In-situ measurements and ex-situ characterisation on Molten Carbonate Fuel Cells: from laboratory cells to full-size stack

AnsaldoFuelCells
A Finmeccanica Company

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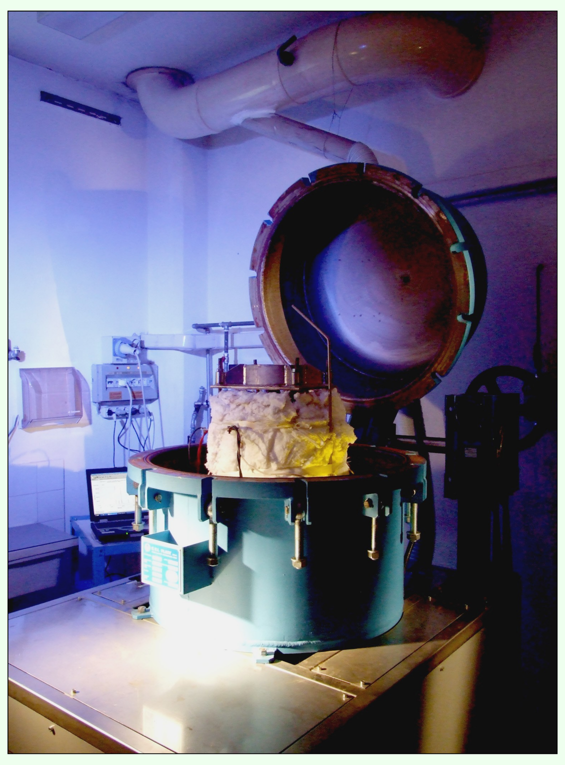
INTRODUCTION

Molten carbonate fuel cells (MCFC) are considered a new and alternative power source, promising for its low environmental emission and for its high efficiency. They convert into electricity the chemical energy of a fuel, either hydrocarbon based like natural gas or renewable like biogas or landfill gas, through a reaction with no intermediate conversion of heat into mechanical energy. For successful market-entry and competitiveness of MCFC systems cost reduction, reliability improvement, performance and endurance have to be maintained along time; so, it still needs a work of optimisation, especially aimed to extend cell life.

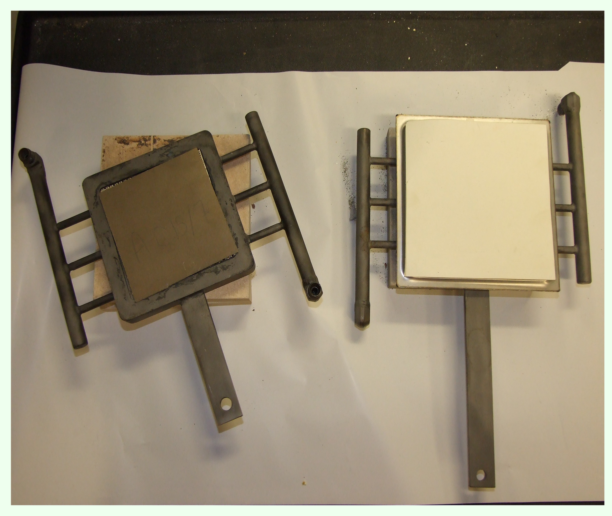
In fact, to assure good lasting performance all the components interacting in the cell have to keep their main characteristics and the required operating conditions. But the severe working conditions, that are high temperature, a quite corrosive environment produced by alkali molten carbonates and an adequate gas composition and distribution, lead to different phenomena altering the components properties and interfering in the cell performance.

Ansaldo Fuel Cells laboratories are concentrating the attention on single cell test facilities, on sub-scale laboratory stacks (tecnostacks) and stack units to study possible solutions to apply on full-size stacks.

