



Plastic deformation and corrosion in austenitic stainless steel: A novel approach through microtexture and infrared spectroscopy



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ABSTRACT

The anodic potentiodynamic polarization behaviors of austenitic stainless steels, with varying Cu (copper) and/or Mo (molybdenum) additions, were explored after plane strain compression. Though all the alloys showed developments in deformed microstructures, the presence of Cu + Mo did not result in strain induced martensite formation (SIMF). However, the presence of Cu + Mo revealed the highest degradation in corrosion performance. A combination of microtexture measurements and fourier transform infrared spectroscopy (FTIR)-imaging revealed that the presence of SIMF promoted post-passivation stability or retention of a protective Cr₂O₃ film.

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1. Introduction

The nature and stability of surface films play a key role in determining the corrosion resistance of austenitic stainless steels [1–7]. The surface films are typically metallic oxides (chromium rich) and may include hydroxides [3,8,9]. Chromium oxide formation provides passivation, while local breakdown – arising from the microstructure, inclusions or from surface film defects – creates activation [1,10–13]. It is nowadays widely acknowledged that film thickness, stoichiometry, microstructure and electronic properties are of critical importance in determining the extent of passivation [14–16]. The microstructure of the metallic substrate is also critically relevant [17,18]. For example, features of the metallic substrate may affect the state of stress and the conduction properties of the film [19–21]. The formation and breakdown of the passive film are mainly controlled by ionic and electronic transport processes

[17,22–24], and dislocations in the metallic substrate may affect conductivity. However generally speaking, with the exclusion of local inclusions (such as sulphides) or Cr-depletion from so-called sensitization, the literature relating the functional substrate microstructure and the resultant nature/stability of the passive film remains limited [17,18,25–27].

Passive films upon austenitic stainless steels are typically a few nanometers in thickness [7,28–30]. This makes their quantification relatively challenging. The characterization of the passive film may involve indirect electrochemical studies: typically anodic potentiodynamic polarization [31–36], electrochemical impedance spectroscopy (EIS) and Mott-Schottky analysis [37–39]. The anodic potentiodynamic polarization test can qualitatively indicate activation/passivation behavior while Mott-Schottky analysis allows probing of the semiconductive nature of the film. Of note with respect to prior studies, Mott-Schottky analysis has been used to relate substrate microstructure, grain size and strain induced martensite formation (SIMF) with acceptor/donor defect densities in the passive film [38–40]. The study of passive films also lends itself to direct characterization. Such efforts, in the literature,

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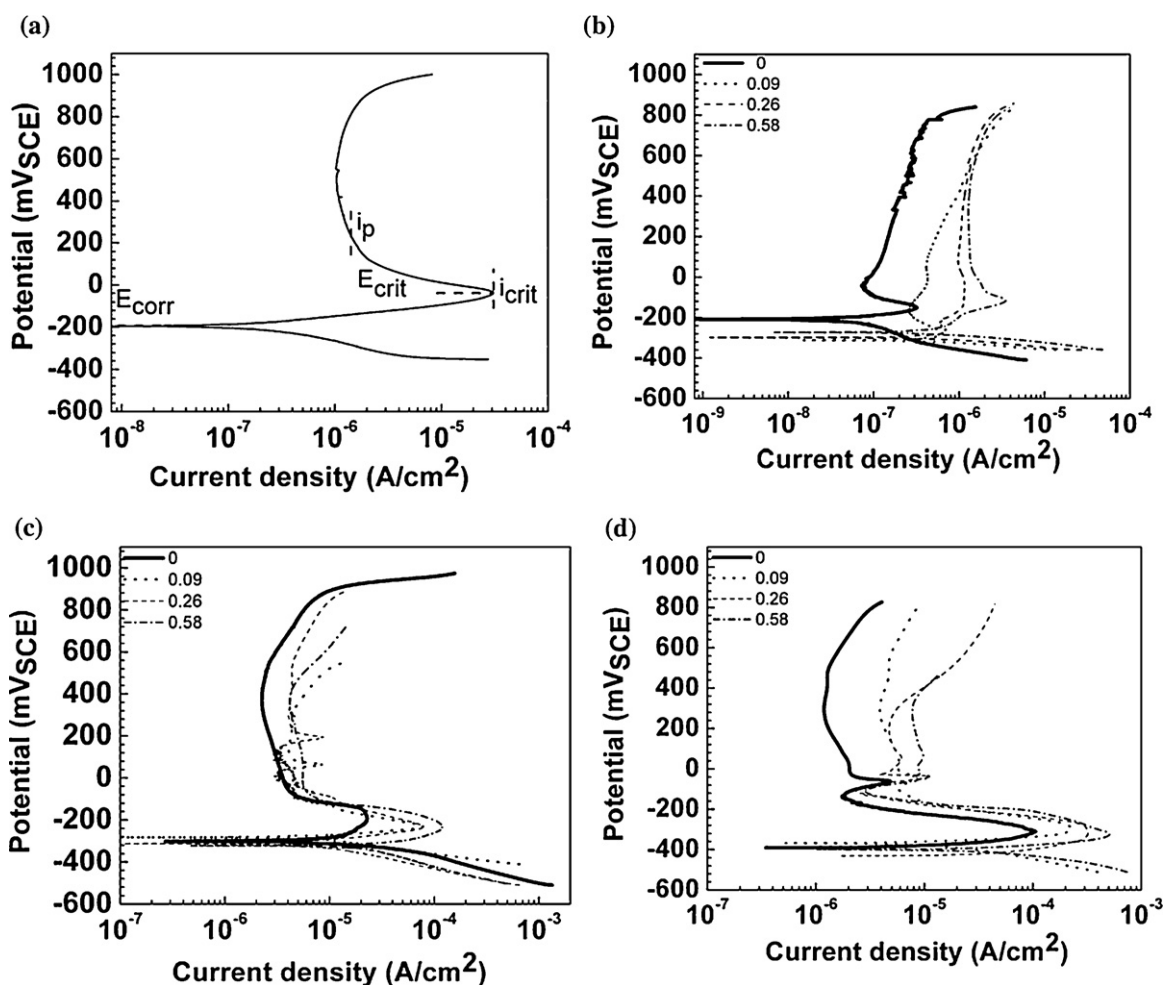


