

## Application of SAM for engine cooling system

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**Abstract.** A kind of SAM film based on octadecylphosphonic acid was prepared on cast iron and steel substrates by the immersion method. The film was characterized by scanning electron microscope (SEM)、wettability studies. The result showed that octadecylphosphonic acid formed compact hydrophobe film on the substrates and the film had efficient corrosion resistant for cast iron and steel.

### Introduction

Corrosion inhibition for metal is significant in construction industry , chemical industry and many other fields. Self-assembled monolayers (SAM) is a kind of surface modification technology developed in recent years., which hold functional molecules on the surface of substrate by chemical bonds. These molecules are tight、steady and form films with different characters include anticorrosion. Compared with other anticorrosion methods , SAM needs less chemical materials and provides lower cost and simpler operation [1] .

Currently, the study of SAM anticorrosion films aimed at the steel, aluminum, copper and other metal materials, research on synthesis, characterization and corrosion inhibition of the films through different methods such as electrochemical analysis.

Because of a wide range of applications and would be more likely to corrode in damp environment, steel was one of the mainly metal substrates for SAM anticorrosion films. thiol [2] fatty acids [3,4], imidazoline [5] and phosphonates [6] were used for preparing films. Phosphonates could be used for other metal materials such as aluminum, copper , and this kind of molecules have wide application prospect.

In some areas with hot climate, in order to improve the cooling efficiency, people would use water instead of engine coolant. but this method caused steel corrosion in the cooling system, especially rusted cast iron and steel. For reduce the corrosion ,SAM film was tried on cast iron and steel substrates which meet the standard of “ASTM 1384 Standard Test Method for Corrosion Test for Engine Coolants in Glassware”, its hydrophilicity and corrosion inhibition were tested.

### Experimental

Octadecylphosphonic acid (Alfa Aesar, 97%), ethanol (analytical grade), concentrated sulfuric acid (analytical grade), deionized water. Cast iron and steel substrates meet the standard of “ASTM 1384 Standard Test Method for Corrosion Test for Engine Coolants in Glassware”.

After polished with sand paper, the substrates were dipped into 5% H<sub>2</sub>SO<sub>4</sub>(V/V) for cleaning the surface, after 30 sec ,got the substrates out and flushed them with deionized water and absolute ethyl alcohol . For preparing SAM film,then dipped the substrates into 5mM solution of octadecylphosphonic acid in absolute ethyl alcohol for 48h,flushed them with absolute ethyl alcohol for removing the molecule which physical absorbed on the surface and dried out.

Placed a drop of deionized water on the surface of the substrates, viewed the shape of drop from the side for investigating the hydrophilicity of different surfaces.

For testing the corrosion inhibition, the substrates with and without SAM film were dipped into water together. The air was introduced into water. After 2h, flushed the substrates with absolute ethyl

alcohol to remove rust and then dried out . Quanta 250 ESEM was used for analysing the surface micrography of the substrates.

## Results and discussion

**Hydrophilicity of the Film.** Fig.1 shows hydrophilicity change before and after prepared SAM film on the surface of cast iron substrate. The static contact angle of cast iron substrate without SAM film(Fig.1a) is obviously smaller than the substrate with SAM film(Fig.1b). SAM film has significant hydrophobicity because long-chain alkane from octagecylphosphonic acid formed hydrophobicity film on the surface of substate.

