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Research on nanometer waterborne ceramic building coating materials based on silica sol

***T.Zheng*[1], *Y.He*[1], *H.Tan*[2]**

[1]Nanyang Institute of Technology, Nanyang, China
[2]Henan Normal University, Xinxiang, Henan, China

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Siloxane monomer and nano-SiO_2-sol were investigated. The sol-gel method is used to obtain a nano-hydroceramic coating. A series of nano-water based ceramic coatings was manufactured, with various sizes of nano-SiO_2 mixed particles. Operational tests were carried out. The experimental results show that when using large-diameter particles and small particles of silicon aerosol, the hardness of the coating increases. There was no significant relationship between the adhesion characteristics and the type of the mixed silica sol.
Keywords: silica sol, nano-size mixed particles, ceramic building coating.

Исследованы силоксановый мономер и нано-SiO_2-золь в качестве основного сырья. Золь-гель метод используется для получения наногидрокерамического покрытия. Изготовлена серия керамических покрытий на основе нано-воды, с различными размерами смешанных частиц нано-SiO_2. Проведены эксплуатационные испытания. Результаты эксперимента показывают, что при использовании частиц большого диаметра и мелких частиц аэрозоля кремния твердость покрытия увеличивается. Нет существенной связи между адгезионными характеристиками и типом золя смешанного диоксида кремния.

Дослідження нанометрових водорозчинних керамічних будівельних матеріалів на основі золю кремнезему. *T.Zheng, Y.He, H.Tan*

Досліджено силоксановий мономер і нано-SiO_2-золь в якості основної сировини. Золь-гель метод використовується для отримання наногідрокераміческого покриття. Виготовлено серію керамічних покриттів на основі нано-води з різними розмірами змішаних частинок нано-SiO_2. Проведено експлуатаційні випробування. Результати експерименту показують, що при використанні частинок великого діаметра і дрібних частинок аерозолю кремнію твердість покриття збільшується. Немає істотного зв’язку між адгезійними характеристиками і типом золю змішаного діоксиду кремнію.

1. Introduction

A water-based ceramic paint has emerged from many varieties of paints as a new generation of water-based paints, and it has the most unusual applications in many industries [1]. The nano-silicon aerosol method is used as a new technology to make new inorganic nano-materials, which have a very low price, and they have a huge advantage in the availability of the material in minerals. In addition, they have such excellent physical and chemical properties as a small particle size, a large specific surface area, low viscosity, and good stability and dispersion when mixed with other substances [2–4]. The main ingredients of the ceramic water-based paint are a nano-scale inorganic dissolved aerosol and water-based silicone, as well as an inorganic resin and an inorganic heat-resistant paint covering the substrate to give the substrate new properties. It has durability, excellent stability, pollution resistance, and non-flammability. The production of

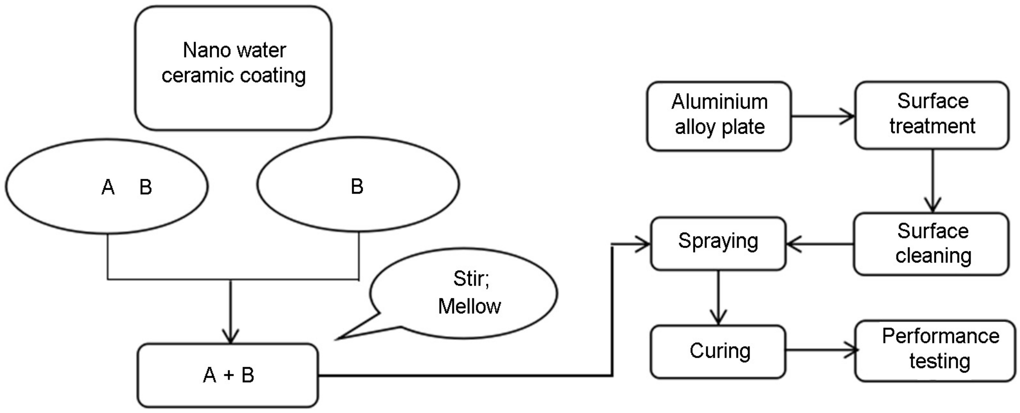


Fig. 1. Synthesis and flow chart of coating process of nano-sized waterborne ceramic coatings.

composite ceramic coatings provides new architectural and decorative materials for the modern construction industry.

