EIS STUDY OF BEER FERMENTATION EFFECTS ON CORROSION BEHAVIOR OF COPPER AND AUSTENITIC STAINLESS STEELS

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Abstract

Beer is a widely consumed alcoholic beverage throughout the world and global production figures have shown an increase in trend during the last decade. Many failures and corrosion problems encountered in brewery and fermentation process due to corrosivity of fluids which are rather acidic and also contain live microfauna. Presence of yeast and chloride ion can cause not only pitting corrosion but also microbiologically induced corrosion which lead to biofouling and failures.

In this study, the effect of fermentation products on corrosivity of copper and three austenitic stainless steel is evaluated by electrochemical methods. The metallic samples put into the fermenter vessel and several electrochemical impedance spectroscopy (EIS) tests performed during the fermentation and after that samples were removed from the fermenter and examined by optical microscope (OM) for detecting biofilm and corrosion products. Results showed that EIS curves have changed during the fermentation due to corrosion and biofilm formation.

Keywords: Brewing, Corrosion, Biofilm, Electrochemical tests, Corrosion products

1. INTRODUCTION

Beer is a widely consumed beverage around the world, made out of water, malt, hops and yeast as basic ingredients. Beer is more or less corrosive [1]. Not only is beer acidic, but also it contains live microfauna which can cause the biological corrosion.

Furthermore, any metal which has been used in the brewing system needs to cause no change in the taste and the smell of the product. In the interest of a better investment, it is also crucial to consider the value of the brewery equipment. Stainless steels and copper are commonly used for fermentation chambers, storage tanks and also piping systems. These materials are acid resistant and do not contaminate the beer.

Copper is a corrosion resistant alloy but it is more resistant to acid than alkaline. Copper alloys also have antibacterial properties however, it is weak to alkaline and oxidative sanitations along with scrubbing and wear weaknesses. Stainless steel has a better wear and corrosion resistance due to the formation of the passive oxide layer that protects the surface. On the other hand, stainless steel is susceptible to pitting corrosion in presence of chloride ions which is common in cleaning solutions. The 300 series alloys are commonly used in the brewing industry and basically, the passivated alloy is inert inserted to the beer [2,3].

In this paper, three austenitic stainless steel and one copper alloy which are mostly used in brewery, have been tested in beer during fermentation and the effects of biological process on corrosion resistance of alloys have been evaluated by Electrochemical Impedance Spectroscopy (EIS) method.

2. MATERIALS AND METHODS

The electrochemical cell was a galss container with a volume of 7 L. The measurements were performed in a conventional three-electrode configuration under open-circuit conditions, requiring testing alloys as working electrod, a graphite rod as counter electrod and a saturated calomel electrode acting as reference electrode.

The testing alloys connected with a wire, sealed in resin and well-defined area of 0.785 cm^2 (a circle with the diameter of 10 mm) of each working electrode was exposed to the electrolyte. The working electrodes were wet groundto 2000-grit by SiC sand paper. A 99.9 % pure copper and 304, 316 and 316L stainless steels were used as the testing alloys or working electrodes.

A malt solution with yeast used as electrolyte and EIS tests were performed during the fermentation with time intervals. Before starting the prosidure, the vesel was sanitated and filled with 5 L of boiled water while 0.8 L malt malt extract and SafAle US-05 yeast were added to the vesel. The cap of the vesel was sealed by a silicone waterproof glue and an airlock was used for checking the sealing.

The EIS tests were conducted using a SP-150 potentiostat, controlled by EC-lab software. The EIS measurements were obtained at Open Circuit Potential (OCP) with voltage perturbation amplitude of 10 mV in the frequency range of 100 kHz to 10 mHz. **Figure 1**, shows the schematic of laboratory experimental apparatus and fermentation setup.

