

## Corrosion of Aluminium Alloy in White Mangrove Wood Ash Solution

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The corrosion of aluminum alloy 2S (1200) grade in white mangrove wood ash solution was investigated at ambient temperature by weight loss and potential-time studies. Surface corrosion deposit composition analyzed with Scanning Electron Micrograph (SEM) equipped with (Energy Dispersive Spectrophotometer) EDS and EECA instrumentations, revealed that the specimens were severely perforated at the edges by hydrogen and surface covered with hard but brittle corrosion deposits.

KEY WORDS: Aluminium alloy, corrosion, mangrove, wood ash, SEM, ESCA

La corrosion de l'alliage d'aluminium, 2S (1200) dans la solution du cendre du bois blanc de mangrove était suivie à la température ambiante au moyen d'études de perte de poids et du temps-potentiel. La composition du dépôt de la surface érodée était analysée en utilisant le SEM équipé d'un spectrophotomètre à énergie et des instruments ESCA. Les spécimens étaient sérieusement perforés vers les bords par l'hydrogène et les surfaces étaient couvertes par des dépôts de corrosion durs et cassants. En dessous de dépôt de corrosion, il y avait de nombreux trous sur toute la surface des spécimens soumis aux tests.

MOTS CLES: alliage d'aluminium, corrosion, mangrove, cendre du bois blanc, SEM, ESCA

### Introduction

The use of white mangrove *Avicennia africana* wood ash solution, locally called 'Odoro' in the South Western part of Nigeria, in cooking of food such as yam, plantain and beans is a long tradition. The solution gives added taste to the food and aids in softening and accelerating the cooking time, and was extensively used to make cooking salt during the Second World War in the riverine areas of Southern Nigeria. Recently, the chemical composition of this versatile solution was characterized (Loto and Akankun, 1989), showing the predominant corrosion reacting species to be  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ . The aggression of chloride ions ( $\text{Cl}^-$ ), in particular, towards the active corrosion of aluminum alloys and ferrous metals like steels has been widely reported (Loto and Cottis, 1988; Loto and Cottis, 1989; Olefjord *et al.*, 1985).

In an attempt to modernize and commercialize this product, attention is being focused towards a suitable and economic material that could be used for both the production and storage. Since the aluminum alloy is the alloy used in about 70% of cooking pots, kettle and aluminum storage facilities in the country, it was chosen for investigation. Corrosion resistance

behavior of the aluminum alloy - 2S(1200) grade in the white mangrove wood ash solution was studied.

### Materials and Methods

#### Preparation of Specimens

The aluminum alloy - 2S(1200) grade; flat, 2.5mm thick) was cut into square test specimens of 15mm long and 225mm wide. The aluminum alloy obtained from an Aluminum of company in Nigeria has an average nominal chemical composition of 0.60% Fe, 0.30% Si, 0.05% Mn and the rest Al. Some of the test specimens were ultrasonically degreased in acetones and mounted in araldite resin after spot welding to flexible wire connections at one end. They were then ground using abrasive papers ranging from 240-600 grit and polished with 1.0  $\mu\text{m}$  diamond paste, washed in distilled water, rinsed in alcohol, dried and stored in a desiccator. The weight loss experiment specimens were similarly degreased ultrasonically in acetone, dried and stored in a desiccator for further corrosion tests.

White mangrove wood obtained from the revarine areas of South-Western part of Nigeria were cut into pieces and dried. One kg. of the wood was then ashed in a Gallenkamp oven at a temperature of 1000°C for 2 hours. The obtained ash (1.25 wt %) was dissolved in 1 litre distilled water by boiling in a flask for 30 minutes. The solution was filtered and stored in bottle for further use. Prior to this, the chemical composition of the solution was analyzed (Loto and Fakanukun, 1989) according to the analytical procedures adopted from the 'Standard methods for the examination of water and waste water (Anonymous, 1971).'

