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Lifetime of Insoluble Anode for Cathodic Protection on Concrete Construction

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In rebar concrete structure, the corrosion of rebar can arise the deterioration of concrete structure and may affect the safety of the whole system. Recently, several methods for corrosion protection have been used and are more important for concrete structure using the sand including chloride ion. Among several protections, electrical cathodic protection has been expected to be one of the most useful methods in corrosion protection for reinforcement of concrete structures. The anode for cathodic protection needs high current density, high corrosion resistance and low overvoltage. To fill up the special qualities, the insoluble anodes were developed and these anodes were coated with metal oxide of TiO_2, ZrO_2, RuO_2, and IrO_2. Lifetime of these anodes can be one of the important factors affecting the lifetime of concrete structure in cathodic protection. In this work, several anodes were made by sol-gel method and thermal decomposition method and the lifetime of these anodes was evaluated by NACE international standard test method, TM 0294-94. Also, we did analyze the properties of coated metal oxides.

Keywords : *concrete, cathodic protection, insoluble anode, metal oxide, lifetime*

1. Introduction

Penetration of chloride into concrete, neutralization, and increased amount of salt sand et al. can corrode shortly the rebar in concrete construction. Therefore, appropriate protection should be applied for life extension of the construction, and thus electrochemical cathodic protection is usually used.[1),2),3)]

Properties of anode for cathodic protection need low overvoltage for oxygen evolution and high corrosion resistance. It is well known that DSA (Dimensionally Stable Anode) is the best anode till now.[4),5),6),7),8)] DSA is mainly composed of RuO_2, IrO_2, ZrO_2, Co_2O_3, and ZrO_2, Ta_2O_5, TiO_2, MnO_2 are added to DSA for better corrosion resistance. In recent, 3-components or multi-components anode are studied because 2-components anode has low corrosion resistance and these electrodes show the lower overvoltage for oxygen evolution and the higher corrosion resistance.

Also, DSA needs the low overvoltage, but lifetime is very important factor. Thus, RuO_2, IrO_2, RhO_2, ZrO_2 are well used for lifetime extension, and many researches are focused on lifetime to be extended by lowering oxygen evolution potential and minimizing dissolution of oxide coatings. This work focused on the study for electrochemical properties and lifetime evaluation of DSA electrodes.

2. Experimental

To make stable RuO_2, IrO_2, ZrO_2 sol at room temperature, ruthenium chloride hydrate ($RuCl_3 \cdot 3H_2O$, Kojima Chemical Co.) and iridium(Ⅲ) chloride hydrochloride hydrate ($IrCl_3 \cdot XHCl \cdot YH_2O$, Aldrich), and zirconyl nitrate($ZrO(NO_3)_2$) are used, and isopropanol ($(CH_3)_2CHOH$, Aldrich) is used as a solvent.

Matrix for coating is used as titanium plate (grade Ⅱ) and its size is 10×80×0.5mm. After mechanical polishing using SiC paper #220, Ti plate is immersed for 30min. in 35% HCl solution at room temperature and rinsed.

Sol-gel coating to Ti plate is performed as follows; 1 cycle coating process is dip-coating(1.0 cm/min), 1st drying(130℃, 10 min.), 2nd drying(450℃, 10 min.), and then 5 cycles are coated and finally heat treated at 450℃ for 1 hr.

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Anodic polarization test(scan rate; 1 mV/sec) and cyclic polarization test(scan rate; 40 mV(SCE) are performed using a Potentiostat (Model EG&G 273A) in 25℃, 1M H_2SO_4 and 25℃, 0.5M H_2SO_4 respectively. Saturated calomel electrode is used as a reference electrode and graphite electrode is used as a counter electrode.

Lifetime is evaluated by NACE Standard TM 0294-94[9] in 3% NaCl, 4% NaOH, and simulated pore water (0.20% $Ca(OH)_2$ + 3.20% KCl + 1.00% KOH + 2.45% NaOH + 93.15% H_2O). Applied current is constantly 320 mA/cm^2 and the experiment is continued before electrode potential reaches 4 V(SCE). Adhesion of coatings to matrix is performed by ASTM D3359-97.[10]

3. Results and discussion

Fig. 1 shows anodic polarization curves of single component coating on Ti substrate in 1 M H_2SO_4 solution at 25℃. In case of non-coated Ti and Zr-coating, passive current is about 10^{-4} A/cm^2 and good passivity is established but oxygen is not evolved till 2 V(SCE).