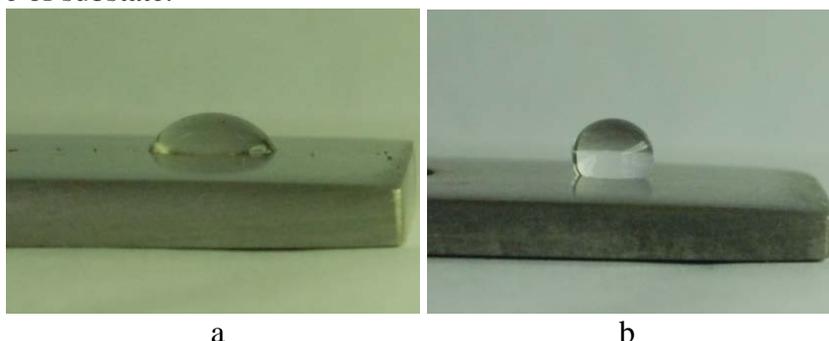


Fig.1 Hydrophilicity change on the surface of cast iron

Fig.2 shows hydrophilicity change before and after prepared SAM film on the surface of steel substrate. The static contact angle of steel substrate without SAM film(Fig.2a) is obviously smaller than the substrate with SAM film(Fig.2b). The result is same as cast iron substrate.

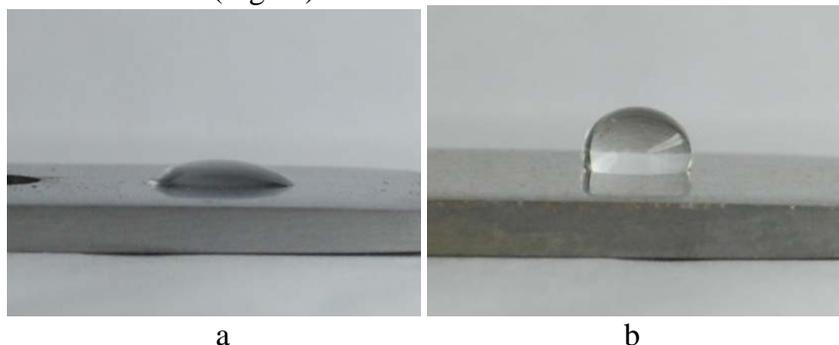


Fig.2 Hydrophilicity change on the surface of steel

**Corrosion Inhibition of the Film.** Fig.3 draws a comparison between cast iron substrates before(Fig.3a) and after(Fig.3b) dipping in water. Under the condition of dipping in water and introducing air , there was significant rust on the surface of the substrate without film(left) while the substrate with film(right) still kept metallic luster and only a few of traces of rust could be found on it.SAM film could reduce the rate of corrosion.



Fig.3 Surface macrography of cast iron

Fig.4 shows the surface micrography of cast iron substrates. Pitting corrosion and granule could be seen on the surface of substrate without film(Fig.4a),while the substrate with film(Fig.4b) still looks clean and smooth.

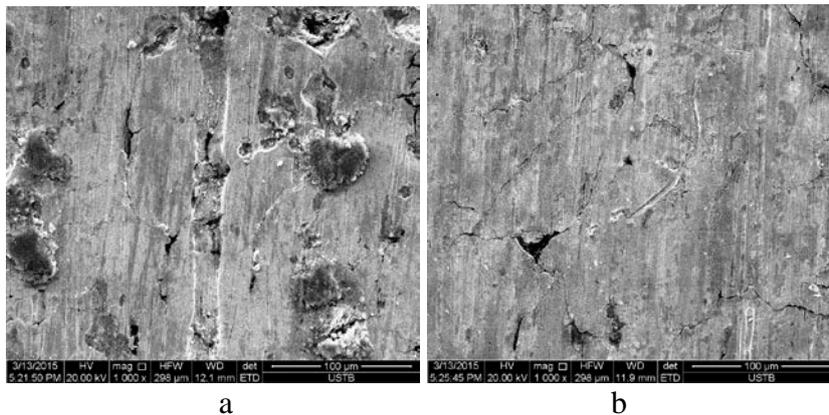


Fig.4 Surface micrography of cast iron

Fig.5 shows EDS spectrum of the cast iron substrate without film. Characteristic peak of oxygen could be found in the spectrum of granule(Fig.5b)while couldn't be found in other area(Fig.5a), this oxide should be rust.