#### Weight Loss

Weighed aluminum alloy test pieces were immersed totally in mangrove wood ash solution for 14 days at ambient temperature. They were taken out every 2 days, washed with distilled water, rinsed with methanol, air dried and re-weighed and plots of weight loss made.

#### Potential Measurements

Three different mounted specimens were tested for potential measurements by immersing them in ash solution in a corrosion cell. The potential was recorded at 24 hour (1 day) intervals using a digital voltmeter and saturated calomel electrode.

#### Scanning Electron Microscopy (SEM) and Electron Spectroscopy for Chemical Analysis (ESCA)

Scanning electron micrograph (SEM) of the specimen's corroded surface was made before immersion into the test medium, and micrographs made (Figures 3-7). The surface composition of the corrosion deposits on the test specimens was also analyzed with the SEM equipped with Energy Dispersive Spectrophotometer (EDS). Further examination of the surface corrosion deposits was carried out by the ESCA (Electron spectroscopy for Chemical Analysis).

**Table 1.** Concentrations of ions in ash (PPM)\*

Parameters	White Mangrove Wood Ash
Na	525,000
K	15,7900
Ca	7,050
Mg	1.0
Cl	27,900
SO	9,914
PO	500
NO	25
Total Solid	97.08
pH	22.4

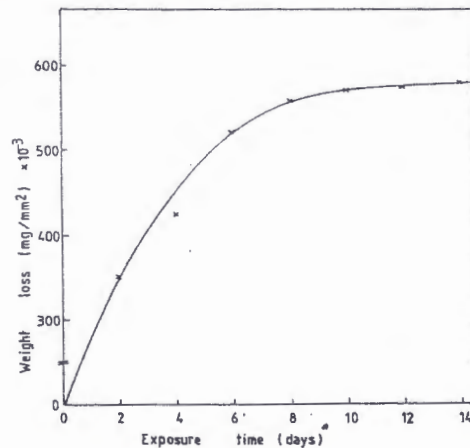
From \* (Loto, C.A. and D.A. Fakankun 1989 of Wood Science and Technology, 13 (4):351-367.)

#### The Ash Solution

Although there were  $K^+$  and  $Ca^{++}$ , the alloy had a high concentration of  $Na^+$  which accounted for its high basic (alkaline) value. The chemistry of the ash solution (Table 1) shows that it contained different captions and anions in the different concentrations. The  $Na^+$ ,  $K^+$ ,  $Ca^{++}$ ,  $Cl^-$  and  $SO_2^{--}$  in the solution, were particularly high, with  $Na^+$  and  $Cl^-$  being the highest caption and anion respectively. The pH of 11.4 obtained, indicated a strong alkaline solution, which implicated effects on the corrosive behaviour of the aluminum alloy.

#### Effect of Exposure Time on Specimen Weight Loss

Corrosion of the aluminum alloy immersed in white mangrove wood ash solution continued throughout the experimental period (Figure 1). The severe perforations observed at the side (edges) were due to the intensive hydrogen bubbles evolving from the areas. This decreased with time and almost ceased by the 14th day. Whitish corrosion deposit at the specimen's surface and some times at the bottom of the corrosion cell (beaker) were observed. In addition, macroscopic pits were also noted on the specimen's surface. The corrosion was not only compact but brittle.



**Figure 1.** Variation of exposure time with weight loss for the aluminium alloy test specimen immersed in white mangrove wood ash solution.

#### Potential Measurements

The results of the potential versus time curve for the test specimens immersed in the white mangrove wood ash solution for fourteen days are presented in Figure 2. The first day showed a little rise in potential which suggested an initial period of passivation due to the formation of a film of aluminum hydroxide which was yet to be penetrated by chloride and other ions in the solution. The potential decreased with time, from the second day till the end of the experiment, with occasional fluctuations. Passive or steady state corrosion reactions of potential with time was observed on the

5th to the 6th day, probably due to the stifling effect of corrosion reactions by the corrosion deposits.

