Decorative Coatings of Plating with Antibacterial Activity

Zhao Zhi-hong,* Seiichiro Eguchi, Yoshio Okada, and Tetsuya Osaka†
Satosen Co., Ltd., 2-20-65, Tamadenishi, Nishinari-ku, Osaka 557
†*Department of Applied Chemistry, School of Science and Engineering, Waseda University, 3-4-1 Ohkubo, Shinjuku-ku, Tokyo 169*

(Received September 27, 1995)

Electroplated coatings of cobalt, zinc, copper and cobalt-containing alloys of nickel, zinc and chromium were found to have bactericidal action. The electroless plated coating of silver also hindered against proliferate of bacteria. Especially, they have bactericide properties to methicillin-resistant strains of *Staphylococcus aureus* (MRSA) in all. In addition, we discussed the relationship between rest potentials of various electroplated coatings and bactericidal action.

Cobalt,[1,2] silver,[3] copper[3] and others metal ions[4] in complexes or metal ions have the inhibitory capability of bacteria, fungi and other microorganisms. This property has been extensively used in zeolites,[5] textiles and various fields. We are, therefore, interested in studying for the new antibacterial methods with broad activity spectra that can control resistant strains of pathogenic diseases that are difficult to cure. It can be proposed that the decorative coatings of plating with bactericidal action is used to prevent contamination of bacteria in hospital facilities and popular equipment.

As an initial study, the Halo-test which is approved by JIS Z 2991 in Japan was used to measure the antibiotic capability of the plated coatings. On the basis of corrosion principle, the inhibitory capability of antibacterial activity materials was evaluated with this method. There was apparently appearance Halo around antibacterial activity materials as the inhibition of early growth of microorganisms. The larger width of Halo shows with increase in the relative intensity of the inhibitory capability.

Halo-test results of 16 kinds electroplated coatings and electroless plated coatings against gram-positive bacteria and gram-negative bacteria are summarized in Table 1. A significant difference in the inhibitory capability of various plated coatings was observed. The electroplated coatings of cobalt, zinc and cobalt-containing alloys of nickel and zinc plated on the metallic substrate and gold plated on the cobalt coating showed significant inhibitory capability against various bacteria tested. However, the electroplated coatings which include nickel, chromium, and chromium plated on the cobalt and nickel, the chromating coating on the zinc showed no inhibitory capability against any bacteria tested. Electroplated coatings of cobalt-chromium alloy and silver showed slightly less active against various bacteria tested. And electroplated coating of copper was the inhibitory capability only against gram-positive bacteria under our studies.

On the other hand, the results of Halo-tests apparently indicate that bactericidal action of silver electroless plated coating on the non-metallic materials possessed somewhat more active against *P. aeruginosa* and *S. aureus* than *E. coli* and MRSA.

We subsequently discovered that the inhibitory capability of gram-positive bacteria and gram-negative bacteria apparently showed different change with rest potentials being shifted. The results are shown in Figure 1. Only against to gram-negative bacteria, the relative intensity of the inhibitory capability of electroplated coatings decreases gradually

Table 1. Halo-test results of various plated coatings[a]

Materials \ Bacteria	Gram (−) Bacteria		Gram (+) Bacteria		
	E.coli 3044	*P.aeruginosa* 3445	*S.aureus* 209	MRSA-3	MRSA-1
	5.5×10^6cfu[d]/ml	2.2×10^6cfu[d]/ml	1.4×10^6cfu[d]/ml	2.5×10^6cfu[d]/ml	1.8×10^6cfu[d]/ml
	Mean±SD[b]/mm	Mean±SD[b]/mm	Mean±SD[b]/mm	Mean±SD[b]/mm	Mean±SD[b]/mm
SUS304	0	0	0	0	0
Co	4.4±0.55	3.8±0.89	3.6±0.71	4.2±0.45	3.6±0.55
Co-Ni	3.3±0.45	3.6±0.55	3.9±0.84	3.2±0.55	3.6±0.55
Co-Zn	4.5±0.55	3.9±0.45	1.8±0.55	2.6±0.45	2.2±0.45
Co-Cr	0.8±0.45	0	0.6±0.55	0.2±0.45	−
Co/Au	4.2±0.45	2.4±0.55	3.2±0.55	2.2±2.2	1.8±0.55
Zn	3.2±0.45	4.8±0.42	3.9±0.84	2.8±0.45	3.4±0.45
Cu	0	0	2.6±0.92	1.8±0.45	1.6±0.45
Zn/chromating	0	0	0	0	0
Ag	0.2±0.65	1.2±0.55	1.0±0.62	0.6±0.6	0.2±0.45
Ni	0	0	0	0	0
Cr	0	0	0	0	0
Ni/Cr	0	0	0	0	0
Co/Cr	0	0	0	0	0
100% nyron cloth[c]	1.2±0.45	2.6±0.71	2.5±0.55	1.2±0.55	2.0±0.55
100% cotton cloth[c]	2.5±0.45	2.8±0.68	2.6±0.45	1.4±0.55	1.6±0.55
nyron net[c]	0.6±0.55	2.8±0.45	1.2±0.52	0.8±0.55	1.6±0.45

[a] Incubation in Mueller Hinton Medium for 24 hours at 37 °C. [b] The mean value of ten same kinds of plated samples and standard deviation of Halo width. [c] Silver electroless plated on non-metallic materials. [d] colony forming unit.