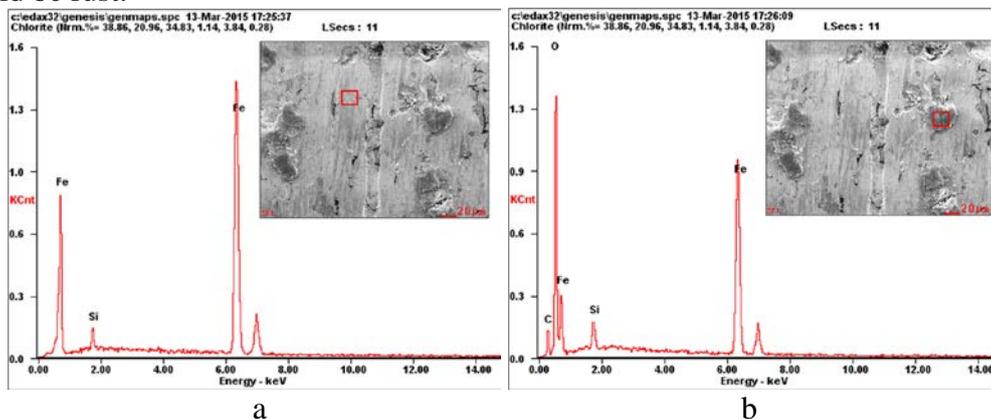


Fig.5 Eds spectrum of cast iron

The results of SEM and EDS spectrum show that, the substrate without film rusted quickly, while the substrate with film didn't rust.SAM film chould reduce the rate of corrosion on the surface of cast iron substrate.

Fig.6 draws a comparison between steel substrates before(Fig.6a) and after(Fig.6b) dipping in water. Under the condition of dipping in water and introducing air , there was significant rust on the surface of the substrate without film(left) while the substrate with film(right) still kept metallic luster and there was hardly any rust.SAM film could reduce the rate of corrosion.

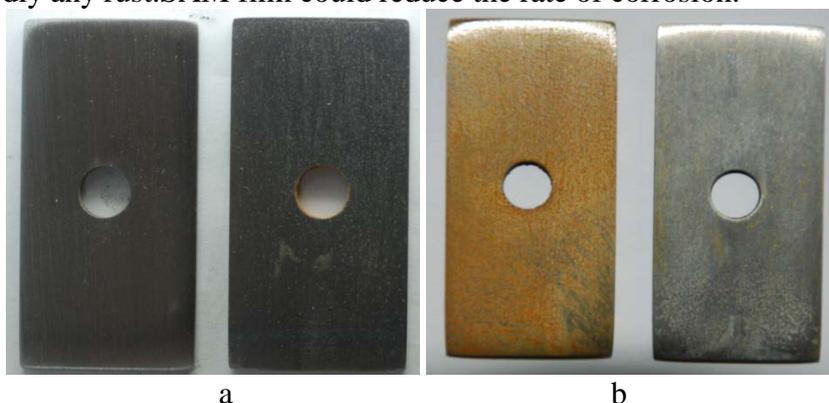


Fig.6 Surface macrography of steel

Fig.7 shows the surface micrography of steel substrates. Pitting corrosion could be seen on the surface of substrate without film(Fig.7a),while the substrate with film(Fig.7b) still looks clean and smooth.

