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# Tensile Stress Induced by Aluminum Corrosion

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# Tensile Stress Induced by Aluminum Corrosion

## **Abstract**

Stress corrosion cracking (SCC) is a critical problem affecting the safety and viability of both existing energy conversion systems and ones under consideration for future development. In SCC, chemical interactions of a metal with the environment during corrosion accelerate degradation of materials under tensile applied stress, by reducing the critical stress intensity for crack propagation. Many competing mechanisms for the effect of corrosion in SCC have been put forth, including formation of brittle oxide or hydride phases, stress concentration at corrosion pits, and absorption of hydrogen. An additional mechanism is based on observed generation of tensile stress during corrosion of SCC-susceptible alloys (1,2). Corrosion-induced tensile stress would combine with externally applied stress to assist crack initiation and growth. Tensile stress may result, for example, from the lattice contraction due to vacancies produced by corrosion. This effect has been examined in the alkaline dissolution of Al, where lattice contraction is observed accompanied by extensive H absorption (3). The contraction was attributed to vacancies stabilized by association with hydrogen. In the same system, corrosion produces large concentrations of subsurface nanoscale voids, also revealing the presence of near-surface tensile stress (4).

## **Keywords**

Chemical and Biological Engineering

## **Disciplines**

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Tensile Stress Induced by Aluminum Corrosion  
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Stress corrosion cracking (SCC) is a critical problem affecting the safety and viability of both existing energy conversion systems and ones under consideration for future development. In SCC, chemical interactions of a metal with the environment during corrosion accelerate degradation of materials under tensile applied stress, by reducing the critical stress intensity for crack propagation. Many competing mechanisms for the effect of corrosion in SCC have been put forth, including formation of brittle oxide or hydride phases, stress concentration at corrosion pits, and absorption of hydrogen. An additional mechanism is based on observed generation of tensile stress during corrosion of SCC-susceptible alloys (1,2). Corrosion-induced tensile stress would combine with externally applied stress to assist crack initiation and growth. Tensile stress may result, for example, from the lattice contraction due to vacancies produced by corrosion. This effect has been examined in the alkaline dissolution of Al, where lattice contraction is observed accompanied by extensive H absorption (3). The contraction was attributed to vacancies stabilized by association with hydrogen. In the same system, corrosion produces large concentrations of subsurface nanoscale voids, also revealing the presence of near-surface tensile stress (4).

Here we investigated stress generation during alkaline Al corrosion by in situ measurements of stress evolution. Measurements on Al thin films were carried out using the cantilever deflection method (5), and compared with experiments on Al sheets using the curvature interferometry method (6). Stress measurement was initiated after exposure of Al samples to aqueous NaOH solutions of pH from 12 to 13 (thin films) and 13 to 13.5 (sheets). The sheet samples permitted use of experimental conditions leading to more extensive corrosion than was possible in the case of thin films, i. e. higher pH solutions and longer exposure times.

Both thin film and sheet samples exhibited large increases of stress-thickness product upon exposure to solution, reaching 20 N/m in times ranging from 20 s (thin films) to 2 min (sheets). These results confirmed the corrosion-induced tensile stress hypothesized in earlier papers (3,4). The more rapid stress increases of thin films possibly indicated that grain boundary corrosion contributed to the tensile shift. The average stress in the thin films was ~ 150 MPa, much higher than the yield stress of Al. Therefore corrosion-induced surface plasticity seems possible in this system. The stress-thickness product of sheet samples increased until reaching limiting values of 45 and 90 N/m at pH 13 and 13.5, respectively. During Al dissolution bulk Cu and Fe impurities are found to enrich near the metal-oxide interface. An analysis of impurity diffusion is presented to reveal possible enhancements of diffusion due to near-surface vacancies.

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