In [5] the authors investigated the influence of various factors on the characteristics of the ceramic coating and found that the influence of different types of siloxanes, silica sol and siloxane ratio on the characteristics of the coating is very different; the effect of different pH values on the curing time and the coating time is quite large; and some special fillers have a good strengthening effect on the characteristics of the ceramic coating. In [6], the authors studied the influence of the preparation process and composition of organosilicon ceramic coatings on coating performance, and analyzed the future development trend of organosilicon ceramic coatings. The authors of [7] showed that the coatings modified with a HTeOS-component, has excellent hydrophobic properties and a certain heat resistance. Article [8] showed that graphene not only improved the strength of composites, but also had good ductility and the effect increased with increasing doping. The author of [9] proves that the wear-resistance is the basis of the new coating.

In this paper, the effects of the different particle size and mixing ratio on the properties of ceramic coatings were investigated. Nano-silica sol is mixed with different particle sizes and masses. Particle sizes in the mixtures are, specifically, 59 nm/7 nm; 59 nm/23 nm; 85 nm/7 nm; 85 nm/23 nm; 107 nm/7 nm; and 107 nm/23 nm. The mixing ratios are 1:1, 2:1, 3:1, 4:1 and 5:1. Five kinds of silica sol with different particle sizes are mixed into the silica sol model p100x, and the mixed silica sol reacts with MTMS to prepare the mixed nano-size particle water-borne ceramic coatings.

2. Experimental

First, the mixed particle size ceramic coatings were prepared:

According to the following mass ratios of SiO_2 contained in the mixed 59 nm/7 nm silica sol coating: 1:1, 3:1, 4:1 and 5:1, the required mass of silica sol was weighed, mixed and placed into five beakers; then CH_3COOH was added to the beakers. The pH value of different mixed nano-SiO_2 sols was measured with a pH meter, and acetic acid was stopped to add when the pH value of the mixed silica sols was adjusted to 3–4.

The above pH adjusted nano SiO_2 sols were transferred to five three-mouth reaction bottles, the mass of MTMS needed to be added was calculated according to the mass ratio of 1:1 for the sol and MTMS, and MTMS was put into the bottles.

The reaction bottle was put into a constant temperature water-bath pot; the constant temperature of the water-bath was adjusted to 25°; the mixing plant was open, the reaction started and continued for 8 h, the reaction was stopped.

Secondly, ceramic coatings with mixed particle size were prepared:

The cured ceramic coatings were sprayed onto the surfaces of the aluminum alloy plates electrically polished by sandpaper; the coating thickness was controlled within the range of 25–30 nm.

After the spraying, the aluminum alloy plates were dried at room temperature for several minutes, then they were put into an oven at 200°, baked for 20 min to take the aluminum alloy plates off the ceramic.

Fig. 1 shows the synthesis of a nano-water ceramic coating and the flow chart of the whole coating process.

The pencil hardness test and adhesion test were used.

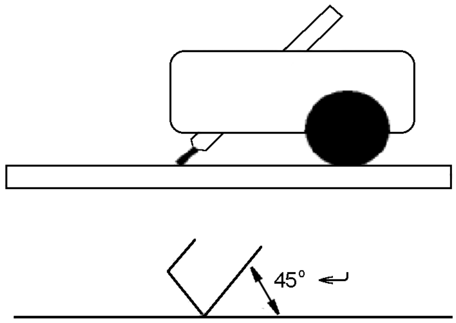


Fig. 2. Operation diagram of ceramic coating.

