatively simple. $C_{\text{eq}}$ indicates the preset temperature value of the system; $C(t)$ indicates the current temperature value of the system.

The Berendsen method, also known as the thermal bath method, adjusts the temperature of the system by setting the temperature of the atoms, suppressing the difference in temperature variation. Its formula is as follows:

$$\delta = \sqrt{1 + \frac{\Delta C}{C(t)} \left( \frac{C_{\text{bath}}}{C(t)} - 1 \right)}.$$  

(21)

3.4. Potential Function. Since molecular dynamics was developed in Newtonian classical mechanics, classical mechanics is related to force fields. According to Newton’s classical mechanics, molecular dynamics moves in a limited time, producing a motion track. Therefore, in the process of simulating molecular dynamics simulation experiments, the potential function becomes the key to determine the accuracy of the simulation results. Classical mechanics describes the behavior of macroscopic objects. Compared with the speed of light, the speed of macroscopic objects is relatively small. Quantum mechanics describes the behavior of microscopic objects, such as subatomic particles, atoms, and other small objects. These two are the most important fields in physics. In the functional model of potential, only the potential between two atoms is calculated, and the force of other atoms is not calculated. Among them, there are two widely used potentials: Morse potential and embedded atomic potential (EAM potential). In the molecular dynamics simulation system, the total potential energy of particles can be summarized as the sum of the potential energy of each particle, and we get

$$V_{\text{total}} = V_{\text{bond}} + V_{\text{angle}} + V_{\text{dihedral}} + V_{\text{improper}} + V_{\text{vdW}} + V_{\text{Coulomb}}.$$  

(22)

The expression of Morse potential in the computational simulation is as follows:

$$F = M_i \left[ x^{2\alpha} (r_{ij} - r_0) - 2x^{\alpha}(r_{ij} - r_0) \right], r < r_c.$$  

(23)

In the formula, $F$ refers to the potential energy function, $M_i$ refers to the binding energy coefficient, $\alpha$ refers to the gradient coefficient of the potential energy curve, $r_i$ refers to the atomic distance between atom $i$ and atom $j$ at equilibrium, and $r_{ij}$ refers to the instantaneous atomic distance between atom $i$ and atom $j$.

The embedded atomic potential is used to describe the total potential energy and its expression is as follows:

$$F_{\text{tot}} = \frac{1}{2} \sum_{ij} F(r_{ij}) + \sum_i F(\beta_i).$$  

(24)
Among them, \( F_{\text{tot}} \) refers to the total potential energy of the system, \( F \) refers to the interaction pair potential between the \( i \) atom and the \( j \) atom, and \( R_{ij} \) refers to the distance between the \( i \) atom and the \( j \) atom. \( F \) represents the intercalation energy of the \( i \) atom when it is embedded in the background electron cloud of density \( \beta_i \). \( \beta_i \) refers to the electron cloud density at the \( i \) atom, which is the superposition of the electron cloud density of all other atoms in the system at the \( i \) atom, which can be expressed by the following expression:

\[
\beta_i = \sum_{j \neq i} h(r_{ij}).
\]  

(25)

4. Application and Safety Performance Experiments of Nanomaterials

The research on the biological effects of nanomaterials is still in its infancy, and scientists have only conducted preliminary studies on the biological effects of carbon-based nanomaterials and metal and its oxide nanomaterials. Nano-TiO\(_2\) is more used in textiles because of its advantages of finishing, self-cleaning, and strong stability. Among them, the application of nanomaterials in finishing is mainly manifested in antibacterial, anti-ultraviolet, antiodor, and so on. This paper will take TiO\(_2\) as the research object to study the application and safety performance of functional nanomaterials in flexible electronic products-nanomaterials in clothing design engineering.

4.1. Self-Cleaning Properties of TiO\(_2\) Sol-Treated Cotton Fabrics

Nano-TiO\(_2\) is affected by ultraviolet light. The self-cleaning performance of cotton fabrics mainly means that when the surface of the fabric is stained with stains, according to the strong photocatalytic properties of nanomaterials, the small molecules of stains can be oxidized and degraded under the condition of light, so as to achieve an effect of cleaning function. The following is to evaluate the self-cleaning performance of cotton fabrics when they are stained with coffee and red wine. First, wash and dry the fabric, adjust the nanoparticles to the colloidal state, and then immerse the fabric in the sol. After binding and drying, make the sol adhere to the fabric surface to get the self-cleaning nano fabric. Figure 5 shows the self-cleaning effect of nano-TiO\(_2\) cotton fabric on red wine and coffee stains.

