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Nano Materials in New Building Materials

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Abstract: Nanomaterials have brought an unprecedented revolution to the development of building materials with their unique properties of light, electricity, heat and magnetism. According to the future development trend of building materials and the development and application prospects of nanomaterials, this paper studies the application of nanomaterials in new building materials, providing a better development space for the future direction of new building materials. This research mainly conducted research from five aspects: the effect of modified carbon nanotubes on the bending performance and compressive strength of cement-based materials; the effect of composite materials on the effectiveness of cement-based materials in electromagnetic wave protection; the effectiveness of nano-carbon fiber cement materials Self-shrinking; Formaldehyde gas sensitivity of nanomaterials; The effect of surface modification of nano-TiO2 on the thermal stability of wheat straw fibers. The test results show that the results of improving the mechanical properties include: compressive strength increased by 132%, tensile strength increased by 34.28%, and flexural strength increased by 124.85%. When the silica fume content is 0, the electromagnetic shielding efficiency of different doped carbon nanometers are 22.1, 25.8, 27.6 and 31.4 respectively. As the silica fume content gradually increases, the ability to shield electromagnetic waves is stronger. When the water-cement ratio is 0.25 and 0.3, the autogenous shrinkage value of the nano-carbon fiber cement paste specimens shows a trend of first decreasing and then increasing. The optimal operating temperature of formaldehyde gas sensor is 250℃, and 2% is the optimal doping concentration of In2O3. In the range of 0-2% nano-TiO2 addition, the content of surface-modified nano-TiO2 particles has little effect on the thermal stability of wheat straw fibers.

1. Introduction

1.1. Background and Significance

With the rapid development of social economy, the construction of civil engineering has entered the golden age. However, with the increasing number of buildings, the old buildings need to be reinforced and renovated due to aging, accidental damage or modern decoration. As a new type of building reinforcement and maintenance materials, the demand of nano materials is increasing, and its application range is also becoming wider and wider. However, the properties of nano materials are still under exploration. Nanomaterials have the characteristics of small particle size, large specific surface area, high surface energy and large proportion of surface atoms. They can be fully combined with cement, give cement high strength and high toughness performance, so as to improve the stability of cement volume, to ensure the mechanical properties and strength of building materials, especially in the case of large and complex infrastructure. In the extreme environment, the combination of various factors also faces many new difficulties to be solved.

1.2. Related Work

(1) Testing methods abroad

Elsener, a Japanese researcher, used a manometer to measure autogenous contraction. This test method refers to the automatic displacement and reference length of autogenous shrinkage measured from a pressure gauge before concrete formwork removal. After taking out the mold, samples were taken, and then the samples were put into plastic bags to seal immediately, and the inherent shrinkage values of different ages were measured. This method can be used to measure the shrinkage of early concrete under the condition of insufficient resistance. However, due to the detector embedded in the concrete, the shrinkage meter tube can not be accurately aligned, so it is difficult to achieve uniformity in different test ages. The self shrinkage value of concrete after 3 days of age is too small, which leads to the decrease of measurement accuracy [1].

(2) Domestic testing methods

Zhu Huifang et al. Proposed an automatic shrinkage contactless induction method based on the change of output voltage of eddy current sensor to measure the distance change between sensor and sensor end. The selected concrete sample size is defined as 50 mm * 50 mm * 60 mm. After the concrete is poured into the test piece, it should be closed immediately, and the automatic shrinkage value of the specimen shall be measured with the mold. When there is a large number of measurements or a long measurement age, first remove the mold and seal the sample, and then measure the automatic shrinkage value of the concrete specimen one day later. The digital temperature in the test device can measure the temperature of 20 points, so that a pair of sensors can measure multiple concrete samples, eliminating the manual measurement error. The method of non-contact measurement of autogenous shrinkage can automatically and continuously measure the autogenous shrinkage of samples, especially the early autogenous shrinkage of samples, with high measurement accuracy [2].