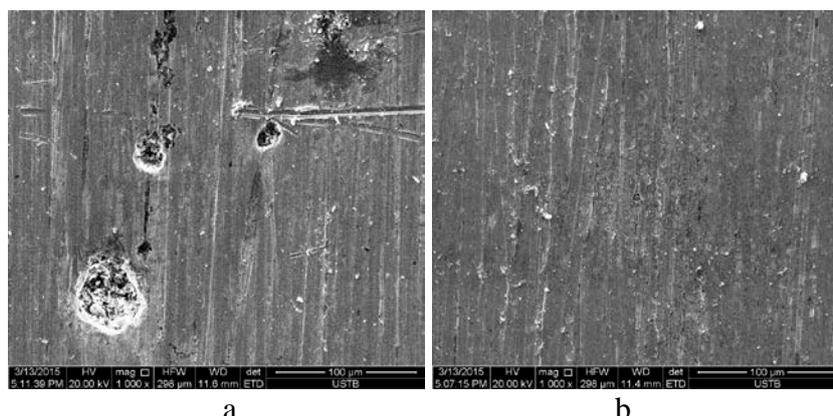


Fig.7 Surface micrography of steel

Fig.8 shows EDS spectrum of the steel substrate without film. Characteristic peaks of oxygen, copper, carbon, silicon could be found in the spectrum of pitting corrosion(Fig.8a)while couldn't be found in other area(Fig.8b), This oxide should be rust. Copper, carbon, silicon are constituents of the steel.

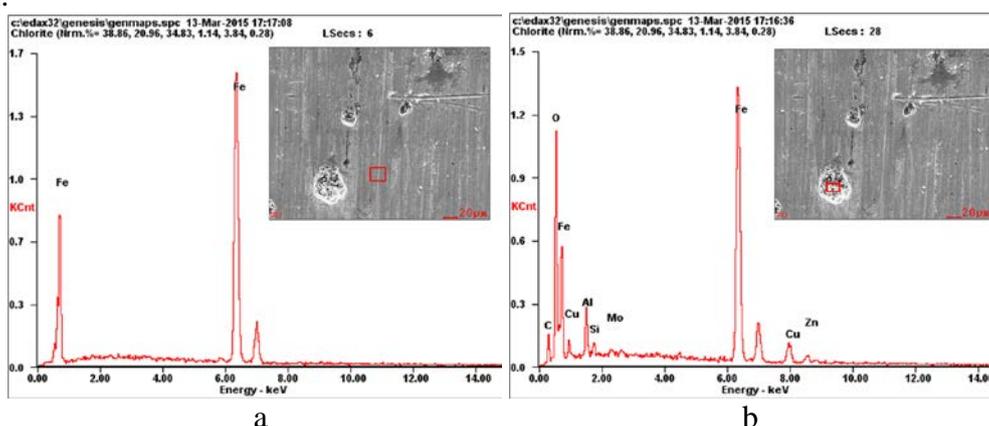


Fig.8 Eds spectrum of steel

The results of SEM and EDS spectrum showed that, pitting corrosion took place on the surface of substrate without film quickly, while the substrate with film didn't rust.SAM film should reduce the rate of corrosion on the surface of steel substrate.

## Summary

SAM film based on was prepared on cast iron and steel substrates based on octadecylphosphonic acid, this film has significant hydrophobicity and could reduce the rate of corrosion efficiently under the condition of dipping in water and introducing air.

## References

- [1] Jun-e Qu, Geng Chen, Hairan Wang, Yan Jiang, Wenwei Li, Progress in research of Sel-assembled Monolayers for corrosion inhibition on active metal surfaces, J. Corrosion & Protection. 33(2006)357-361.
- [2] Jing Wang, Degang Li, Xianjin Yu, Yunhui Dong, Lipeng Zhang, SAMs of dodecyl mercaptan and its corrosion protection on iron surface, J. Journal of Chinese society for corrosion and protection. 30(2010)207-212.

- [3] Aramaki K, Shimura T, Protection of passivated iron against corrosion in a 0.1M NaNO<sub>3</sub> solution by coverage with an ultrathin polymer coating of carboxylate SAM, J. Corrosion Science. 51(2009) 1887-1893.
- [4] Aramaki, K Shimura T, An ultrathin polymer coating of carboxylate self-assembled monolayer adsorbed on passivated iron to prevent iron corrosion in 0.1M NaSO<sub>4</sub>, J. Corrosion Science, 52(2010)1-6.
- [5] Ramachandran S, Self-assembled monolayer mechanism for corrosion inhibition of iron by imidazoline, J. Langmuir, 12(1996)6419-6428.
- [6] Raman A, Dubey M, Gouzman I, Formation of self-assembled monolayers of alkylphosphonic acid on the native oxide surface of SS316L, J. Langmuir. 22(2006)6469-6472.