As can be seen from Figure 5, under the action of ultraviolet rays, the color of the stain on the cotton fabric loaded with nano-TiO\(_2\) has obvious changes over time, and

![Table 1: UPF value and protection class.](image)

| UPF range | Protection classification | Ultraviolet transmittance% | UPF grade |
|-----------|---------------------------|-----------------------------|-----------|
| 15–24     | Better protection         | 6.7–4.2                     | 15,20     |
| 25–39     | Very good protection      | 4.1–2.6                     | 25,30,35  |
| 40–50,50+ | Excellent protection      | \(<2.5\)                    | 40,45,50,50+ |

![Table 2: UV protection factor table of different fabrics.](image)

| Fabric type                                      | UVF  | T (UVA) (%) | T (UVB) (%) |
|-------------------------------------------------|------|-------------|-------------|
| Original cloth                                  | 8.17 | 18.93       | 9.48        |
| Dip rolling baking finishing                    | 134.62 | 6.18      | 0.33        |
| Dip rolling drying hydrothermal finishing       | 171.35 | 4.50      | 0.29        |
| Dip rolling drying steam finishing              | 194.9 | 3.00       | 0.32        |

![Table 3: Specimen weight change data table.](image)

| Number | Sample size/cm | Ultrasonic frequency/KHZ | Ultrasonic time/min | Nano solution concentration (%) | Weight before cleaning/g | Weight after cleaning/g | Weight after nano finishing/g |
|--------|----------------|--------------------------|---------------------|-------------------------------|--------------------------|------------------------|-----------------------------|
| 1      | 10 × 10        | 12                       | 10                  | 20                            | 2.813                    | 2.791                  | 2.797                       |
| 2      | 10 × 10        | 12                       | 20                  | 10                            | 2.806                    | 2.745                  | 2.787                       |
| 3      | 10 × 10        | 12                       | 30                  | 20                            | 2.889                    | 2.836                  | 2.874                       |
| 4      | 10 × 10        | 12                       | 10                  | 40                            | 2.755                    | 2.717                  | 2.728                       |
| 5      | 10 × 10        | 12                       | 20                  | 40                            | 2.814                    | 2.762                  | 2.798                       |
| 6      | 10 × 10        | 12                       | 30                  | 40                            | 2.858                    | 2.802                  | 2.832                       |
| 7      | 10 × 10        | 12                       | 10                  | 60                            | 2.803                    | 2.725                  | 2.777                       |
| 8      | 10 × 10        | 12                       | 20                  | 60                            | 2.845                    | 2.798                  | 2.831                       |
| 9      | 10 × 10        | 12                       | 30                  | 60                            | 2.856                    | 2.801                  | 2.836                       |
| 10     | 10 × 10        | 12                       | 10                  | 80                            | 2.749                    | 2.706                  | 2.725                       |
| 11     | 10 × 10        | 12                       | 10                  | 80                            | 2.865                    | 2.793                  | 2.832                       |
| 12     | 10 × 10        | 12                       | 30                  | 80                            | 2.814                    | 2.785                  | 2.876                       |
| 13     | 10 × 10        | 12                       | 10                  | 100                           | 2.866                    | 2.802                  | 2.840                       |
| 14     | 10 × 10        | 12                       | 20                  | 100                           | 2.875                    | 2.811                  | 2.848                       |
| 15     | 10 × 10        | 12                       | 30                  | 100                           | 2.873                    | 2.823                  | 2.864                       |
the longer the time, the lighter the color of the stain. This shows that the cotton fabric has achieved the effect of cleaning and removing stains after finishing. The traditional finishing method of fabric is convenient to process, and with low cost. It is not restricted by the type of fiber, and the self-cleaning effect is excellent.

4.2. Experiment on UV Protection Performance of TiO$_2$. According to the above experiments on cotton fabrics with different finishing processes, the surface scattering and UV absorption properties of nano-TiO$_2$ cotton fabrics were experimentally compared, and the values and protection levels of UPF in Table 1 and the UV protection coefficients of different fabrics in Table 2 were obtained.

It can be seen from Tables 1 and 2 that the UV protection index of the cotton fabric after finishing is above 50+, which has good UV resistance. The ultraviolet transmittance of cotton fabrics before and after finishing is very different, and the transmittance of cotton fabrics after different finishing methods is also different. Among them, the cotton fabric after pad-drying-steaming finishing has the best performance in absorbing and scattering ultraviolet rays, the pad-drying-hydrothermal finishing is medium, and the pad-drying-baking finishing has the worst performance.