1.3. Innovation

(1) surface modification of nano TiO_2 was carried out by using silicon coupling factor, which improved the dispersing ability of nano TiO_2 and applied to the /PP foam composites of wheat straw fiber. The mechanism of surface modification of nano TiO_2 was revealed.

(2) nano TiO_2 surface modified suspension was used to impregnate and process wheat straw fiber, and nano TiO_2 surface modified wheat straw /PP composite foam. The mechanical properties and UV aging resistance of the composites were improved, which revealed the strengthening mechanism of nano-TiO_2 at the interface between wheat straw fiber and PP.

2. Nanomaterials

2.1. Nano Silica

Nano silica (SiO2) is a kind of ultrafine powder with hydroxyl acid salt on the surface, which is hydrolyzed by high temperature organic silicon chloride. The particle size is less than 100nm, usually 10-30g, with high chemical purity, good dispersion and large specific surface area [3]. There are two preparation methods of Nano-SiO2: gas phase method (dry method) and precipitation method (wet method). The basic principle of producing nano-SiO2 by gas-phase method is: through the hydrolysis method of inorganic silicon chloride or silicone, the refined hydrogen vapor, air and silicon are put into the water digestion furnace in a certain proportion for high-temperature hydrolysis to produce silicon aerosol, and the condenser collects nano silicon particles [4]. The nano-SiO2 produced by gas-phase method is different from that by precipitation method. The nano-SiO2 produced by gas-phase method has the following characteristics: large specific surface area, low impurity content and easy dispersion, but it is expensive. The nano-SiO2 prepared by precipitation method has the characteristics of large structure gap, hairiness and strong alkalinity. In industrial production, more nano-SiO2 is produced by gas phase method [5].

Nano silica is a kind of white powder. It is a kind of non-toxic, tasteless and pollution-free inorganic nonmetal material with flocculent and reticular quasi particle structure. Due to the large surface effect, a single nano-SiO2 contact will form a secondary structure. This accumulation structure can be divided into hard accumulation and soft accumulation [6]. The soft packing may diffuse to the primary structure again under the shear force, while the hard packing is irreversible. It can only make the nano-SiO2 particles larger and larger, but can not be dispersed again [7]. The results show that the nano-SiO2 prepared by gas-phase method has a solid structure, its internal structure has relative physical and chemical stability, and its composition remains basically unchanged. However, the nano-SiO2 prepared by precipitation method has the characteristics of loose structure and hairy shape. The air is easy to penetrate, and the inner part of the primary structure is easily oxidized by air to form a hard block.

Organic resins can produce a variety of complex materials [8]. With the increasing requirement of resin efficiency in building materials industry, nano-SiO2 is more and more used in traditional resin modification. As long as nano-SiO2 particles can be fully and evenly dispersed in resin materials, the performance of resin based materials can be improved. Nano-SiO2 and organic polymer have bonding effect, filling the small problems in the adhesive, increasing the resistance of the material, overcoming the shortcomings of low hardness and poor wear resistance, improving the impact resistance and heat resistance. In addition, nano-SiO2 can strongly reflect ultraviolet radiation, which can significantly reduce the degradation of seasonal resin by ultraviolet radiation, so as to delay the aging of materials [9]. Due to the high specific surface area of nano-SiO2, the physiological properties of epoxy resin adhesive will change, making the material surface more solid and smooth.

2.2. Adsorption of Carbon Nanotube Materials

Carbon nanotubes (CNTs) are used as one-dimensional nanomaterials due to their unique size ratio. Compared with other space grade materials, carbon nanotubes have excellent physical and chemical properties [10]. Both capacitive materials and sensitivities support modernization. Carbon nanotubes (CNTs) belong to nano material SP2 and have no surface connection, so they are ideal electrode materials. As one-dimensional nano materials, the size ratio of carbon nanotubes is very large, which leads to their own stacking and entanglement, which limits their direct application in different fields. In the process of manufacturing carbon nanotubes, there are pentagonal and hexagonal defect structures on the edge or side wall of carbon nanotubes. The carbon ring with end shape provides favorable conditions for the operation of "end" and "side wall" of carbon nanotubes, and the former is more specific and active than the latter [11].