Fig. 1. (a) Schematic of anodic potentiodynamic polarization curve showing E_{corr} , i_p , i_{crit} and E_{crit} . Anodic potentiodynamic polarization curves after progressive plane strain compression (true strains of 0.09, 0.26, 0.58) in (b) alloy A, (c) 316L and (d) 304L.

involve electron spectroscopy for chemical analysis (ESCA) [41–44], auger electron spectroscopy (AES) [45–47] and secondary ion mass spectroscopy (SIMS) [48–51]. Though Raman spectroscopy has been used [52–56], there is a notable absence of the use of infrared spectroscopy. Absorption, or transmission, of the infrared spectrum can be studied as a function of wavelength in infrared spectroscopy [57]. The technique involves use of the thermal spectrum originating from vibrations and accompanying rotational absorption bands. This has been used for routine characterization of oxides [58–60], including characterization of oxide films [61,62]. However, use of infrared spectra in electrochemistry or corrosion is less common, the authors came across to only one such example [63]: relating the infrared signal to possible corrosion products. The use of infrared spectroscopy therefore is therefore a novel aspect of the present study.

Plastic deformation is a simple means for modifying microstructures in a metallic substrate. Other than changing the grain shape (and possibly the grain size), plastic deformation increases dislocation densities and may result in substructures depending on the applied strain. In austenitic stainless steels, plastic deformation is also expected to generate strain induced martensite [64–69]. Such microstructural modifications are expected to alter the electrochemical behavior [70–77], namely the nature/stability of resultant oxide films. This study aims to relate microstructural features in a stainless steel substrate with the characteristics of the attendant oxide film via a combined electron backscattered diffraction (EBSD) and post-anodic potentiodynamic polarization oxide

Table 1

The chemical composition (in wt% alloying elements) of the three austenitic stainless steel grades.

	C	S	P	Mn	Si	Cr	Ni	N	Cu	Mo
Alloy A	0.020	0.015	0.025	2.0	0.60	27.00	31.00	0	1.09	3.6
316L	0.020	0.020	0.010	1.0	0.38	16.25	10.73	0.10	0.03	2.37
304L	0.029	0.010	0.025	1.78	0.20	18.01	8.21	0.037	0.2	Trace

film quantification using Fourier transform infrared spectroscopy (FTIR)-imaging.

2. Experimental methods

Three grades of austenitic stainless steels were employed in this work. These were designated as alloys 'A', '316L' and '304L', according to Table 1. Alloy A, is marketed by Sandvik®. The alloy is sold under the trademark Sanicro™28 and has been referred to as alloy A in this manuscript. It is noted that alloy 'A' is rich in Cr, Ni, contains Cu and Mo and has no added N. The samples of all the three grades (alloy A, 316L, and 304L) were supplied in the fully recrystallized condition, and had average grain sizes of 150, 70 and 30 μm , respectively. Specimens were deformed at room temperature (25 °C). Two different types of deformation were used, (i) laboratory cold rolling to true strains of 0.26 and 0.58, and (ii) split channel plane strain compression [78–80] to true strains of 0.04 and 0.09. It is noted that

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