MCFC: IN-SITU DIAGNOSTIC TECHNIQUES



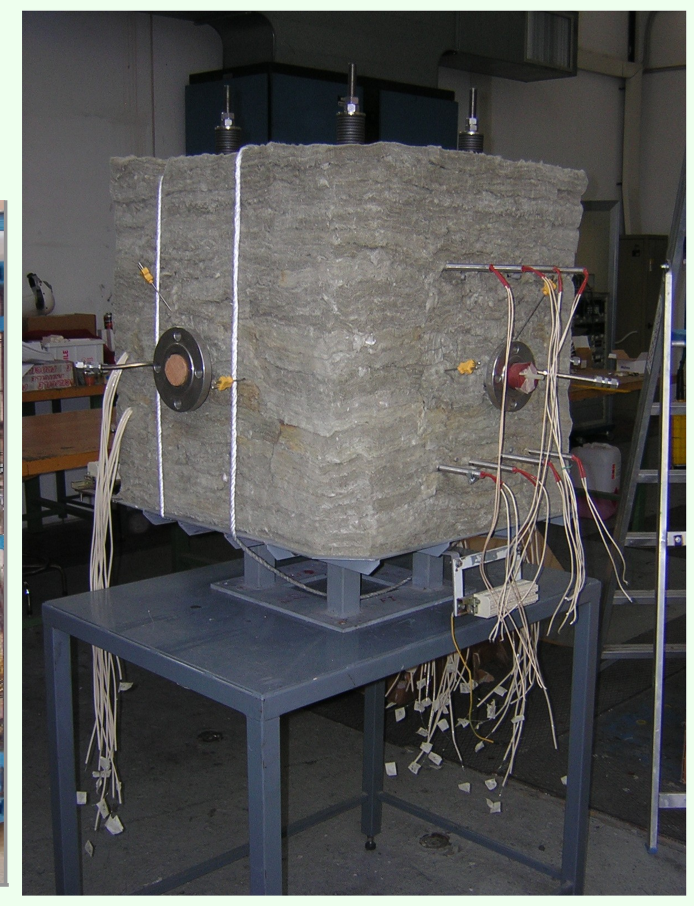
SINGLE CELL TEST



- ☺ Short time for testing
- ☺ Modest cost of realization
- ☺ High flexibility
- ☹ Different configuration respect to full size stack
- ☹ Difficult scalability to full scale stack

TECNOSTACK

- ⇨ Study of new operating procedures
- ⇨ Analysis of new cell configuration
- ⇨ Test on different materials
- ⇨ Design more similar to full size stack
- ⇨ Easier scalability to full size stack

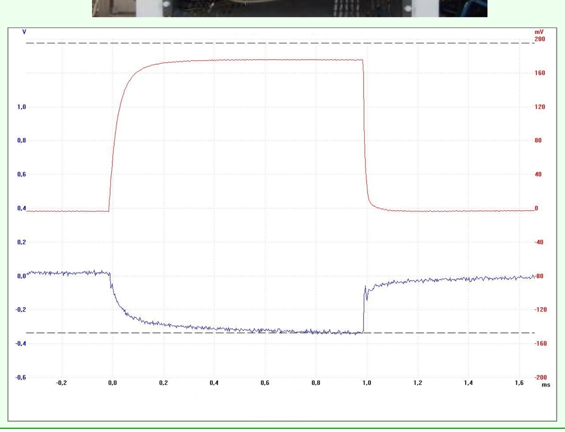


GAS ANALYSIS

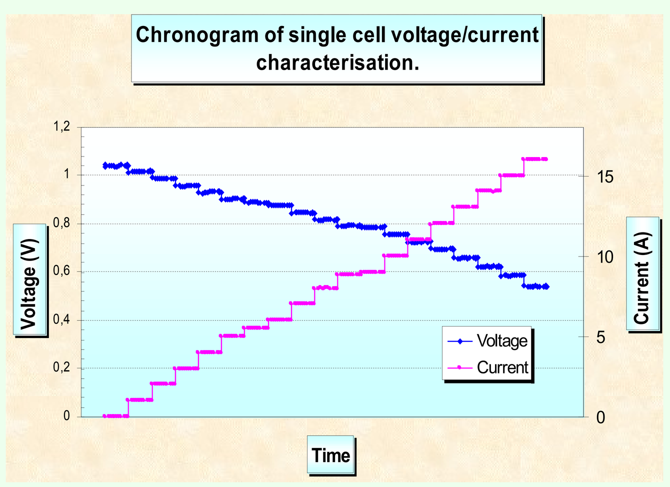
to verify the correct composition of the fuel-in and oxidant-in gas and to measure produced output gas composition, related to effective reaction rates and competing reactions.