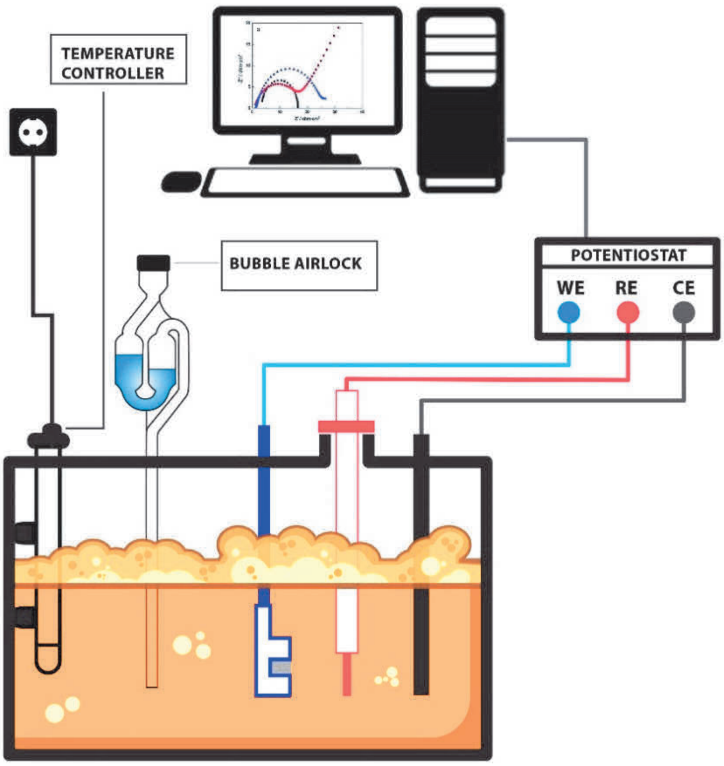

Figure 1 Schematic of laboratory experimental apparatus and fermentation setup

3. RESULTS AND DISCUTION

Figure 2, shows the impedance curve of copper, 304, 316 and 316L stainless steel. After the second day, huge changes in all of the curves have been observed. then the changes decreased and eventually, reached to a steady state condition. For the stainless steels, a defiusion control condition can be seen due to finite warburge element which is recognised as a diagonal line with a slope of 45° at low frequencies[4]. For comparing the resistance in varoius tests, the maximum resistance at the lowest frequency exteracted from each curve (**Table 1**) and polted versus time in **Figure 3.** As is evidenced by this figure, the values of the resistance has a huge shift in copper after a day and subsequently, for countinuing the fermentation, it varied smoothly. Unlikely, stainless steels show less changes after first day and then reach a lower resistance for steady state situations. This can be assigned to aeration condition of vesel during the fermentation. In the begining of the fermentation the solution still contains oxygen which has a great effects on corrosion resistance of copper and stainless steel. Copper is a noble metal which is not passivated in oxidative condition. So, by continuing the fermentation, the oxygen in the cell is consumed and the cell enters to a desarated condition which increases the corrosion resistance. On the other hand, the less oxidative condition which caused by less soluble oxygen in the vessel makes the stainless steel more vulnarable to corrosion due to weak passive layer in reductive condition [5].

