Corrosion properties of Electropolished Stainless Steel

Calamo AB

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Corrosion properties of electropolished stainless steel

Several studies have been conducted in the area of corrosion properties of electropolished stainless steel. The electropolishing and corrosion measurements methods are different in the studies which makes a comparison difficult. The reviewed studies show that the corrosion resistance is improved, or in a few cases unchanged, after electropolishing of stainless steel.

The trend throughout the studies is that a less noble steel gains more in corrosion resistance from electropolishing then a more noble steel.

There are different theories about why electropolishing improves the corrosion resistance. Some suggests that a smoother surface decreases the total surface area and also decreases the number of weak spots where the corrosion initiates. A more common theory is that electropolishing increases the Chrome/Iron (Cr/Fe) ration on the steel surface which gives a higher corrosion resistance.

To get an overview, this report is grouped according to the different steel qualities. First a summary of the Austenitic steels that are divided into two groups, 304/304L and 316/316L. Then a short summary of the Duplex Stainless Steels and at the end a paragraph about more applied studies.

Austenitic Stainless Steel 304/304L

Momeni et al. shows that electropolishing increased 100mV in corrosion potential, 200mV in pitting potential and also that the passivity current density decreased for a decade[1](Figure 1.). They could not detect any difference in Cr/Fe ratio. The explanation to this is that they used Energy dispersive X-ray spectroscopy (EDX). EDX analyses the material several micrometers into the material and the passive oxide layer is only around 20 to 50Å thick.

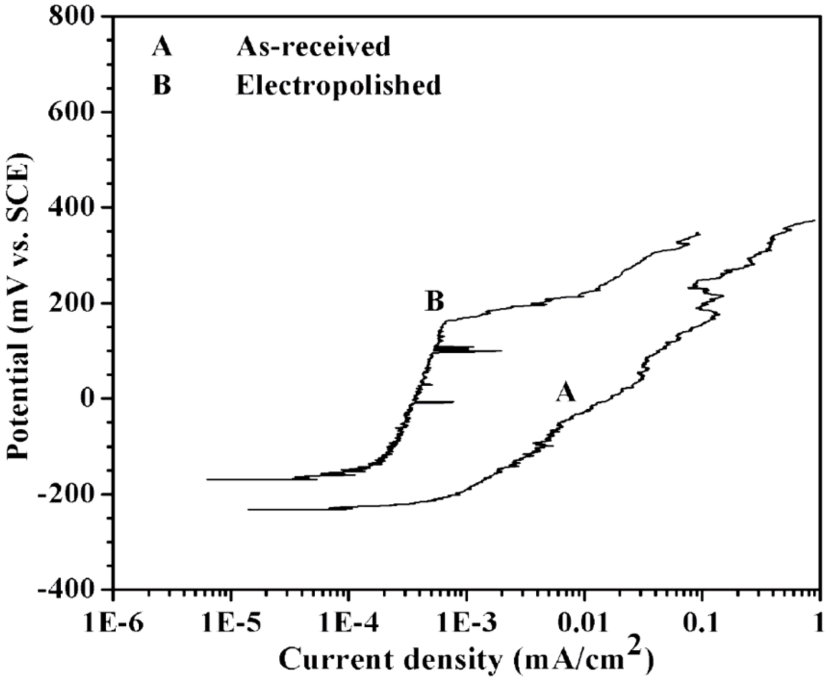

Fig1. Potentiodynamic polarization results for electropolished (red) and as-received (black) in 0.5M NaCl solution and 60mV/min scanning rate[1]

Rokosz et al. have used X-ray photoelectron spectroscopy (XPS) to study the Cr/Fe ratio on the surface of electropolished 304L[2]. In the paper they compare standard electropolishing (EP50) with a very high current electropolishing (EP1000). Figure 2 shows their main result from the study where it is showed that the Cr/Fe ratio after electropolishing (EP50) was 6.6[2].