The pencil hardness of the ceramic coating is determined by the trolley method. The hardness of the ceramic coating is the pencil hardness of the ceramic coating when the pencil passes through the ceramic coating and leaves its mark on the surface (if the pencil with a hardness of 6H passes through the ceramic coating and leaves its mark, and the pencil with a hardness of 5H passes through the ceramic coating and there is no mark, the hardness of the ceramic coating is recorded as 5 H). Figure 2 shows the operation diagram of ceramic coating.

The adhesion of the ceramic coating is determined by the method of "100 grid knife". The cross-grid pattern is cut on the ceramic coating with a 100 grid knife. Table 1 shows the specific evaluation criteria for adhesion.

3. Results

3.1 Performance of 59 nm mixed particle size ceramic architectural coating

It can be seen from Fig. 3 that for the ceramic coating with 59 nm/7 nm mixed particle sizes at their mass ratios of 1:1, 2:1 and 3:1, the hardness and adhesion performance of the ceramic building coating have no change. When the mass ratio of the two components is 4:1, the hardness of the ceramic building coating reaches up to 9 H, and the adhesion property of the coating is also the best. When the mass ratio of the two is 5:1, the hardness of the ceramic building coating decreases and the adhesion becomes worse. As seen from Fig. 4, when the silica sol consists of mixed particles with 59 nm and 23 nm sizes, the hardness of the ceramic building coating increases with the decrease of the content of small size particles. When the mass ratio of the two is 2:1 or greater, the adhesion property of the ceramic building coating does not change, and the adhesion grade is 3. When

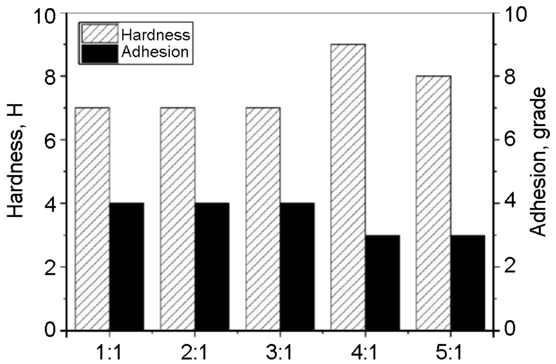


Fig. 3. Hardness and adhesion of 59 nm/7 nm mixed particle size ceramic coating.

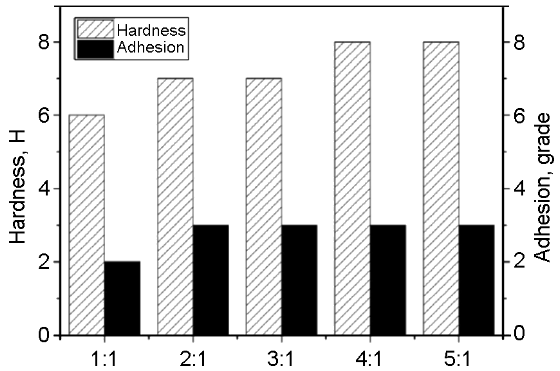


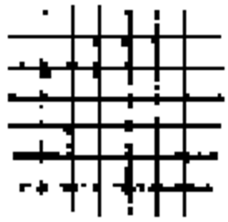
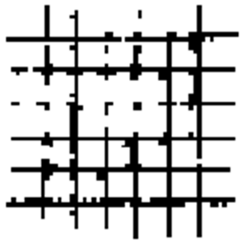
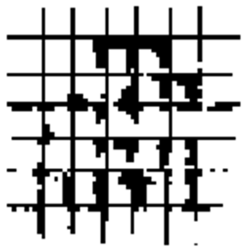
Fig. 4. Hardness and adhesion of 59 nm/23 nm mixed particle size ceramic building coating.

the mass ratio of the two is 4:1 and 5:1, the hardness of the ceramic coating reaches a maximum of 8H.

