X-ray Photoelectron Spectroscopy of Carboxylic Acids as Corrosion Inhibitors of Aluminium Alloys

Jacek Ryl[1*], Joanna Wysocka[2]

[1] Advanced Materials Center, Faculty of Applied Physics and Mathematics, Gdańsk University of Technology, (11/12 Gabriela Narutowicza Street, Gdańsk, Poland)
[2] Institute of Biotechnology and Molecular Medicine (25 Kampinoska, Gdańsk, Poland)
[*] Correspondence author: jacek.ryl@pg.edu.pl

Abstract

The datasets, titled X-ray Photoelectron Spectroscopy studies of citric acid adsorption on aluminium alloy 5754 in alkaline media and X-ray Photoelectron Spectroscopy studies of various carboxylic acids adsorption on aluminium alloys in alkaline media, contain XPS studies of the corrosion inhibitory action of selected dicarboxylic acids towards commercially available aluminium alloy 5754 in alkaline media at pH=11. These datasets are part of a studies undertaken to determine the efficiency of carboxylic acids as green corrosion inhibitors. The datasets allow the analysis of raw XPS data and evaluation of the accuracy of the deconvolution models selected for this study, which is of key importance for any analytical technique based on the construction of a model to estimate experimental data.

Keywords: X-ray photoelectron spectroscopy; XPS; corrosion inhibitor; aluminium alloy; carboxylic acid

Specification table (data records)

Subject area	Electrochemistry, Corrosion Science, Materials Engineering
More specific subject area	X-ray Photoelectron Spectroscopy, Adsorption Studies
Type of data	Text

How the data was acquired	The data were measured with an Escalab 250Xi (ThermoFisher Scientific) using the Avantage 5.973 software at the Gdańsk University of Technology
Data format	The tables are in .avg and .vgd formats
Experimental factors	The data contained in the dataset were not processed
Experimental features	The XPS spectra were collected under identical conditions for each study on carboxylic acid
Data source location	MOST Wiedzy Open Research Catalog, Gdańsk University of Technology, Gdańsk, Poland
Data accessibility	The dataset is accessible and is publicly and freely available for any research or educational purposes

Background

Along with steel, aluminum alloys are the most commonly used construction materials with versatile applications, while the corrosion resistance of aluminium is determined by the presence of a so-called passive layer, a thin aluminum oxide film, which is unstable in acidic and alkaline environments. Its corrosion resistance may be enhanced by using corrosion inhibitors, but these are often expensive or toxic chemical compounds. There is impetus to investigate biodegradable and non-toxic alternatives; green corrosion inhibitors, often made of plant extracts or post-production wastes. An aluminium corrosion inhibitor's inhibitory action depends on the successful formation of the adsorbed layer, a barrier preventing the direct contact of the protected metal with the corrosive media. The adsorption mechanism and corrosion inhibition efficiency depend on the molecular structure of the chemical compound. The undertaken study aims to reveal the alteration of influence of the corrosion inhibitor based on the amount of carboxyl and hydroxyl functional groups within the molecule and the presence of an amine functional group. The studied carboxylic acids are citric, succinic, malic, maleic, tartaric, tricarballylic, and serine.

The datasets discussed within this data descriptor reveal the surface chemistry analysis with XPS of the adsorption of selected carboxylic acids at the surface of aluminium alloy in alkaline pH, on which the inhibitory action depends. X-ray photoelectron spectroscopy (XPS) is a modern analytical method used in many leading research centres worldwide. The signal resulting from the photoelectric effect differs depending on the electron binding energy resulting from the presence of various chemical bonds or other molecular interactions, moreover, it is generated at a depth of only a few nanometers below the surface of the sample, which makes XPS ultra-surface sensitive for the determination of the chemistry of thin adsorbed layers of corrosion inhibitors. However, for a more advanced analysis, a fitting procedure, deconvolution, should be performed.

The analysis requires the construction of fitting models, often quite complex, to properly consider each type of chemical bonds present at the investigated material's surface.