Carbon nanotubes (CNTs) have the characteristics of large contact surface and excellent hollow tube structure, which have advantages in absorbing inert gas. Due to the chemical stability of inert gases, the energy between carbon nanotubes is mainly the energy of van der Waals. At present, molecular power simulation method is mainly used to study the adsorption behavior of inert gas, and guide the adsorption and analysis of inert gas with carbon nanotube materials in the experiment [12]. However, some adsorption methods and materials have great defects, which can not cover the high-efficiency absorption and separation effect of some specific gases.

The mechanism of using nanomaterials in gas absorption and separation process can include one or more of the following aspects:

(1) The molecular effect caused by the size or shape of adsorbent;

(2) Due to the different thermodynamic equilibrium effect between adsorbent and adsorbed object, the interaction is also different;

(3) The mechanical effect is different in adsorption percentage;

(4) Due to the different quantum energy levels of individual or molecule, heavy isotopes are preferentially adsorbed.

Theoretically, the separation process using adsorbents can be divided into two categories: separation and purification [13]. Important separation and purification applications include air separation, CO2 / CH4 separation, H2 and CH4 separation, CO2 removal for fuel cell technology, desulfurization of transportation fuel and separation of n-alkanes [14]. As potential adsorbents for gas separation and purification, MOFs and COMS provide unique advantages for specific applications due to their structural characteristics.

2.3. Dispersion of Carbon Nanotubes in Cement-Based Materials

CNT is a new type of carbon nanotube structure. Carbon nanotubes (CNTs) are non seamless nanotubes formed by the decay of single or multi-layer graphite sheets. According to the number of graphite sheets, carbon nanotubes can be roughly divided into two categories: single wall carbon nanotubes (SWCNT) and multi wall coal nanotubes (MWCNT) [15]. Single walled carbon nanotubes (SWCNTs) are composed of single-layer carbon atoms with good symmetry. Multi walled carbon nanotubes (MWCNTs) are wrapped in a layer of carbon atoms, which is similar to the shape of a uniaxial cable. The basic characteristics of carbon nanotubes show that the rubber coefficient of carbon nanotubes is as high as 2tpa, which is about three times of that of Q235 steel [16]. The tensile strength of carbon nanotubes is as high as 400 GPA, which is about 15 times of that of Q235 steel. The density of carbon nanotubes (3.12 / cm3) is less than 1 / 2 of that of steel (7.42 / cm3). In addition, carbon nanotubes have low resistance, good chemical stability, high thermal stability and electromagnetic wave absorption characteristics, so they are ideal fillers. For composite materials, due to their superior and unique properties, their application fields include nano electronic devices, electrochemical materials, hydrogen storage materials and composite materials, such as polymers, ceramics and cement-based composites [17].

However, carbon nanotubes as nano fillers have a huge special surface, so they have high power van der Waals force. It is a fibrous material with a high size ratio and is easy to be wound into a ball [23]. In addition, the carbon atoms on the CNTs are hybridized by SP2 to form a hexagonal group of three carbon atoms. This leads to its low solubility in water and various other solvents. For composite materials, the better the uniform dispersion of reinforcement or modified phase in the matrix, the better the overall efficiency and stability of the composite [18]. Therefore, it is necessary to promote the dispersion of carbon nanotubes in the composites through the dispersion process. The dispersion methods of CNT in cement-based composites include physical method, chemical method and physical-chemical combination method. In particular, physical methods include: mechanical stirring method, grinding elastic method and ultrasonic dispersion method [19]. Chemical methods include: chemical modification of unipolar bond and chemical modification of non unipolar bond. At present, there are also new ideas for the dispersion of carbon nanotubes, such as the combination of carbon nanotubes with other fillers through electrostatic self-assembly, the increase of in-situ carbon nanotubes in cement particles or other cement-based composites, and the spraying of carbon nanotube coating in inert gas, etc. [20-21]. Among the numerous dispersion methods, mechanical stirring is usually a necessary step for manufacturing cement-based composite materials. Complete mixing has little effect on the dispersion of carbon nanotubes, and the sphere has high energy consumption and complex operation [22]. The in-situ growth ability of carbon nanotubes on the surface of composite materials is low. The method of spraying carbon nanotubes on the surface of thin components limits the deformation and strengthening effect of carbon nanotubes.