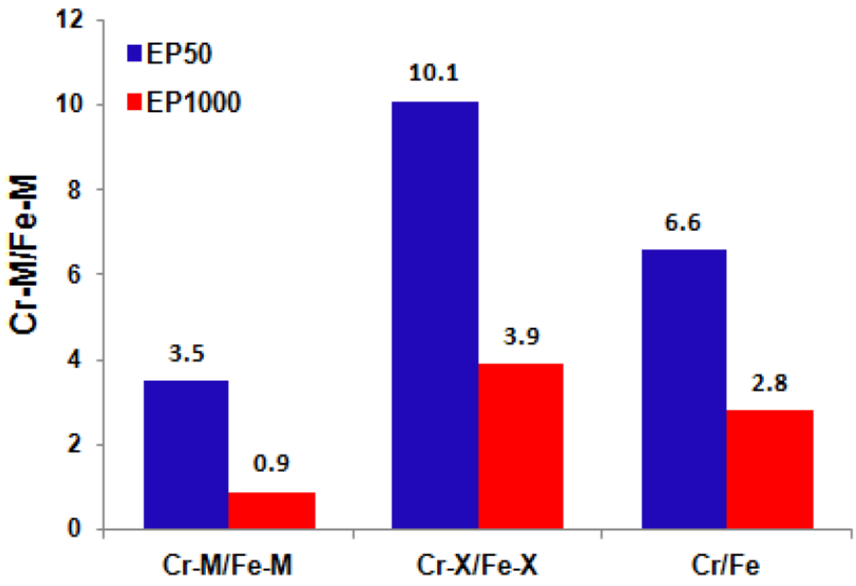

Fig2. Chromium metal to iron metal (Cr-M/Fe-M), chromium compounds to iron compounds (Cr-X/Fe-X) and total chromium to total iron (Cr/Fe) ratios as obtained on the basis of high-resolution XPS spectra[2]

Ziemniak et al. did choose a more applied approach and compared corrosion inside stainless steel tanks containing deionized, hydrogen-sparged water at 260°C and a pH(at 260°C)=6.70. They concluded that the corrosion rate of the electropolished surface was lowered with a factor of three compared with a machined surface. It was explained that the electropolishing removed the surface macrostrain that was imparted during fabrication of the component[3].

Austenitic Stainless Steel 316/316L

Lee et al. showed that the electropolishing process is an effective technology to improve the corrosion resistance of stainless steel 316L[4]. From Table 1: The uniform corrosion after EP process shows a significant 60–80% improvement[4]. Localized corrosion after EP process were significant (85–91%) for all process conditions[4]. In the same paper the Cr/Fe ratio increased from 0.76 to 2.22 after electropolishing. Auger electron spectroscopy (AES) confirmed the XPS analyses and determined the thickness of the passive film to 25Å (Fig.3)[4].

According to Habibzadeh et al the passive layer formed at electropolishing is 50-120% thicker than the natural formed layer, Figure 4[5]. The Cr/Fe ratio for the same layer was 2.1 compared with the natural formed layer the was 0.5[5]. The study also showed a increased protection against corrosion after electro polishing[5].

At the end of the 1990s Calamo was required to analyse the passive layer after electropolishing tubes for the semiconductor industry. This was made with booth XPS and AES. A summation of the results show that the passive layers varied between 30-45 Å in thickness and the Cr/Fe ratio was between 1.8 to 4.0. Figure 5 showes an example of one of the AES diagram.

Table 1. 316L[4]

Results of uniform corrosion and EPR tests at the EP process

Test no.	Uniform corrosion		EPR test	
	Corrosion rate (mmpy)	Percentage of improvement	Pa	Percentage of improvement
Original	9.55E−02		4.99E−02	
1	3.54E−02	62.952	4.04E−03	91.918
2	2.78E−02	70.881	6.23E−03	87.527
3	3.21E−02	66.406	7.41E−03	85.170
4	2.86E−02	70.018	6.67E−03	86.665
5	3.03E−02	68.232	7.23E−03	85.525
6	3.99E−02	58.200	5.87E−03	88.238
7	3.82E−02	59.968	5.53E−03	88.919
8	2.10E−02	78.027	5.42E−03	89.153
9	3.57E−02	62.653	6.67E−03	86.648