The superimposition of peaks from various chemical states, surface contamination due to air exposure, or the appearance of surface ionisation spectral shift in the case of insulating materials, are only a few things that need to be considered appropriately.

Our datasets allow for free access to the raw XPS data obtained during studies on aluminium alloys' green corrosion inhibitors. It has been shared to allow us to study and evaluate the fitting model applied by us in our studies. The results of the dataset titled X-ray Photoelectron Spectroscopy studies of citric acid adsorption on aluminium alloy 5754 in alkaline media are part of the manuscript (Wysocka et al., 2017), while X-ray Photoelectron Spectroscopy studies of various carboxylic acids adsorption on aluminium alloys in alkaline media contains the XPS results presented as a part of our second manuscript in this series (Wysocka et al., 2018).

Methods

The XPS results were obtained using an Escalab 250Xi multi-spectroscope from ThermoFisher Scientific, with the Avantage 5.973 software provided by the manufacturer. The spectroscope is equipped with a monochromatic AlKα X-ray source. The surveys were carried out at a binding energy of 150 eV, while for high-resolution measurements, the binding energy did not exceed 20 eV. The charge compensation was performed through a low-energy electron, and low-energy argon ion flow using a flood gun. The detailed experimental conditions are contained within each file in the dataset.

The datasets contain the results of the survey and high-resolution XPS measurements for the aluminium alloy 5754 exposed in bicarbonate buffer (pH = 11) without and with the addition of studied carboxylic acid in different concentrations. The exposure to the corrosive media was 100 minutes for each sample.

The data in the dataset titled X-ray Photoelectron Spectroscopy studies of citric acid adsorption on aluminium alloy 5754 in alkaline media contain citric acid adsorption studies at different concentrations, characteristic to various stages of interaction identified for this group of compounds. Stage 1 – concentration insufficient for effective 3D adsorption layer formation (2 and 4.5 mM), Stage 2 was the interstage, Stage 3 – full surface coverage by the corrosion inhibitor (9 and 20 mM), Stage 4 – an excess of corrosion inhibitor (100 mM). These results are compared to aluminium alloy surface chemistry in the absence of citric acid within the electrolyte (folder file: bufor).

The data in the dataset titled X-ray Photoelectron Spectroscopy studies of various carboxylic acids adsorption on aluminium alloys in alkaline media show the follow-up studies and reveal the variable interactions of aluminium alloy with different dicarboxylic acids (succinic acid, folder file bursz; malic acid, folder file jabl; maleic acid, folder file malein; tartaric acid, folder file winowy), tricarboxylic acids (citric acid, folder file cytr; tricarballylic acid, folder file trikarb) and one amino acid (serine, folder file seryna) when dissolved in the alkaline media. These studies were carried out at two concentrations of each compound, namely 4.5 and 20 mM, which correspond to the inhibitory action of Stage 1 and Stage 3 for citric acid. Different interaction derives from the altered amount of carboxylic and hydroxylic functional groups in each studied compound.

Data quality and availability

All measurements were collected using an Escalab 250Xi spectroscope (ThermoFisher Scientific) using the Avantage 5.973 software and typical operating parameters, as described within each experimental file. The dataset may be opened with Avantage or any other processing software developed for XPS analysis, such as CasaXPS, available at http://www.casaxps.com/.

References

Wysocka, J. et al. (2018) 'Carboxylic acids as efficient corrosion inhibitors of aluminium alloys in alkaline media', *Electrochimica Acta,* 289, 175–192. DOI: 10.1016/j.electacta.2018.08.070.

Wysocka, J., Krakowiak, S. and Ryl, J. (2017) 'Evaluation of citric acid corrosion inhibition efficiency and passivation kinetics for aluminium alloys in alkaline media by means of dynamic impedance monitoring', *Electrochimica Acta,* 258, 1463–1475. DOI: 10.1016/j.electacta.2017.12.017.