3.2 Performance of 85 nm mixed particle size ceramic architectural coatings

It can be seen from Fig. 5 that when the silica sol 85 nm/nm particles are mixed and the mass ratio of the two is 1:1, 2:1 and 3:1, the hardness and adhesion properties of the ceramic building coating prepared have no change. When the mass ratio of the two is 4:1, the hardness and adhesion properties of the coating reach the best values. When the mass ratio of the two was 5:1, the hardness and adhesion of the coating decreased. It can be seen from Fig. 6 that when 85 nm and 23 nm silica sols are mixed, the hardness of the coating increases first and then decreases. When the mass ratio of the two is 4:1, the hardness and adhesion of the coating reach the best values. It's a mixture of these two systems determines the ceramic coating properties, and the mixture consists of 85 nm and 23 nm silicon particles provides a good ceramic coating.

Table 1. Adhesion evalution criteria

Level	Specify	Coating surface appearance
0	The cutting edge is completely smooth without any shedding	
1	A little part of the coating fell off at the intersections of the incisions, but the cross-cutting area was not significantly affected by more than 5%	
2	There is coating falling off at the crossing of the incisions and along the edge of the incision. The affected cross-cutting area is obviously greater than 5%, but not significantly greater than 15%	
3	The cross-cutting area affected is obviously greater than 15%, but not significantly greater than 35%	
4	Large fragments were peeled off along the cutting edge, and some squares were partially or completely peeled off. The affected cross-cutting area was obviously greater than 35%, but could not be significantly greater than 65%	
5	The degree of shedding is greater than grade 4	

3.3 Performance of mixed particle size ceramic building coatings

It can be seen from Fig. 7 and Fig. 8 that, similar to the test results of the previous two groups, the hardness of the ceramic coating with mixed particle sizes reaches the maximum when the silica sol mass ratio of the two groups reaches 4:1. The maximum hardness of the ceramic coatings reaches 9 H when it is mixed according to the route. The maximum hardness of the ceramic coatings reached 8 H with the mixing of 10 nm and 23 nm particles. It can also be seen from the figure that under the same mixing mass ratio, the hardness of the ceramic coating prepared with the mixing ratio of 10 nm to 23 nm is better and is basically greater than 1 H. These two mixing systems have the same properties as the ceramic coating, which is basically two to three.

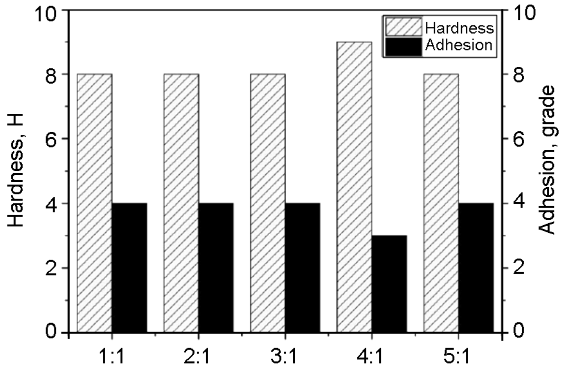


Fig. 5. Hardness and adhesion of ceramic building coatings with 85 nm/nm mixed particle size.

Table 2 presents a summary of the optimal hardness and adhesion of the ceramic coatings with composite particle sizes of 59 nm, 85 nm and 107 nm.

3.4 Performance of p100x mixed particle size ceramic architectural coatings

Table 3 shows the performance data of p100x mixed silica sol for ceramic building coatings.

As can be seen from Table 4, the hardness of the ceramic coating prepared by p100x mixed silica sol is as high as 9 H and the adhesion is on the level of 2. Its hardness and adhesion performance are better than those of the previous mixed particle size ceramic coatings.