2.4. Molecular Dynamics (Md) Simulation

Molecular dynamics simulation (MD) method is also used in simulation calculation. This method can determine the initial configuration according to the predetermined atomic power and the initial velocity of atomic motion, and calculate the initial configuration of the atom through simulation calculation of a single trajectory [23]. In this process, the total energy of the system is stable, and only kinetic energy and potential energy are continuously converted [24]. MD simulation is non-material and global, which is evolved from the computational system according to Newton's equation of motion. The common methods to solve Newton's equation of motion are as follows:

$$F = ma \quad (1)$$

Where F represents the resultant force produced by the particle, m represents the mass of the particle, and a represents the acceleration of the particle. According to the formula, the particle strength can be obtained by solving [25]. At first, molecular dynamics was only used in theoretical physics, but now it is widely used in many fields such as physics, chemistry, biological science and material science.

3. Experimental Study on the Application of Nano Materials in New Building Materials

3.1. Experimental Setup

In this experiment, two factors affecting the water cement ratio and the content of modified carbon nanotubes were studied. The main evaluation is: first, when the water cement ratio of the sample is the same, the influence of the content of modified carbon nanotubes on the mechanical properties of the samples should be considered, and the relationship between the bending strength and the compressive strength with the content of linear modified carbon nanotubes should be considered. Second, the influence of water cement ratio on the mechanical strength of the modified carbon nanotubes is the same. Water cement ratio: the representative water cement ratio is 0, 0.1, 0.2 and 0.3 respectively. The ratio of sand glue is 2:1. The amount of modified carbon nanotubes: 0.0%, 0.3%, 0.6% and 1.0% is related to the quality of cement.

3.2. Experiment

In the test, the standard sand and Portland cement are mixed evenly according to the mass ratio of 2:1, and the carbon fiber and micro silica fume materials with certain mass ratio are used to replace the concrete materials, and the alkali water content is 2%. The modified cement mortar was poured out, and the samples were prepared under the conditions of 25-27 ℃ and relative humidity > 75%. The standard curing period was three weeks in the incubator.

Pd-sno2 porous nanospheres were prepared by impregnation reduction method. Firstly, 0.1 g SnO2 was added into three 30 ml conical flasks, and then appropriate amount of ultrasonic dispersed distilled water was added. Then, 2.5 ml, 7.3 ml and 10.3 ml pdon solutions with the concentration of 2 g / L were added into the two conical flasks, and then added 40 25 ml distilled water, stirring for 3 hours, centrifuging, washing the solution with deodorizing water and total ethanol, waiting for the end of drying, and placing the sample in an oven tube of 180 degrees. Under this condition, the redox reaction of hydrogen and oxygen will take place for one hour. Finally, PD doped SnO2 porous nanospheres are obtained, which are labeled as pure SnO2, 2% In2O3-SnO2 and 5% In2O3-SnO2, respectively. The three samples were dispersed in ethanol until they were ground to a paste, coated on the alumina tube and aged at 300 ℃.

3.3. Statistical Methods

For the full curve constitutive model of compressive stress-strain, we can draw these conclusions. The test rising scheme of pressure can be a square or cubic equation, and the descending section is a logical component model, which is the most representative and globally recognized component model. These two models include the following contents:

The first model:

$$\left\{\begin{array}{ll} y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 & x \le 1 \\ y = \dfrac{x}{b_0 + b_1 + b_2 x^2} & x \ge 1 \end{array}\right. \quad (2)$$

In the formula, a0,a1,a2,a3 and b0,b1,b2 represent undetermined coefficients.