However, corrosion deposit alone was not effective in causing total passivation of the aluminum alloy, although it was thick, compact and brittle. The cracked part of the brittle deposit allowed ingress of the corrosion reacting species including  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{PO}_4^{3-}$  and  $\text{NO}_3^-$  from the solution to corrode the specimen's surfaces. This resulted in severe pitting and evolution of hydrogen by chemical reactions.

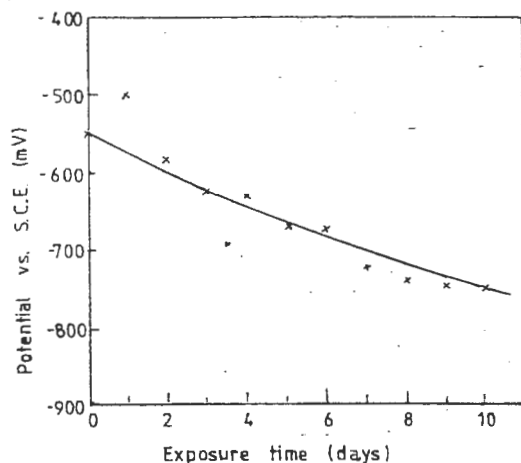


Figure 2. Variation of potential with time (in days) for the aluminium alloy specimens immersed in white mangrove wood ash solution

#### SEM Characterization

The scanning electron micrographs made before and after immersion are presented in Fig. 3-7, shows that the corrosion deposits could probably be oxide layers. Clear are the salts' crystals from the predominant sodium, potassium, calcium and magnesium. Fig 7 shows the pitting surface of the test aluminum alloy specimen, which occurred from the reacting species (e.g.  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ ) while penetrating the specimen's protective film. The evidence presented above shows a lack of corrosion resistance of the aluminum alloy in the given environment.

Further analysis of the corrosion deposit composition with the SEM equipped with EDS (Energy Dispersive Spectrophotometer) presented in Fig. 8 showed the presence of sodium, aluminum, sulphur, chloride, potassium and calcium in the deposits.

#### ESCA Spectra

It was not possible to record any spectra with AES (Auger Electron Spectroscopy) after ion etching to a depth of  $5\text{Å}$  because of the non-conductive nature of the corrosion deposit oxide layer which was charring. ESCA spectra recorded from the surface of the corroded test sample (from the corrosion deposit) confirmed the presence of aluminum, sodium, chloride, oxygen and carbon. The oxygen signal was deconvoluted into two peaks representing oxygen in

oxide ( $\text{O}^{2-}$ ) and hydroxide ( $\text{OH}^-$ ) formed on the surface of the corroded metal deposits. The surface oxide must have been more of aluminum oxide which suggested its non-conducting nature. The carbon in the spectra probably comes from carbonaceous materials present as impurities in the methanols or introduced manually during the handling of the specimen.

#### Conclusion

- The aluminum alloy 2S(1200) had no corrosion resistance in the tested white mangrove wood ash solution environment under the tested conditions.
- The chloride ions as well as sulphate, phosphate and nitrate ions (though in very low concentration), in addition to the very alkaline nature of the solution must have been responsible for the severe corrosion of the aluminum alloy in the solution.
- The corrosion form was predominantly pitting and side perforations by hydrogen.
- The compact but brittle corrosion deposit was not very protective and consists of aluminum oxide, sodium, potassium, calcium, chloride and sulphur.