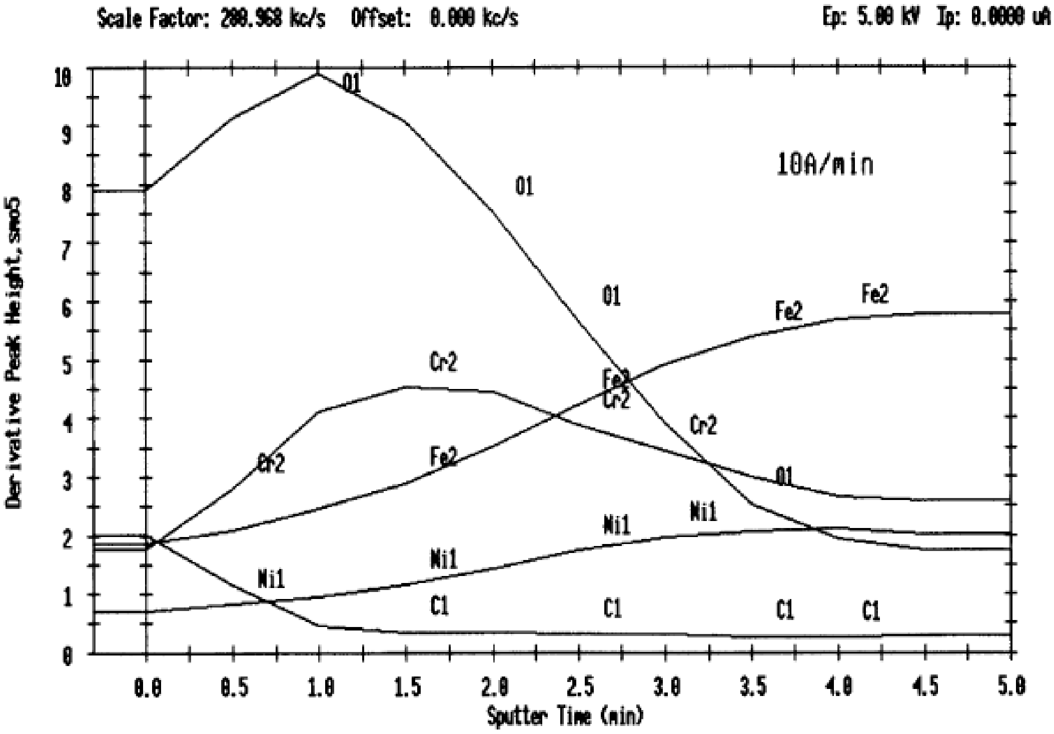

Fig3. Results of AES depth profile analyses, the oxide thickness is 25Å .[4]