In the second model, the ascending and descending sections are the same equation, but the parameter values are different. A1, A2, B1, B2 are undetermined coefficients.

$$y = \frac{A_1 + B_1 x^2}{1 + A_2 x + B_2 x^2} \quad (3)$$

4. Experimental Analysis of Nano Materials in New Building Materials

4.1. Mechanical Properties of Carbon Nanotubes Composite Cement-Based Materials

Early studies have shown that carbon nanotubes have a great influence on the hydration process and hardness of cement-based composites. The results on the mechanical properties of carbon nanotube composite cementitious materials are summarized in Table 1.

As shown in Table 1, the best mechanical properties enhancement effects of carbon nanotube composite cement-based *materials* include: compressive strength increased by 132%, tensile strength increased by 34.28%, fracture toughness increased by 124.85%. In addition, it should be pointed out that the introduction of carbon nanotubes will also change the constitutive relationship of the composites. The mechanical properties of carbon nanotubes composite cement-based materials are not only closely related to the type, content, surface state and dispersion degree of carbon nanotubes, but also closely related to the composition of cement materials.

Table 1. Enhancement of mechanical properties of cement-based materials by carbon nanotubes

Project	Performance improvement	CNT content (multi wall)
Compressive strength	21	0.4
	65	0.03
	74	0.01
Tensile strength	37	0.2
	24	0.3
	21	0.4
Breaking strength	33	0.6
	38	0.7
	46	0.8

4.2. Electromagnetic Wave Shielding Performance

With the wide application of electrical and electronic equipment, electromagnetic wave pollution and its harm to human body can not be ignored. Therefore, the cement-based composite materials with electromagnetic wave shielding function have attracted people's attention. Carbon nanoparticles have excellent electrical properties, and the addition of carbon nanoparticles increases the interfacial polarization and anisotropic properties of cement-based composites. Therefore, carbon nanoparticles can improve the excellent electromagnetic shielding performance of cement-based materials. In this experiment, the influence of different amounts of silica fume (0%, 0.1%, 0.2% and 0.3% based on the quality of cement) on the electromagnetic shielding effectiveness of carbon nanomaterials (0.0%, 0.3%, 0.6% and 1.0%, respectively, denoted as C0, C0.3, C0.6 and C1.0) with different contents of silica fume (0%, 0.1%, 0.2% and 0.3% based on the quality of cement) were studied, as shown in Figure 1.