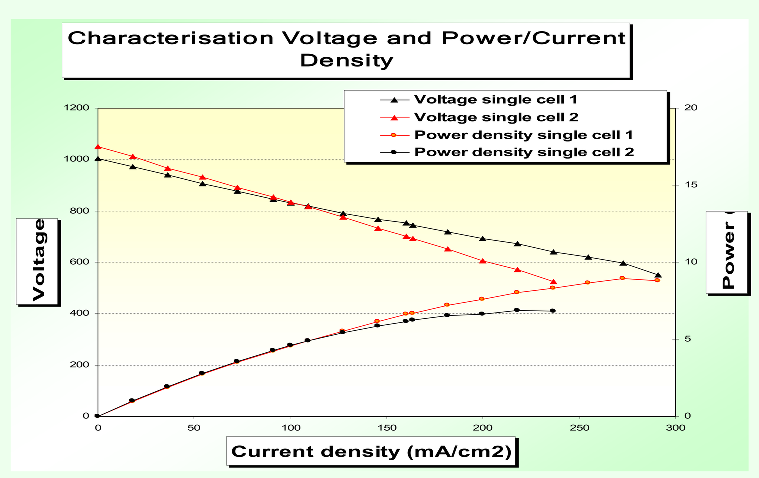
INTERNAL RESISTANCE (iR) MEASUREMENT

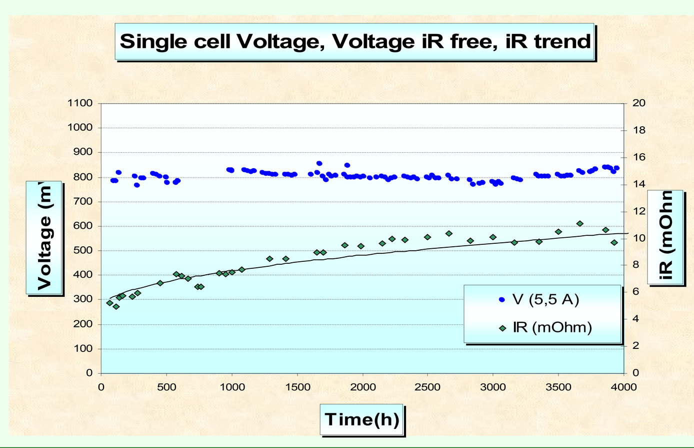
to evaluate the total ohmic resistance of a fuel cell and stack of fuel cells



CHARACTERISATION VOLTAGE/CURRENT AND POWER/CURRENT DENSITY AS AN INDEX OF PERFORMANCES

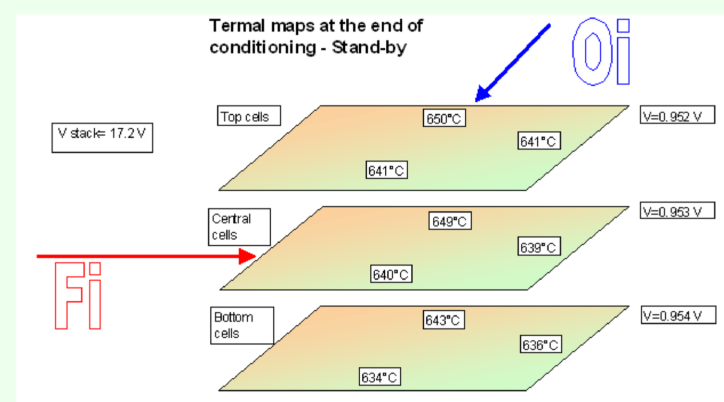






TEMPERATURE AND VOLTAGE MAPPING

Single cell voltages and local temperature inside the stack are measured to monitor local operating conditions