Single component coatings (Ru and Ir) show low passive current density and oxygen evolution potential is about 1.2 V(SCE) and the potentials are similar to each other. Open circuit potentials (ocp) of non-coated Ti and Zr-coating are low, but the others are relatively high.

Fig. 2 shows anodic polarization curves of 2~3 components coating on Ti substrate in 1 M H_2SO_4 solution at 25℃. Passive current density is a little increased than 1 component coating and they show a similar oxygen evolution potential. 2~3 components coatings show similar open circuit potentials.

Fig. 3 shows cyclic polarization curves of 1~3 components(Ru or Ir or Zr) coating on the Ti substrate and Ti substrate in 0.5M H_2SO_4 Solution at 25℃. In case of non-coated Ti substrate, anodic scan shows large current, and reverse scan shows small current and low ocp occurs by reverse scan.

However, in case of 1~3 components coating, current hysteresis is small and high ocp occurs by reverse scan.

Lifetime of anode is very important factor in cathodic protection for concrete construction. Therefore, a lifetime is evaluated by NACE international standard test method (Standard TM 0294-94 Item No. 21225). Fig. 4 represents calculated lifetime of several coatings, and lifetime can be calculated by the standard.[9] 3 kinds of oxide coatings are used as a reference (mesh, ribbon, tube are commercial anodes).

Fig. 3a shows a lifetime in 3% NaCl. Single Ir-coating only has relatively high potential, but the others are similar to each other. Fig. 3b shows a lifetime in 4% NaOH.

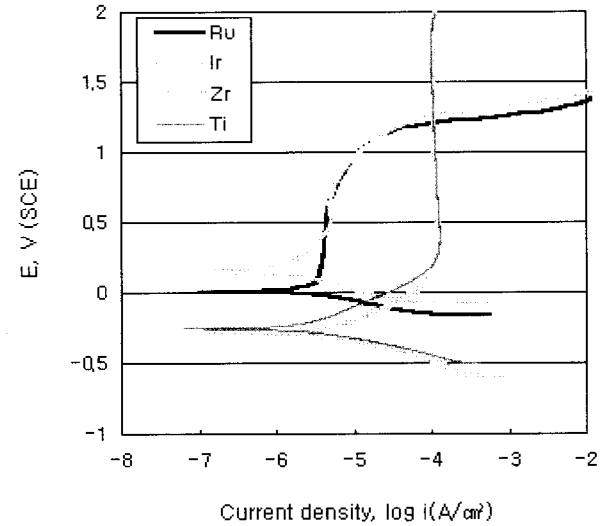


Fig. 1. Anodic polarization curves of single component coating (Ru, Ir, Zr coating on the Ti substrate) and Ti substrate in 1M H_2SO_4 solution at 25℃

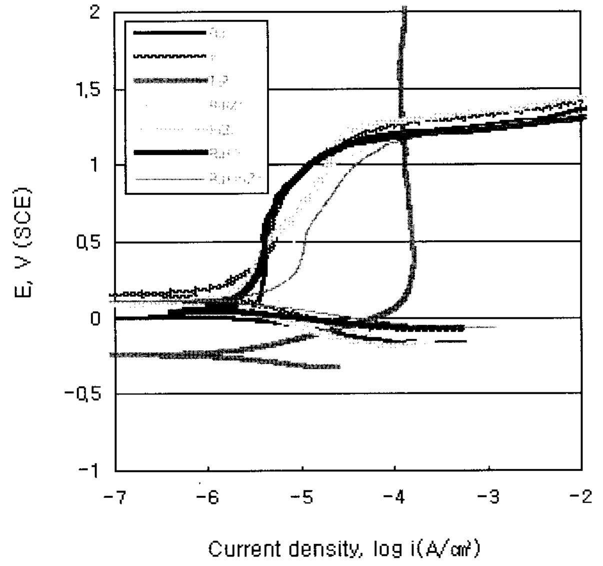


Fig. 2. Anodic polarization curves of Ru or Ir or Zr coating on the Ti substrate and Ti substrate in 1M H_2SO_4 solution at 25℃

Potential of single Ir-coating sharply increases after 32 years. This increase is due to the dissolution of conductive oxide coating and the reveal of Ti substrate as shown in anodic polarization curves. The others show good calculated lifetime.