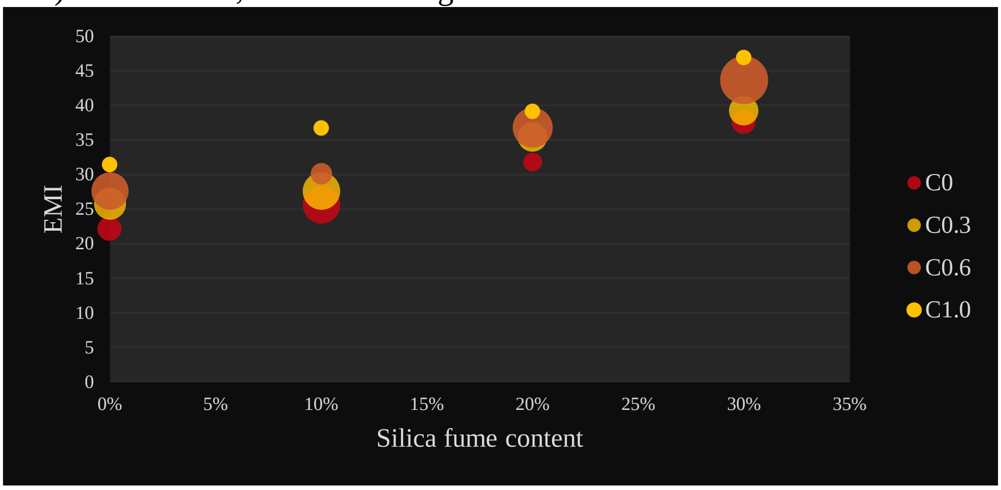

Figure 1. Shielding performance of electromagnetic wave

From the above experimental data, when the content of silica fume is 0, the shielding performance of carbon nano particles with different contents is 22.1, 25.8, 27.6 and 31.4, respectively. With the gradual increase of silica fume content, the ability of shielding electromagnetic wave is stronger. The addition of silica fume improves the electromagnetic shielding effectiveness of carbon nano composite cement-based materials. This is mainly because silica fume can promote the dispersion of carbon nano particles, which makes the increase of interfacial polarization and anisotropy of carbon nano composite cement-based materials more prominent. When the content of silica fume is the same, with the increase of carbon nano content, the shielding effect of electromagnetic wave can also be enhanced. The electromagnetic shielding performance of carbon nano composite cement-based materials is mainly related to the amount of carbon nano particles, the dispersion of carbon nano particles, the ratio of composite materials, the age of composite materials and the thickness of composite materials.

4.3. Autogenous Shrinkage Test Results of Nano Carbon Fiber Cement-Based Composites

The effects of nano carbon fiber content, water cement ratio, age and surfactant methyl cellulose on the autogenous shrinkage of cement paste were studied. The results of autogenous shrinkage test of nano carbon fiber cement-based composites are shown in Figure 2.

(1) At the same water cement ratio, the autogenous shrinkage of nano carbon fiber cement paste changes with age.

(2) At a certain water cement ratio, the autogenous shrinkage of nano carbon fiber cement paste changes with age.

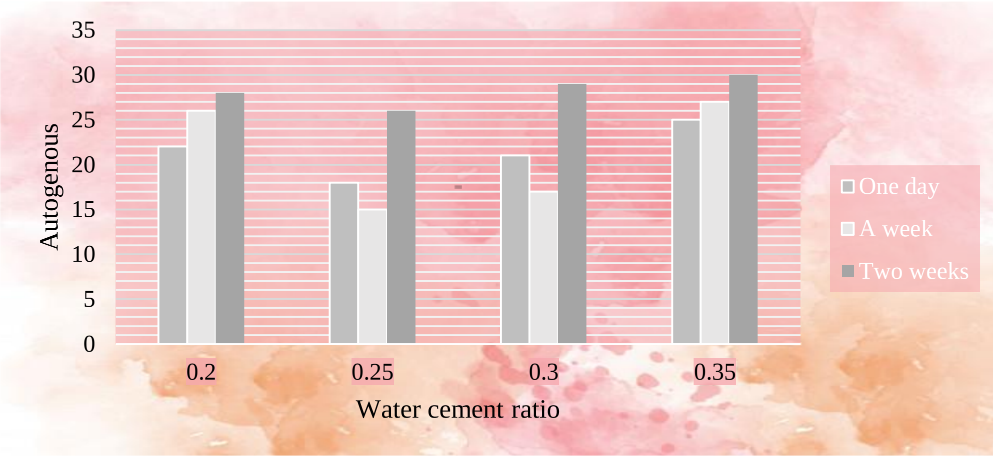

Figure 2. Autogenous shrinkage test of nano carbon fiber cement

When the water cement ratio is 0.25 and 0.3, with the increase of age, the autogenous shrinkage value of nano carbon fiber cement paste decreases first and then increases; if the water cement ratio is 0.2, the autogenous shrinkage value increases with the increase of age, and the self shrinkage value develops rapidly from the initial setting time to the first day of test age. However, after 7 days of measurement, the growth rate of autogenous shrinkage value of NCF cement paste decreases gradually. When the water cement ratio of nano carbon fiber cement paste is 0.25 and 0.3, in the first week of measurement of nano carbon fiber cement paste, the expansion value generated by thermal expansion is greater than the self shrinkage value, which leads to the decline of the self shrinkage curve, and the self shrinkage value presents a negative value. With the increase of age, the hydration reaction of cement is slow, which weakens the thermal expansion phenomenon, and the self shrinkage value is gradually greater than the expansion value, The autogenous contraction curve increased and the autogenous shrinkage value gradually showed positive value. However, when the water cement ratio is 0.2, the autogenous shrinkage value is much greater than the thermal expansion value even on the first day of measurement, so the autogenous shrinkage value of the specimens increases with the increase of age.