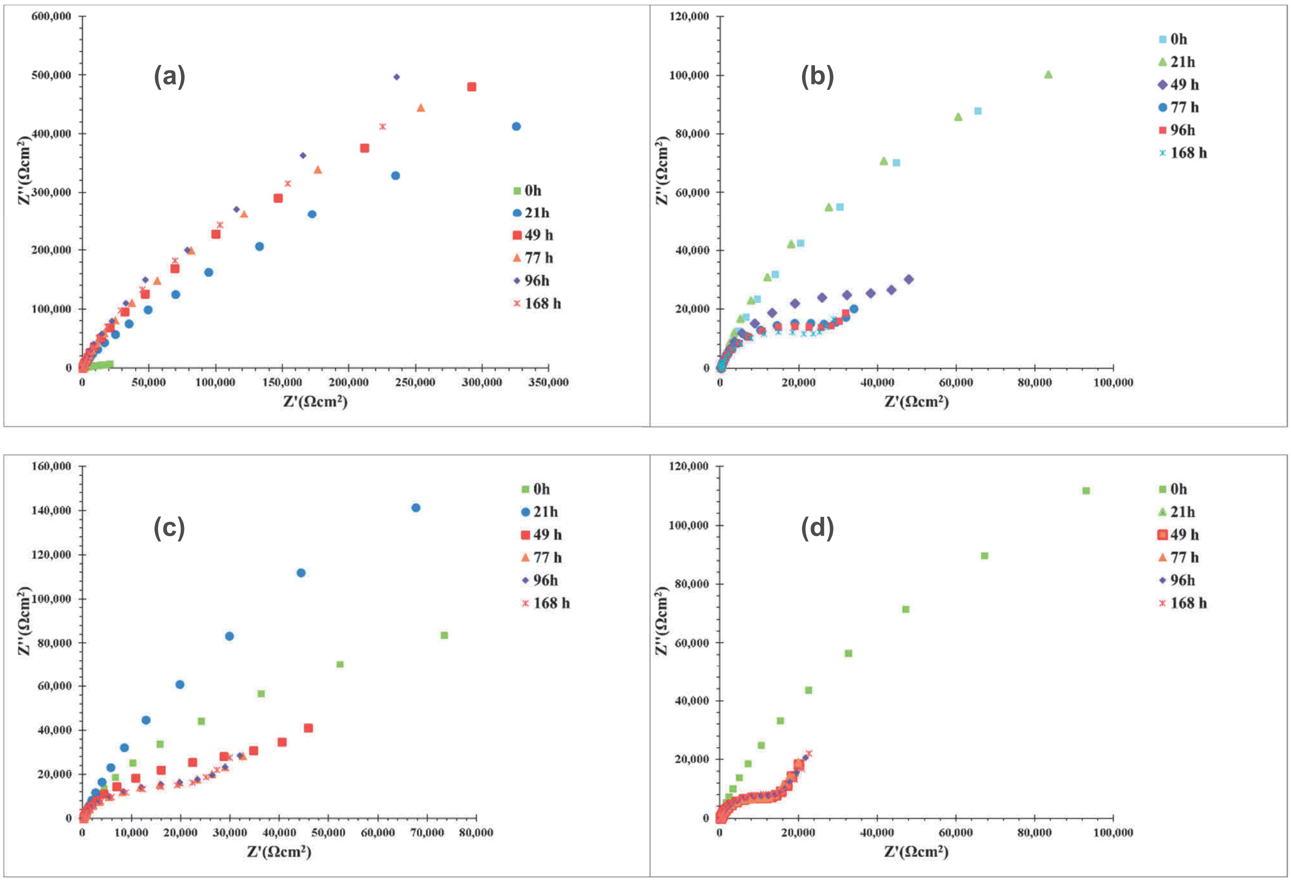

Figure 2 Nyquist curves for (a) copper, (b) 304, (c) 316 and (d) 316L stainless steel.

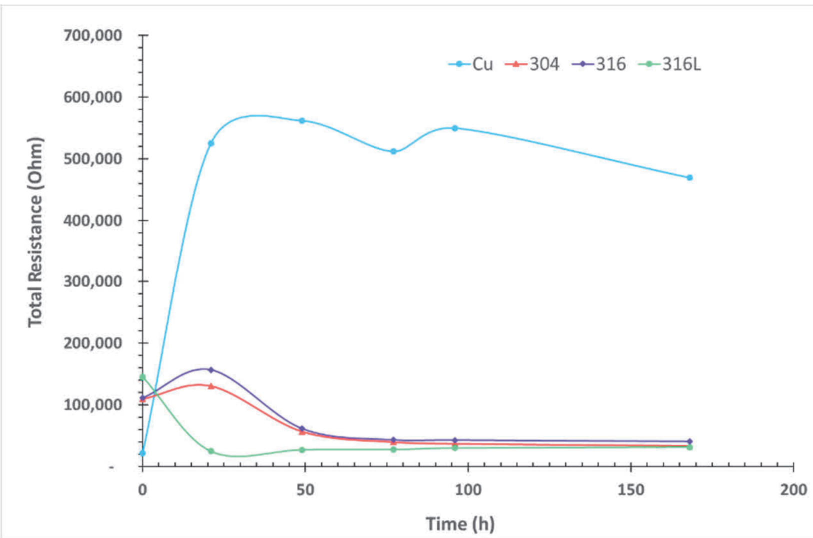

Figure 3 Resistance changes during the fermentation

Table 1 Total resistance extracted from impedance curves for testing samples during the fermentation

	Cu	304	316	316L
Time (h)	Resistance (ohm)	Resistance (ohm)	Resistance (ohm)	Resistance (ohm)
0	21,832	109,538	111,226	145,390
21	525,468	130,422	156,713	24,690
49	561,732	56,617	61,450	27,139
77	511,955	39,555	43,204	27,643
96	549,849	36,911	42,853	29,986
168	469,478	33,298	40,694	31,567