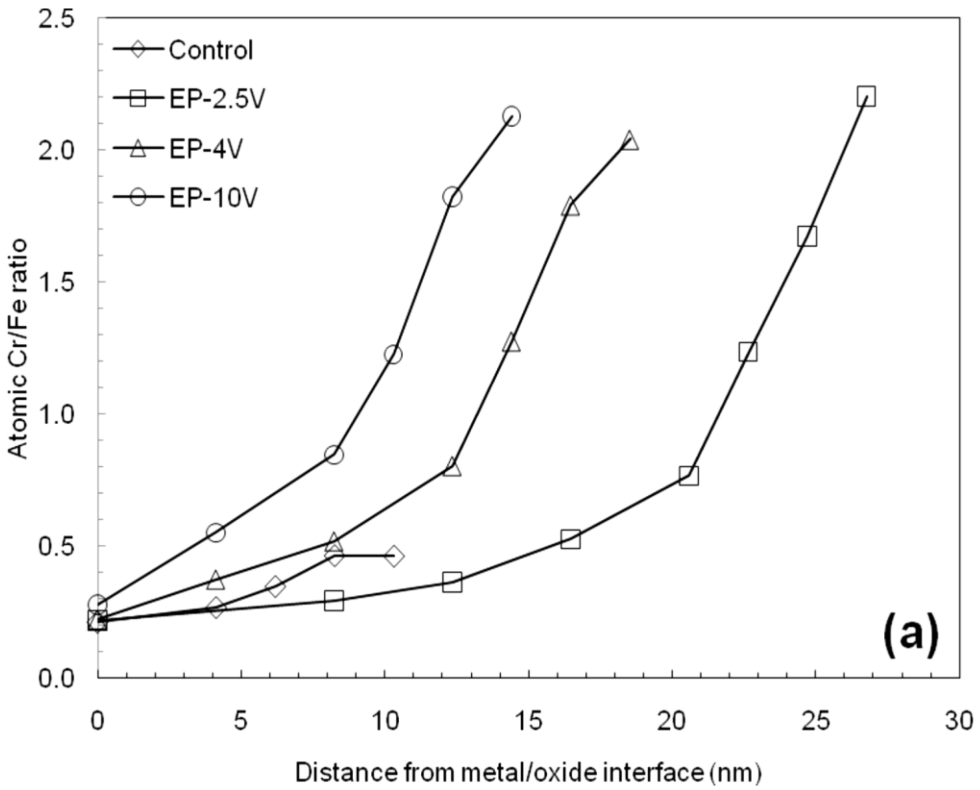

Fig4. (a) Cr/Fe atomic ratio for naturally grown passive film on 316L-SS (control), and passive films formed on 316L-SS by electrochemical polishing at cell voltages of 2.5, 4 and 10 V.[5]

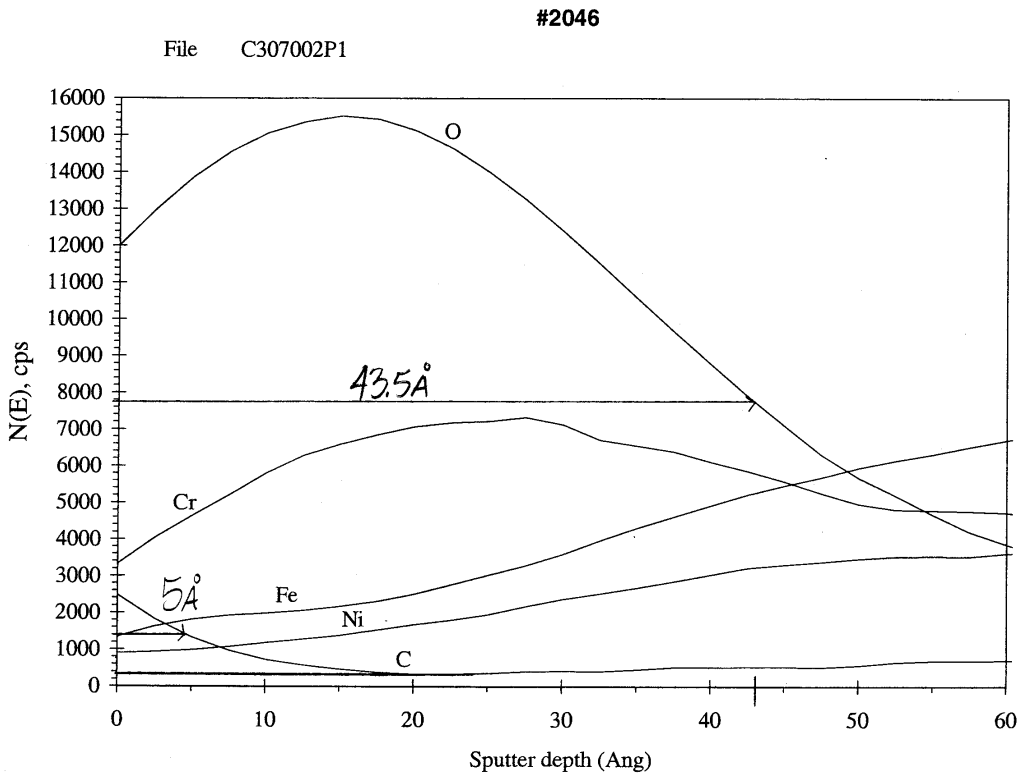

Fig5. AES på ett av Calamo elektropolerat rör av 316L med tjockleken på oxidskiktet 43,5Å.