4.4. Formaldehyde Gas Sensitivity of Materials

In order to study the gas sensing properties of the synthesized nano materials for formaldehyde, pure SnO2 and different concentrations of In2O3 doped SnO2 were compared. Three variables were set for comparison: the gas sensing response of pure SnO2, 2% In2O3-SnO2 and 5% In2O3-SnO2 to 120ppm formaldehyde from 100 ℃ to 500 ℃, as shown in Figure 3.

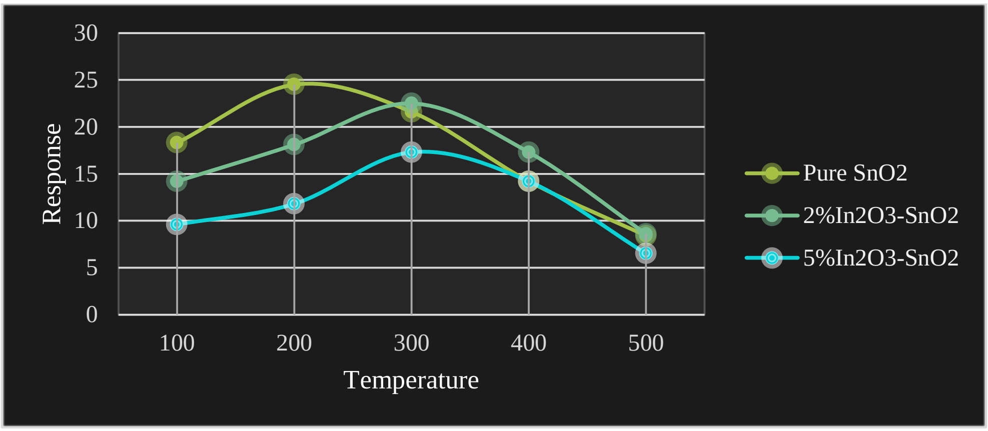

Figure 3. Gas sensitivity of formaldehyde

It can be seen from the figure that with the increase of working temperature, the response value of formaldehyde begins to increase, and reaches the maximum response at a certain temperature, and then the response value decreases with the continuous rise of temperature. The maximum response value of pure SnO2 is 18.3 at 200 ℃, and the maximum response value of 2% In2O3-SnO2 is 22.5 at 300 ℃. Obviously, compared with pure SnO2, In2O3-SnO2 has lower optimum operating temperature and higher gas sensing response. For 5% In2O3-SnO2 sample, the gas sensing response value increased from 9.5 to 17.3. Based on the above results, 250 ℃ is selected as the optimal working temperature and 2% is the optimal doping concentration for further gas sensing performance research.

4.5. Effect of Surface Modified Nano-TiO2 on Thermal Stability of Wheat Straw Fiber

After pretreating wheat straw fiber, the quality loss trend of wheat straw with different surface treatments was basically the same. There are three stages in the thermal degradation of wheat straw fiber before and after treatment. The weight loss at 0-100 ℃ is the desorption process of physical adsorption water of wheat straw fiber and the thermal decomposition process of silane coupling agent. As the final moisture content of untreated wheat straw fiber is slightly higher, the mass loss of untreated wheat straw fiber in the first stage is significantly greater than that after treatment. Since the weight loss in this stage mainly depends on the initial moisture content of the fiber, the thermal properties should be analyzed from the second stage of thermal degradation. The degradation zone of the second stage was between 100 ℃ and 300 ℃, and that of the third stage occurred above 300 ℃. The second stage of degradation mainly comes from the degradation of cellulose, lignin and other low molecular weight substances. The decomposition temperature of wheat straw fiber treated with surface modified nano-TiO2 was slightly higher than that of untreated wheat straw fiber, but the effect of the amount of surface modified nano-TiO2 was not obvious, which indicated that the thermal stability of wheat straw fiber could be improved by adding surface modified nano-TiO2 particles.Thermal stability of wheat straw fiber is show in Figure 4.