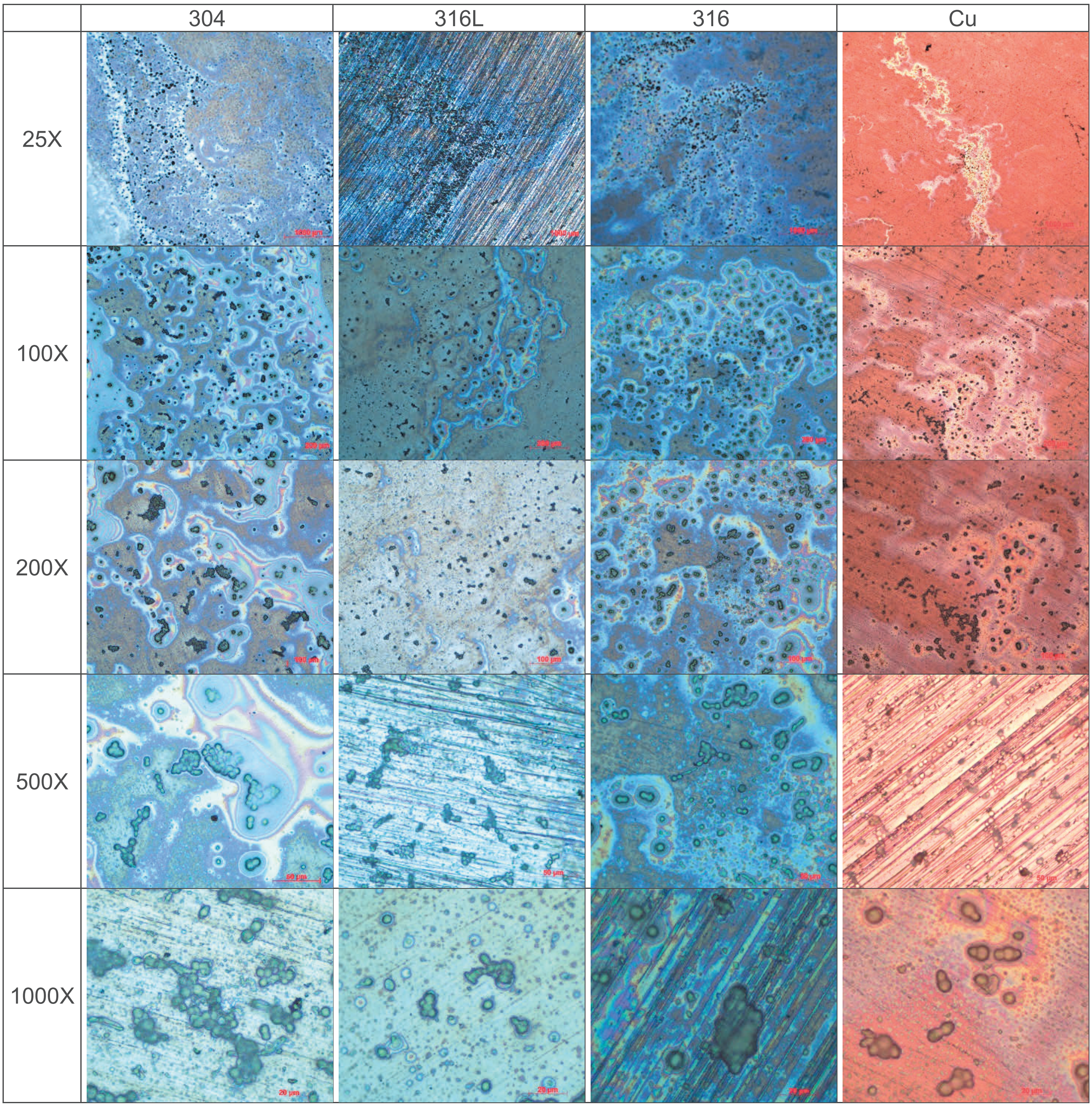

Figure 4 Optical microscope image of the yeast colony morphology and corrosion products after being exposed to fermentation solution for 200 hours

Figure 4 shows the optical images of copper, 304, 316 and 316L stainless steel after 168 hours of suspention in the test setup. As can be seen, all of the samples are covered by a very thin corrosion products; also biofilm and the yeast cells can be observed in a higher magnification. It seems that, less colony of cells attached to the surface of copper rather than stainless steels which can be atributed to antibacterial effect of copper. Generally, it can be concluded that, the side effects of fermentation for decreasing the amount of soluble oxygen in the cell has more effects on the corrosion resistivity than formation of biofilms on the surface[6].

4. CONCLUSION

In this study, the effect of fermentation products on corrosivity of copper and three austenitic stainless steel are evaluated by electrochemical methods. The metallic samples put into the fermenter vessel and several electrochemical impedance spectroscopy (EIS) tests performed during the fermentation and after that, the samples are removed from the fermenter and are examined by optical microscope (OM) for detecting biofilm and corrosion products. Based on the EIS results, the changing in aeration condition has more effects than the biofilm formation and colony growth.

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