Study of the degradation of heat exchanger materials in the acidic environment of Teide National Park

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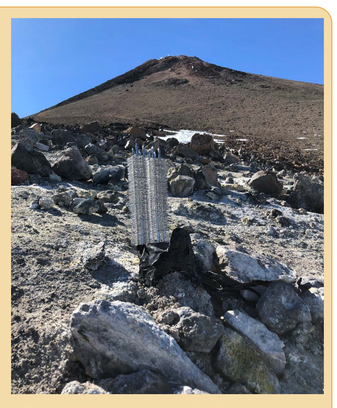
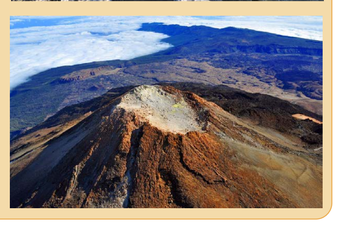
INTRODUCTION

Supplying power to **volcanic monitoring stations** constitutes a **challenge** due to both the access difficulties and the **acidic environment** associated with volcanoes. ELECTROVOLCAN project is developing **thermoelectric generators** that make use of the temperature of the available fumaroles to directly supply electricity to the stations in a robust, compact and reliable way. The main element of thermoelectric generators are the thermoelectric modules, based on Seebeck effect. Nonetheless, since the efficiency of these modules increases with the temperature difference between their sides, the introduction of **heat exchangers** becomes essential. The present study analyses the **behavior of different materials** used in the construction of the heat exchangers in the acidic environment of **Teide** National Park.





METHODOLOGY

Seven different commercial alloys have been tested (Copper, Brass, galvanized steel, anodized Aluminium, Pure Titanium, AISI 304 and AISI 316L stainless steel) in two corrosion tests:

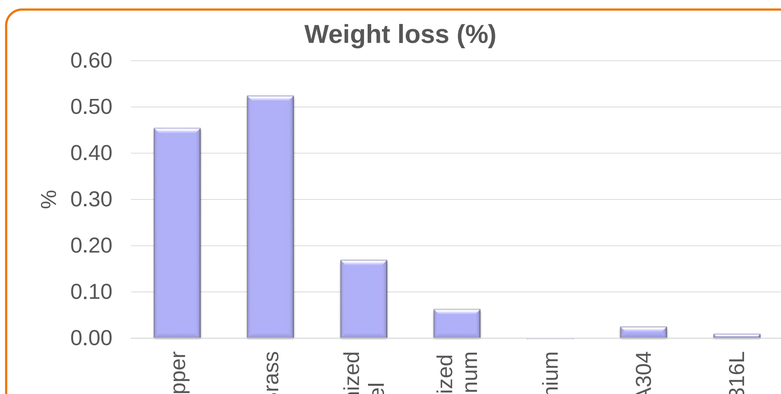
KESTERNICH

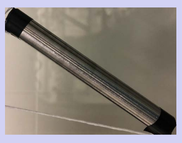
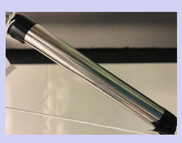
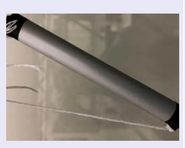
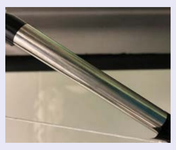
- **0.2 L SO_2(g) and 100% humidity, 10 cycles.**
- After Kesternich test, weight loss, MO, SEM and XRD analyses have been performed.

FIELD

- **In Teide volcano since December 2018**
- Photographs have been taken periodically.

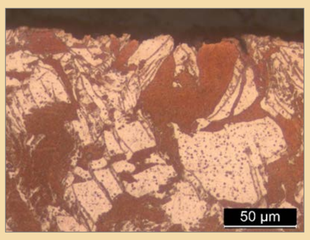
KESTERNICH TEST



	Copper	Brass	Galvanized steel	Anodized aluminium	Titanium	AISI 304	AISI 316
5 cycles							
10 cycles							

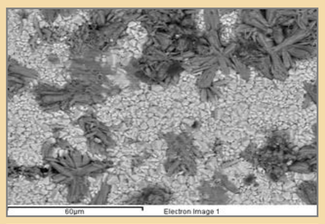
COPPER

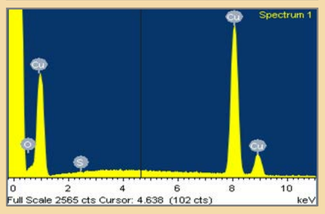
Optical microscopy

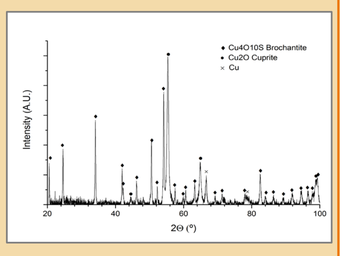


General and **pitting corrosion** is detected

Characterization of Corrosion products



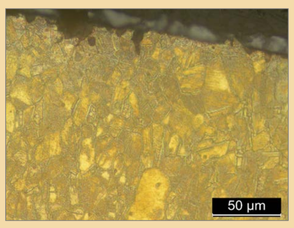




Highest peaks correspond to **brochantite** ($Cu_4O_{10}S$) and **cuprite** (Cu_2O)