Compared with untreated wheat straw fiber, the degradation rate of wheat straw fiber decreased with the addition of surface modified nano-TiO2 particles. When the amount of surface modified nano-TiO2 particles was 2%, the degradation rate of wheat straw fiber was the lowest, and the weight loss rate was about 6% lower than that of the control group, which further indicated that the surface modified nano-TiO2 particles had a certain effect on the thermal stability of wheat straw fiber. At a higher temperature (300 ℃), the surface hydroxyl polycondensation of nanoparticles produces water, resulting in secondary weight loss. In the range of nano-TiO2 content selected in this experiment, the content of surface modified nano-TiO2 particles has little effect on the thermal stability of wheat straw fiber.

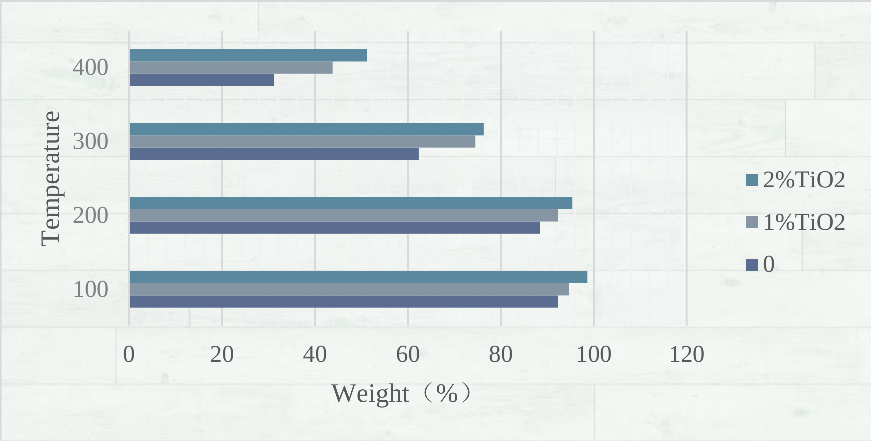

Figure 4. Thermal stability of wheat straw fiber

5. Conclusion

At present, the national economy is developing very fast, but the infrastructure needs to be improved. The specific problems reflected in the construction projects will become increasingly obvious, which makes the durability problem become an important research direction, which has very important scientific research value and practical significance. When a certain amount of carbon nanotubes are introduced into cement-based materials, carbon nanotubes with special mechanical properties may play a certain role in restraining the formation and development of cracks in cement-based materials. When the cement-based materials are damaged, they can absorb energy, significantly improve the bending resistance, compression resistance and fracture resistance of cement-based materials, and prevent aqueous solutions and harmful ions Into cement-based materials. However, the low ability of carbon nanotubes to disperse carbon in water is an important obstacle to its application in this field.

Firstly, SnO2 porous nanospheres were prepared by a simple hydrothermal method. After impregnation with palladium nitrate solution, centrifugation, drying and reduction with H2, the porous SnO2 nanospheres containing PD were obtained. PD doping significantly improved the gas sensitivity of SnO2 porous nanospheres to BTEX. 5% PD doped SnO2 can increase the gas sensing response value of 100 ppm benzene, toluene, m-xylene, o-xylene and p-xylene by 1-3 times, and the optimal working temperature is also significantly reduced, which has good stability. The improvement of detection efficiency of BTEX gas by PD doped SnO2 may be due to the spillover effect of noble metal Pd, and the catalytic effect of PD reduces the surface reaction barrier of target gas.

In a highly corrosive environment, the deterioration of materials caused by environmental factors leads to premature damage of building materials, which greatly reduces the expected life and causes significant economic losses. Carbon nanotubes can solve this problem because of their excellent properties, but there are still many problems in the process of achieving this goal. High cost and poor dispersion are the problems we must explore and solve. This is also the prospect of the application of carbon nanotubes and other nano materials in new building materials.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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