4. Conclusions

The results of the experiments show that, using mixed particles with a large diameter and small particles of the silicon aerosol, the hardness of the coating is increased. There was no significant relationship between the adhesion performance and the type of the mixed silica sol. The adhesion of the coating with a poor performance was basically above grade 2. The experimental results are presented for hardness and adhesion of the ceramic coatings with the large particle diameter of the silicon solution, the small particles of silicon solution, and the ceramic coatings with the small particles of the silicon aerosol. The p100x composite sol contains nano-SiO_2 particles of various sizes. The void structure of the prepared ceramic coatings has a higher degree of filling by various small particle sizes, so the hardness of the coatings reaches 9 H.

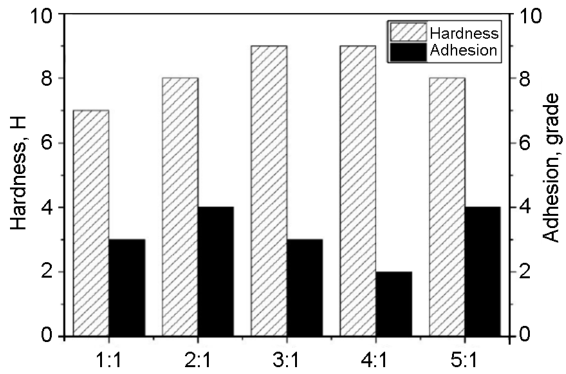


Fig. 6. Hardness and adhesion of 85 nm/23 nm mixed particle size ceramic building coatings.

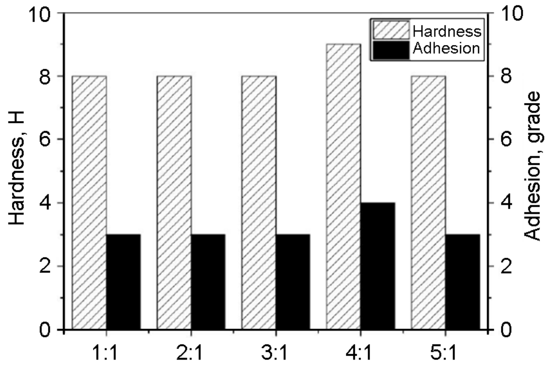


Fig. 7. Hardness and adhesion of 10 spoilage/spoilage ceramic building coatings

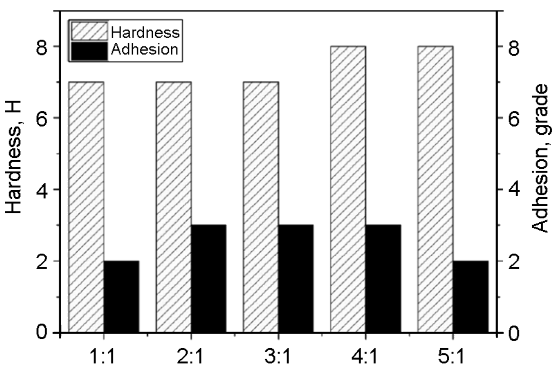


Fig. 8. Hardness and adhesion of 10 nm/23 nm composite particle size ceramic building coatings.

Table 2. Summary of optimal hardness and adhesion of composite particle size ceramic coatings

Serial number	59 nm/23 nm (4:1,5:1)	85 nm/23 nm (4:1)	107 nm/7 nm (4:1)
Hardness	8 H	9 H	9 H
Adhesion	3	2	4

Table 3. Hardness and adhesion data of ceramic building coatings prepared with silica sol

Serial number	1	2	3
Hardness	9 H	9 H	9 H
Adhesion	2	2	2

When the large and small particle size silica sol mass ratio is 4:1, the coating hardness and adhesion performance are good. The size gradation of micro- and nano-particles is different from that of macro particles.

In this experiment, a series of nano-sized water-borne ceramic architectural coatings with mixed particle sizes were prepared. Testing the properties of the ceramic coatings showed the hardness higher than the values specified for GB/t23443-2009 aluminum veneer for architectural decoration, and the adhesion was at the level of 2. Therefore, the coating was found to be of great market application value. In the future experimental exploration, well intensify the research on improving the adhesion performance.

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