4.3. Release during Functional Finishing of Nano-TiO$_2$. Because many nanomaterials are combined with textiles, they need to rely on the joint action of certain compounds such as adhesives or resins to strengthen the firmness between nanomaterials and textiles. Therefore, the nanoparticles in the nano-clothing materials will be affected by many factors when the nanomaterials perform the finishing function process. Nanoparticles are easily exfoliated into the surrounding environment, which may cause certain harm to the surrounding environment or people. In this paper, under the condition of the same ultrasonic frequency, different nano-TiO$_2$ concentrations, and different experimental times, the weight change of cotton fabrics before and after finishing was observed after the washing process, obtain the weight data in Table 3 and the weight change of cotton fabric under different ultrasonic time in Figure 6.

It can be seen from the chart that the quality of the cotton fabric decreased after cleaning with different concentrations of nano-TiO$_2$ and different experimental times. It can be explained that the nanomaterials are released from the cotton fabric during the washing process. After the nano-finishing of cotton fabrics, the quality of all cotton fabrics increased, which indicated that nanometers entered the cotton fabrics again during the finishing process. In the ten-minute experiment, the TiO$_2$ solution with a concentration of 60% released the most amount of nanometers, and the change was the most obvious; at other times, the difference in nanometer release amount was basically not obvious.

After the above experiments, we obtained that the nano-TiO$_2$ material has a certain self-cleaning function and anti-ultraviolet performance, but also have the advantages of antibacterial properties, anti-aging properties, anti-static properties, and thermal insulation properties. With the continuous exploration of these advantages of nano-TiO$_2$ materials and the emergence of new demands in the modern textile industry, nano-TiO$_2$ materials are increasingly used in the field of clothing.

4.4. Toxicological Experiments of Nanometer TiO$_2$. From the above experimental results, it can be seen that nanomaterial textiles are likely to fall off and release during use. As an
inorganic functional material, nanomaterials themselves have certain biological toxicity. Some studies have found that after nanomaterials enter the human body, they have an effect on the immune cells of the human body and affect the normal operation of the human immune system. Therefore, the safety assessment of nanomaterials used in the field of clothing needs further consideration.

Three different cells were placed in different concentrations of nano-TiO₂ solution, and cell viability was observed after 24 and 48 hours, as shown in Figure 7. It can be seen from the figure that the cytotoxicity of different concentrations of nano-TiO₂ is very small, the cell viability is not less than 80%, and there is a certain concentration effect. After 48 hours, all three cells showed cytotoxicity at doses of 150,200. It shows that the nanomaterials can only cause cytotoxicity under the condition of a long time and high concentration of nano-TiO₂. Even under this condition, cells may die, and cell death rates vary under different conditions. Under long-term and high concentrations, the amount of nano-sized adhesion on the cell surface increases. The larger

**Figure 7:** Cell viability after coincubation of four kinds of nano-TiO₂ and three different cell lines for 24 h and cell viability graphs at different concentrations at different times.
the nano-sized amount, the stronger the toxicity of cells. Therefore, the toxicity of nano-TiO₂ is mainly affected by time and dose.

Some studies have also pointed out that a small amount of nanomaterials can metabolize cells after entering cells, and the metabolic system can still carry out normal metabolic activities. But when the amount of nanomaterial coverage is too high, the normal cell exocytosis will be disturbed. Therefore, in the process of applying nano-TiO₂ to clothing fabrics, it is necessary to pay attention to the amount of nano-TiO₂ material.

5. Discussion

This paper mainly studies and analyzes the application and safety performance of flexible electronic products based on functional nanomaterials in clothing design engineering. It takes nano-TiO₂ as the research object, analyzes the photocatalytic mechanism of nano-TiO₂, as well as various properties of nano-TiO₂ materials, and analyzes whether nano-TiO₂ materials are suitable for clothing fabrics. In this paper, the molecular dynamics method is used to explore the toxicological research of nanomaterials, and to explore whether nanomaterials will induce various pathological toxicological reactions in clothing design in biological environments.

6. Conclusions

As an inorganic functional material, nano-TiO₂ produces a finishing function under the action of photocatalysis and has certain advantages such as self-cleaning function, anti-ultraviolet performance, and antibacterial performance. Supported by these advantages, the application of nanomaterials in the field of clothing is becoming more and more extensive. However, through the toxicological experiments on nano-TiO₂ materials, it is found that if the concentration of nano-TiO₂ is excessive, the toxicity of nano-TiO₂ materials will be greater, which will cause harm to human cells. Therefore, the amount of nano-TiO₂ materials used in clothing fabrics need to be strictly controlled.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare no conflicts of interest.

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