Duplexa Stainless Steel

The number of reports on electropolishing of Duplex steels is not as great as for the Austenitic ones. Anyway Rokosz et al. showed that the Cr/Fe ratio was 1.9 after electropolishing of Duplex 2205 SS[6]. Two different reports booth claimed that electropolishing followed by a passivation, was the most affective protection against pitting corrosion of 2205[7,8].

Juuti et al[9] has investigated a metastable Austenitic-Ferritic stainless steel and discovered that the Austenitic phase on the surface can transform to Martensitic during mechanical polishing. They also showed that this phenomenon does not occur with electropolishing and that the Martensitic phase can be removed with electropolishing, figure 6.

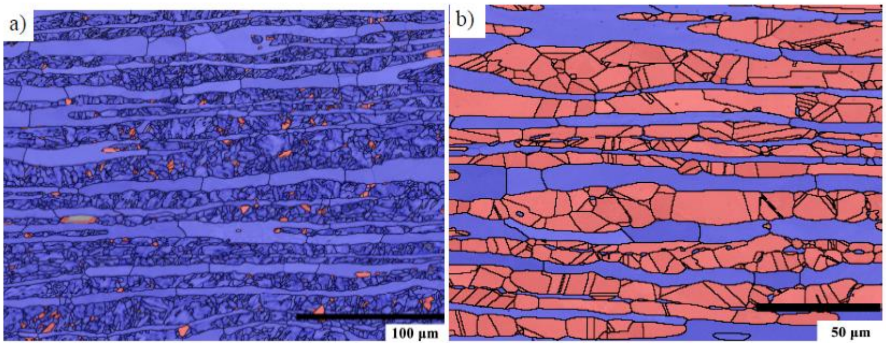

Fig6. EBSD phase map of a) mechanically polished sample and b) electropolished sample (blue=bcc, red=fcc)[9].

Applied Studies

Rodelas et al[10]. have compared welds done in 304L. Welds that have been mechanical grinded and welds that have been grinded and electropoished[10]. As seen in Jutti et al[9]. there will appear Martensitic and Ferritic phases on the surface after mechanical grinding and polishing of the welds, figure 7.

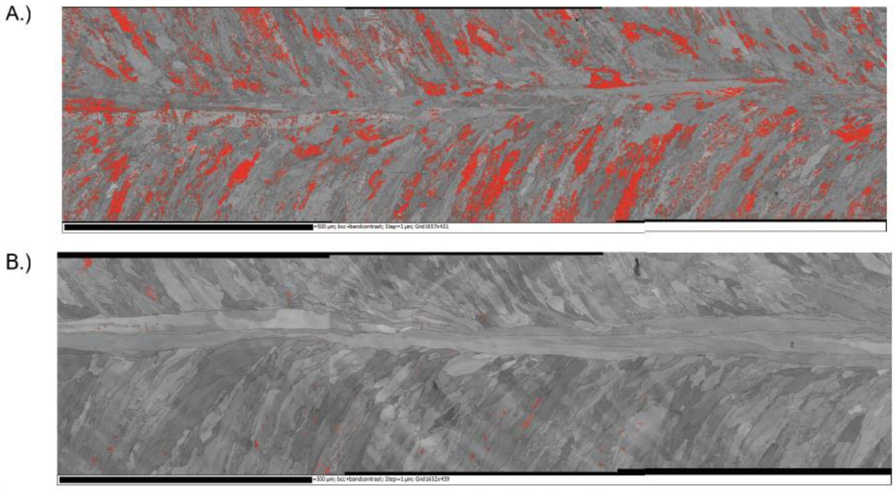

Fig7. Band contrast map of plan view section of weld metal. Red pixels denot phase indexed 'bcc' ferrite for A.) mechanically polished and B.) electropolished material[10]

Rouge can form in high-purity water biopharma systems and is an industry concern. Raney et al[11]. shows in three different industrial cases where rouge has appeared. All three systems where made of 316L and in all three cases the rouging disappeared after electropolishing and had not returned after 12 months of service[11].

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