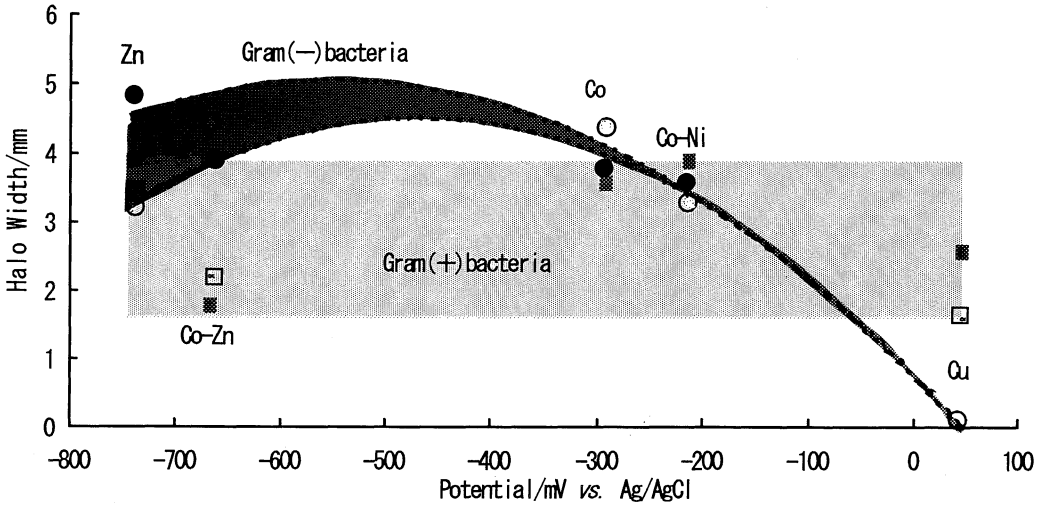

Figure 1. Relationship between rest potential and width of Halo-test of various electroplated coatings in Mueller Hinton Medium. Incubation at 37 °C for 24 h. Gram(−)Bacteria{*P. aeruginosa*(●) *E. coli*(○)}, Gram(+)Bacteria{*S. aureus*(■) MRSA1(□)}

when rest potential of electroplated coating is shifting to noble. For gram-positive bacteria, the inhibitory capabilities do not show significant change.

For the mechanism of inhibitory capability, some possibility are speculated that plated coating metal ions bind to sulfhydryl groups of respiratory enzyme[6] in sensitive bacteria or to nucleic acids[7] in bacteria, resulting in inhibition by cleaving chemical bonds. Also activating oxygen O* species[8] caused by the metal surface reaction works for bacteria decomposition. A significant difference of the inhibitory capability between various plated coatings is because the ability of biological molecules which react with these metal ions may be distinct from the accessibility of the metal ions. Therefore various metal ions have different effect to the nucleic acid. In these series, the gram-negative bacteria may be either more or less susceptible to the effects of metal ions than the gram-positive bacteria, so the gram-negative bacteria, correspond well to the base metal rest potential. But the gram - positive bacteria does not correspond to the rest potential. Because of the activating oxygen O* species produced easily at the base metal potential.

The authors express their gratitude to Dr. T.Yamayoshi, Department of Environmental Microbiology, Osaka Prefecture Institute of Public Health, Osaka.

References and Notes

1 K. Dey, R. K. Maiti, J. K. Bhar, *Agents Actions*, **11** 762(1981).
2 A. Y. Ali-Mohamed, R. D. Gillard, D. E. Hughes, *Transition Met Chem.* **14** 185(1989).
3 M. Takayama, H. Sugimoto, R. Uchida, R. Yamauchi, and K. Tanno, *J. Antibact. Antifung. Agents*, **22** 531(1994).
4 S. J. Slade and G. F. Pegg, *Ann, appl. Biol.* **122** 233 (1993).
5 K. Hiyama, N. Moriyasu, T. Omori, O. miyagawa, Y. Seino and Y. Goto, *J. Antibact. Antifung. Agents*, **23** 197(1995).
6 F. Shimizu, Y. Shimizu, and K. Kumagai, *Antimicrob. Agents Chemother.*, **10** 57(19976).
7 H. Nishioka, *Mutat. Res.*, **31** 185(1975).
8 H.Pezeart, *Mechanisms in Fibre Carcinogenisis Plenum* Press, New York(1991).