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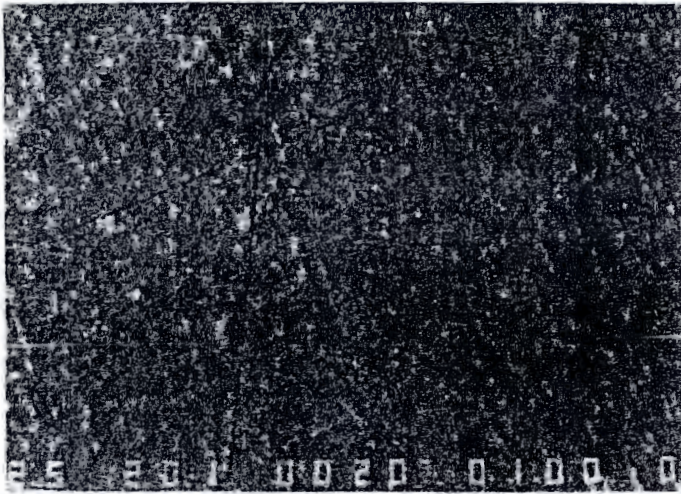


Figure 3. S.E.M. micrograph of the test aluminium alloy's surface before immersion in test environment.

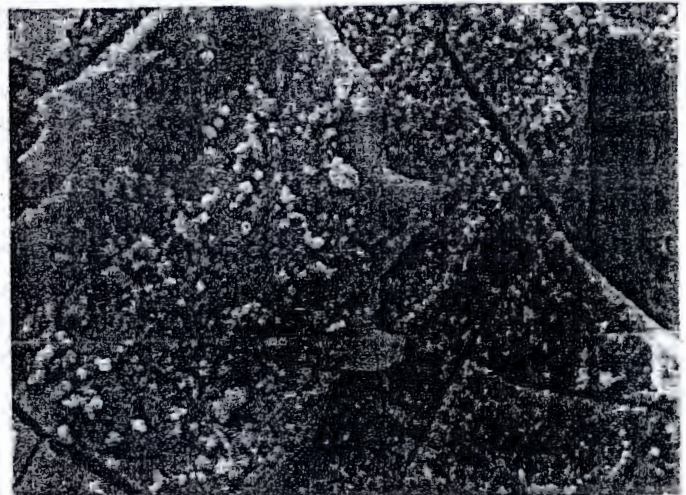


Figure 4. S.E.M. micrograph of the test aluminium alloy's surface after immersion in test environment showing hard brittle corrosion deposits and oxide layers.



Figure 5. Surface of the test aluminium alloy after immersion showing further corrosion deposits and cracked oxide layers.



Figure 6. Surface of the test aluminium alloy after immersion showing further corrosion deposits and cracked oxide layers as in Fig. 5, but at higher magnification.



Figure 7. S.E.M. micrograph of the test aluminium alloy surface after immersion showing extensive pitting of the specimen's surface located underneath the corrosion deposits.

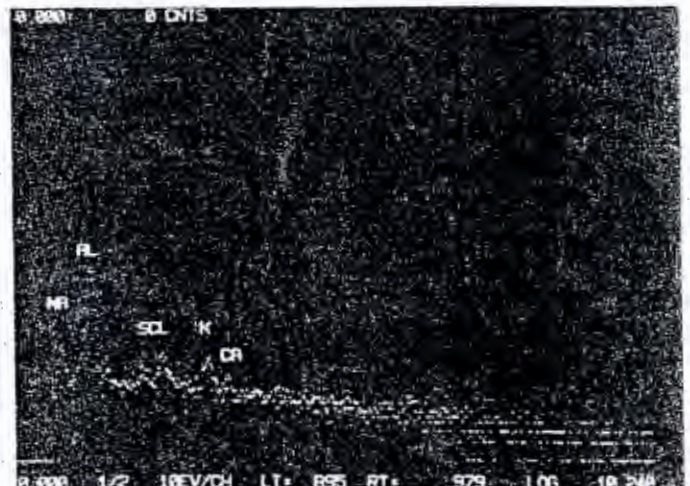


Figure 8. S.E.M./E.D.S analysis of the corrosion deposit on the test aluminium alloy surface after immersion in the mangrove wood ash solution.