Fig. 3c shows a lifetime in simulated pore water solution. Potential of single Ir-coating sharply increases after 56 years. This increase is due to the dissolution of conductive oxide coating and the reveal of Ti substrate as shown in anodic polarization curves. The others show good calculated lifetime. Fig. 3d summarizes the potential

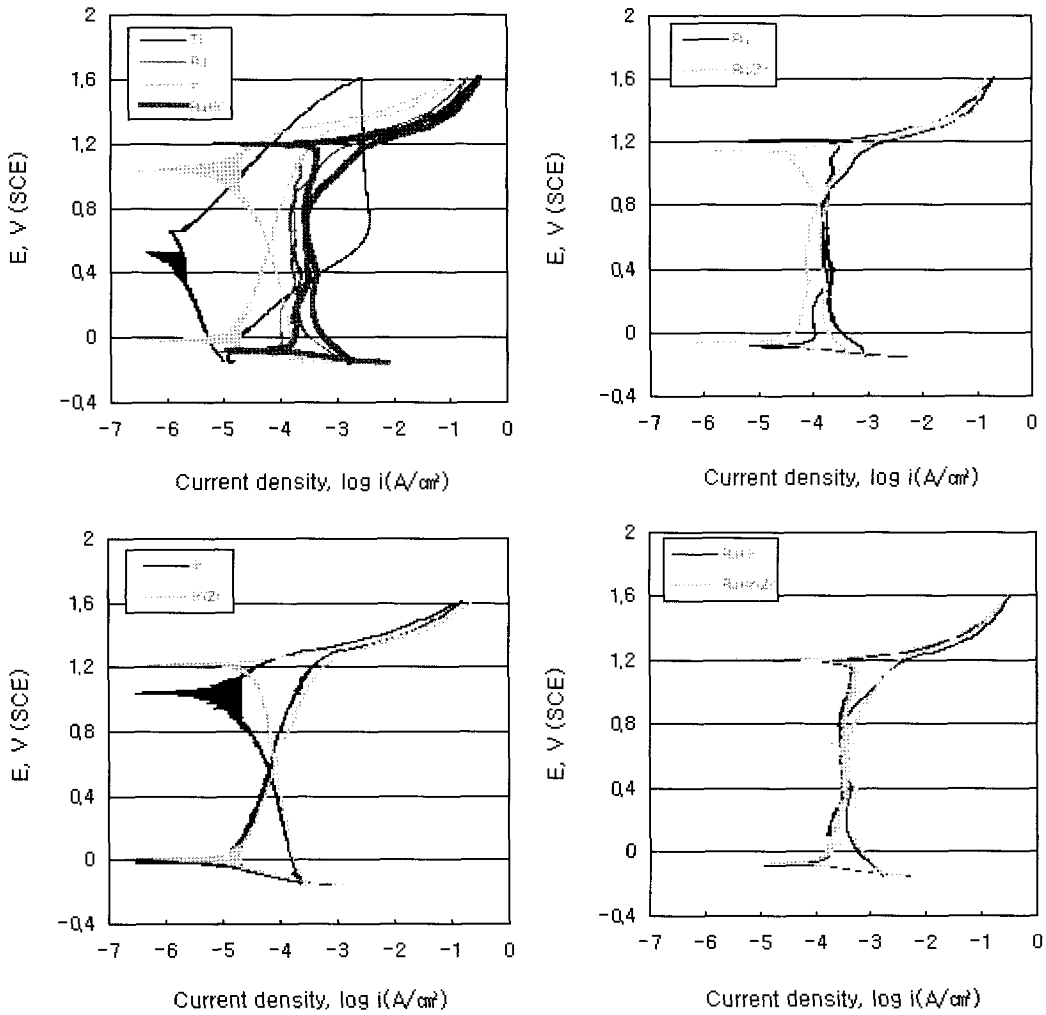
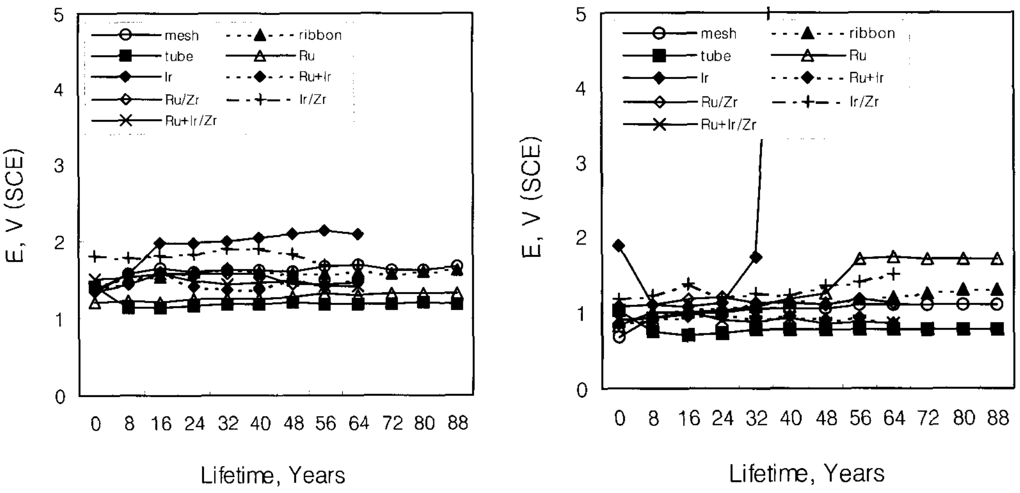
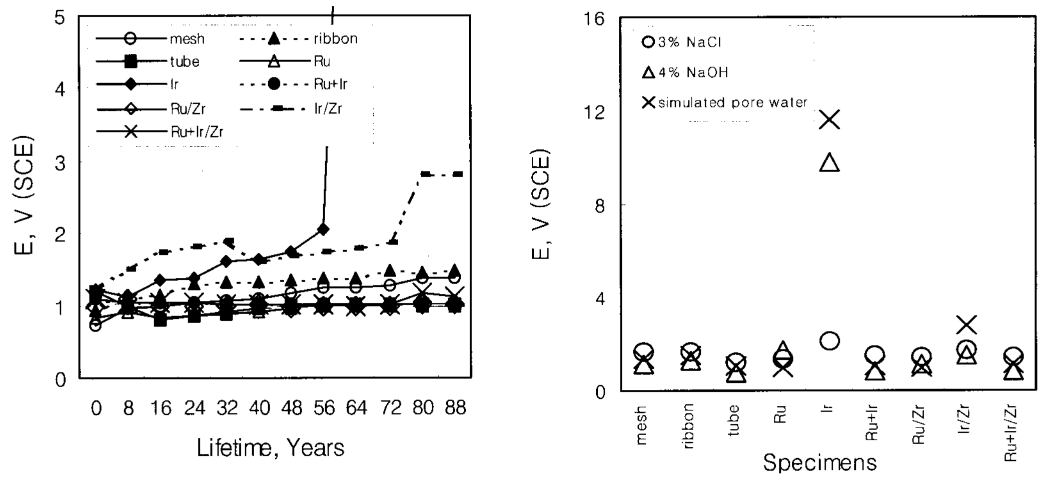


Fig. 3. Cyclic polarization of Ru or Ir or Zr coating on the Ti substrate and Ti substrate in 0.5M H_2SO_4 solution at 25℃



(a) (b)



(c) (d)

Fig. 4. Result of lifetime testing, (a) 3% NaCl solution, (b) 4% NaOH solution (c) Simulated pore water solution, (d) Potential of lifetime testing

at 56 years. Only single Ir-coating shows very high potential and thus this type's anode can't use for cathodic protection of rebar corrosion.

For application of anode, appropriate adhesion strength is needed. Thus, this work performs cross cut tape test by ASTM D3359-97.[10] All coatings show adhesion strength of 5B scale.

4. Conclusions

Non-coated Ti substrate shows high overvoltage for oxygen evolution, but 1~3 components oxide coatings show very low overvoltage. By cyclic polarization test, non-coated Ti substrate shows large current hysteresis, but oxide coatings show very small hysteresis.

Potential of single Ir-coating increases in a short period by lifetime evaluation test. This increase is due to the dissolution of conductive oxide coating and the reveal of Ti substrate as shown in anodic polarization curves. The others show good calculated lifetime.

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