MCFC: EX-SITU AND POST-TEST CHARACTERISATION

Fig. 5

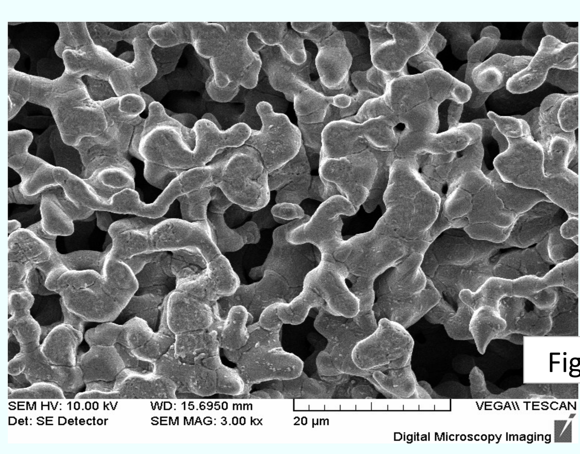
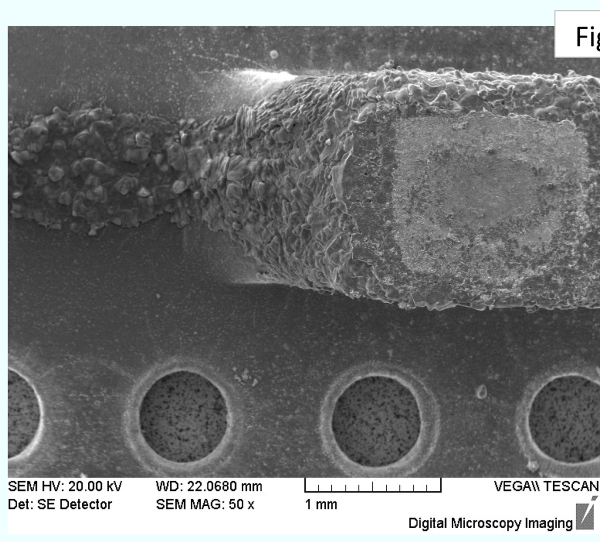