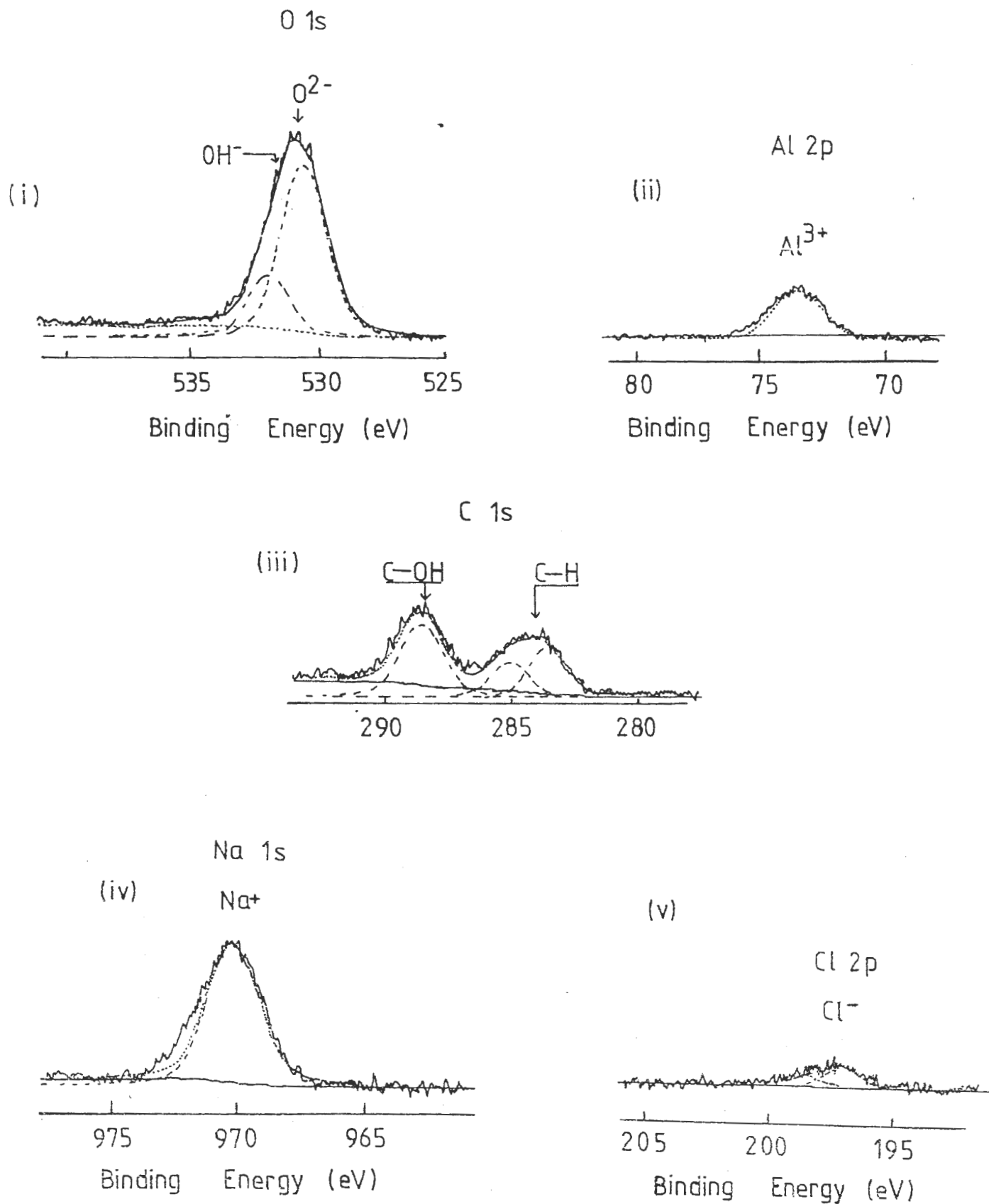


Figure 9. ESCA spectra of the corrosion deposit recorded after corrosion test from aluminium alloy test specimen exposed to white mangrove wood ash solution for 14 days at ambient temperature