BRASS

Optical microscopy



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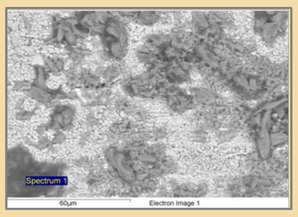
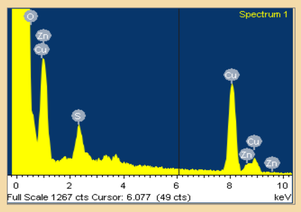
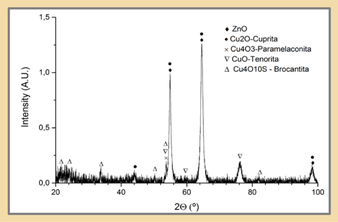






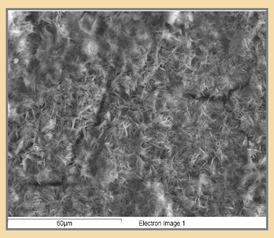
Cuprite (Cu_2O) and **ZnO** correspond with the highest peak intensities **Brochantite** ($Cu_4O_{10}S$) is also identified with several peaks.

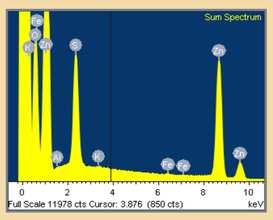
GALVANIZED STEEL

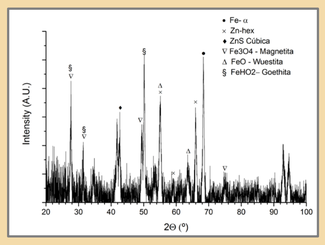
Optical microscopy

Thickness decrease of Zn layer

Characterization of Corrosion products



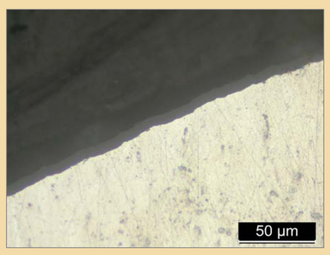




Sulfides (ZnS) were identified. Iron oxides were formed - **magnetite** (Fe_3O_4) and **wustite** (FeO) were detected

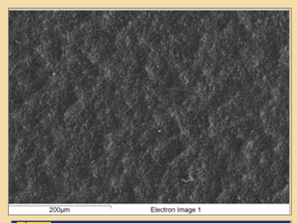
ANODIZED ALUMINUM

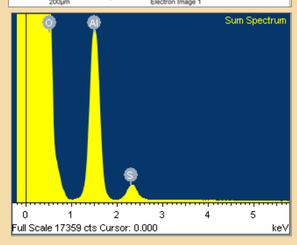
Optical microscopy

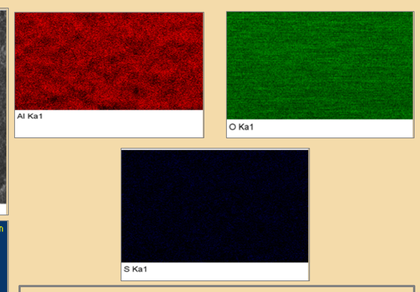


No signs of corrosion

Characterization of Corrosion products

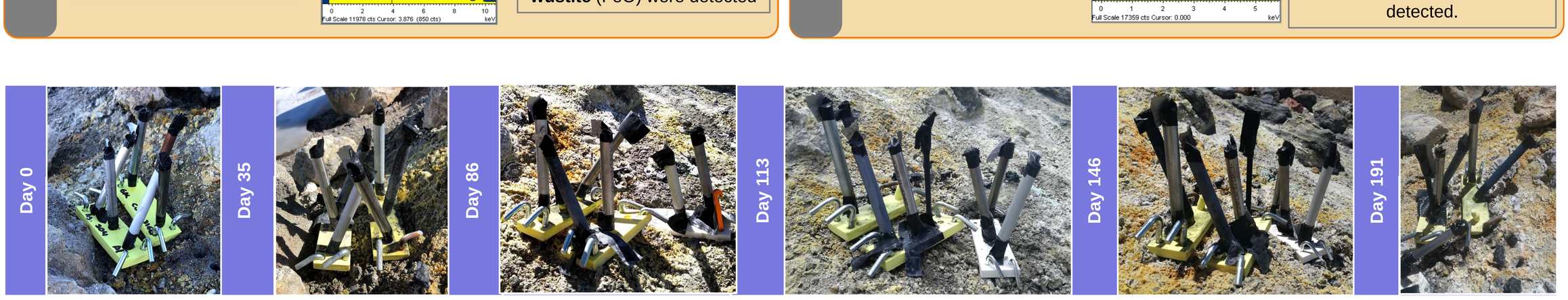






Aluminium and oxygen were the two main elements identified. A small peak of sulphur is detected.

FIELD TESTS



CONCLUSIONS

- **Brass, copper and galvanized steel** are the most affected materials, both at Kesternich and field tests (Teide National Park).
- **Cuprite and brochantite** were identified in XRD analysis in cupper and brass, whereas in galvanized steel **sulphides (ZnS)** and **iron oxides (FeO, Fe_3O_4)** were formed indicating the corrosion of steel base.
- Considering other features, titanium is expensive and aluminum has less density and much higher thermal conductivity than steel alloys, important properties for this application.
- With the results of this work, **anodized aluminum** seems to be the best option as structural material in heat exchangers for **thermoelectric generators** located in volcanic acidic environments.

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