Fig. 7



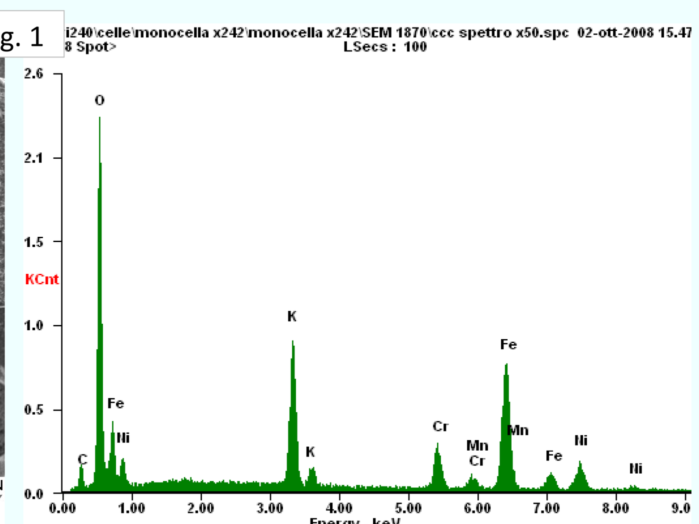


Fig. 1

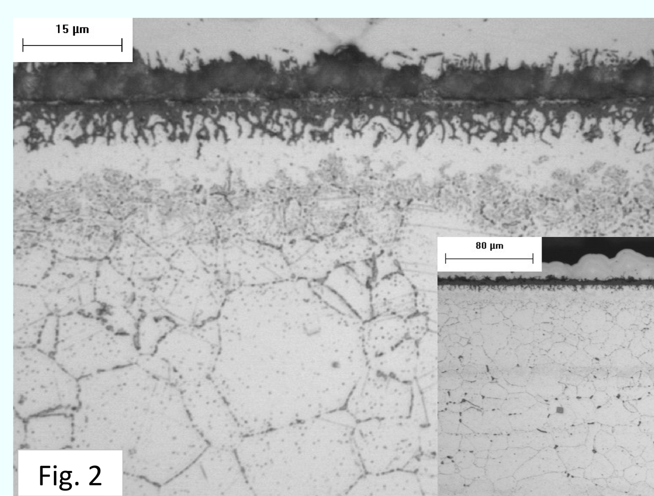


Fig. 2

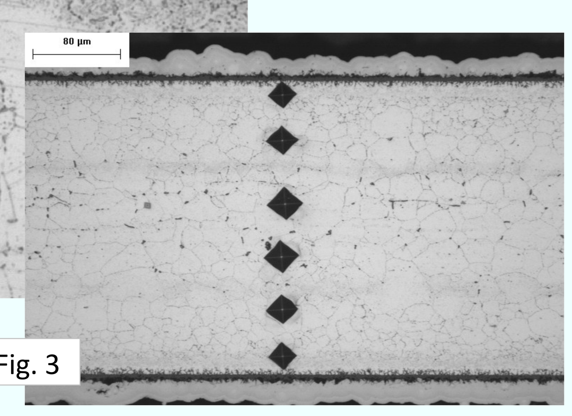
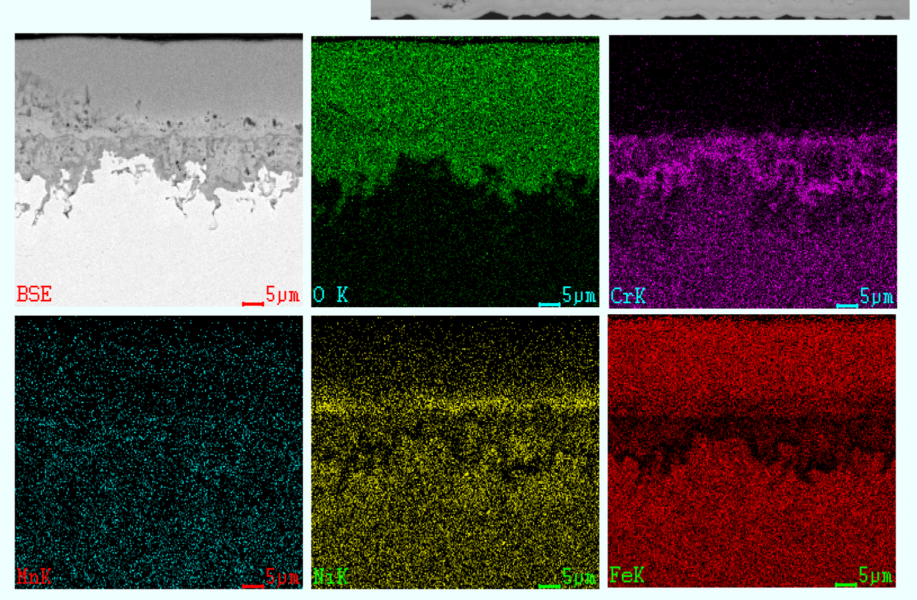
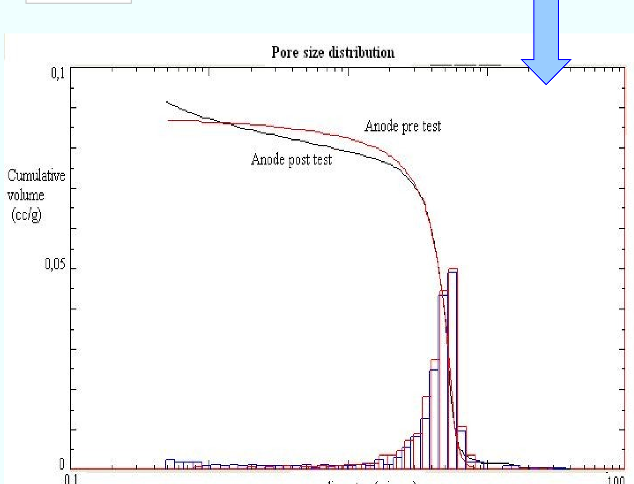


Fig. 3





After the test, the cell (single cell, tecnostack cell or full-size cell) is disassembled, verifying the expected typical features for all the components.

Complete post test analysis have to be planned for qualitative and quantitative determinations:

- Ni cathode dissolution and Ni distribution inside the matrix (Fig. 6) ;
- the electrodes structure changes by porosimetric analysis (Fig. 5) and microscopy analysis (Fig. 7)

Main parameters tested on metallic materials:

- the penetration rate of the corrosion film;
- the carburation of alloys;
- the electrical conductivity of oxide;
- the mechanical resistance of corroded alloys.

Different techniques have to be used to investigate the properties of corroded alloys in different environments:

- ➢ SEM with energy dispersive X-Ray spectrometer (EDS) and metallurgical microscope (Fig. 1 and Fig. 2);
- ➢ Vickers micro-hardness measurements through the cross section of the corroded samples (Fig. 3);
- ➢ Electrical conductivity measurements (Fig. 4)

Applied techniques

- Optical Microscope
- Scanning Electron Microscope (SEM) equipped with Energy Dispersive X-ray Spectrometer (EDS)
- Atomic Absorption
- Mercury Porosimetry (Fig. 5)

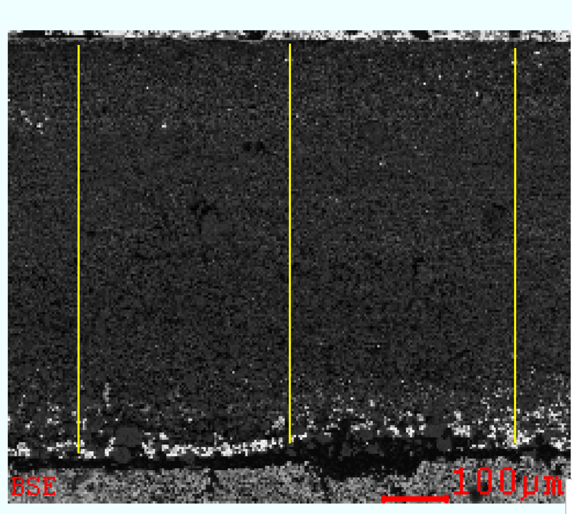
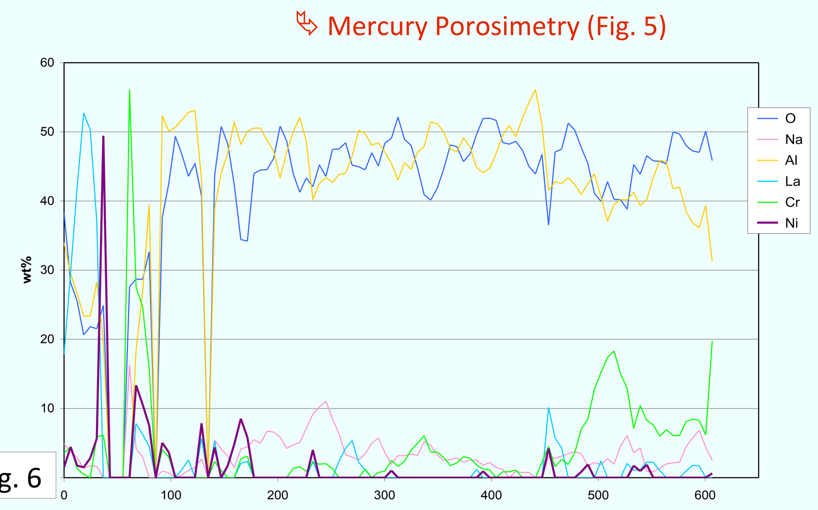


Fig. 6



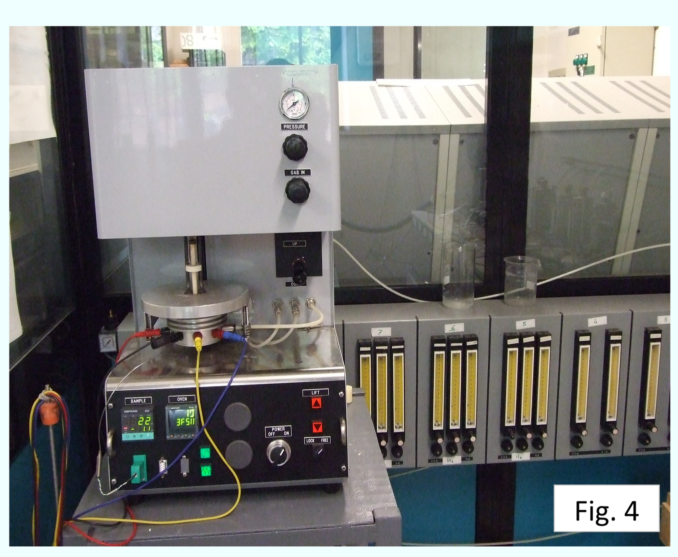


Fig. 4

CONCLUSIONS

Diagnostic tools and post-test analysis give important informations about alternative configurations or processes or new materials with the aim to improve life, reduce costs, increase performance in full-size stack, investigating the degradation phenomena.

The monitoring of cell life and performances passes by:
- V/I curve
- iR measurements
- Gas analysis

About materials, AFCo has pointed out three main phenomena:
- cathode dissolution
- matrix straightening
- metallic components corrosion