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# DEVELOPMENT OF NOVEL AND COST-EFFECTIVE COATINGS FOR HIGH-ENERGY PROCESSING APPLICATIONS. APPLICATION TO KILN REFRACTORIES. H2020 FORGE PROJECT.
# ATTACK OF REFRACTORIES INSTALLED IN INDUSTRIAL ROLLER CERAMIC KILNS.

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## 1. Introduction

Energy intensive industries deal with materials deterioration caused by the extreme conditions generated by the industrial processes. The FORGE project (*), entitled “Development of novel and cost-effective coatings for high-energy processing applications”, is a research and innovative project, funded by the European Commission under the Horizon 2020 programme, that is addressing this topic by developing new compositionally complex materials.

The project is focused on developing and testing advanced coatings for the materials used in energy-intensive industries, that have to withstand harsh conditions when they are implemented at industrial facilities, such as high temperature, corrosion and erosion. The improvement in the performance of the materials will yield a longer lifespan of the equipment and higher production efficiency.

The FORGE consortium comprises 13 partners from 8 countries. It includes industrial user members from steel, cement, aluminium and ceramic industries and specialist materials, to ensure the project's focus on real-world issues, coupled with world-leading experience in the development of materials, protective coatings and their application to harsh environments.

The ceramic industry is participating in the project with the objective of testing new coatings, developed in the framework of FORGE project, to be applied in the insulating refractory bricks used in continuous roller kilns used for firing ceramic tiles, with the objective of reducing the corrosion that reduces its lifespan and cause defects in the final ceramic tiles.

## 2. EXPERIMENTAL PROCEDURE

Samples were taken from different sections of an industrial ceramic kiln to analyse the attack developed during working service (Figure 1).

Microstructural characterisation of the surface and cross-section of the refractories was carried out by SEM-EDS. The composition profiles were determined by taking three energy-dispersive X-ray (EDS) spectra of 2600x230µm at each depth and averaging the results. The surface composition was determined by EDS, in randomly selected 250x250µm areas and averaging the results.

## 3. RESULTS AND DISCUSSION

### 3.1 JM26 wall refractory operating at 1185ºC for 5 years

Figure 1. Appearance of the JM26 wall refractory operating at 1185°C for 5 years.

The depth profile was divided into five zones (Figure 2 and Figure 3). The most superficial layer exhibited a high content of $ZrO_2$, $SiO_2$, $Al_2O_3$, fluxing oxides (mainly $Na_2O$ and $K_2O$) and MgO. Zone 2 showed the highest $ZrO_2$ content and, consequently, the lowest proportion of the remaining oxides. This zone was related to the $ZrO_2$-rich protective coating, which had been applied to the refractory after installation. In zone 3, a thin $Al_2O_3$-rich layer was detected, which matched with the pinkish, highly densified region identified in the stereo micrograph (zone 3 in Figure 2). This region was made up of corundum crystals embedded in a silicoaluminous glass matrix, with a high $Na_2O$ an $K_2O$ content.

In zone 4, with lower $Al_2O_3$ and higher $SiO_2$ and alkali oxides ($Na_2O$ and $K_2O$) content, the microstructure consisted of mullite crystals embedded in abundant silicoaluminous glass matrix.

In zone 5, the porous texture (constant chlorine profile) and the composition of the refractory were similar to the original, although with a still important content of $Na_2O$ and $K_2O$, more mullite crystals than in zone 4 and a lower proportion of glass phase of similar composition.

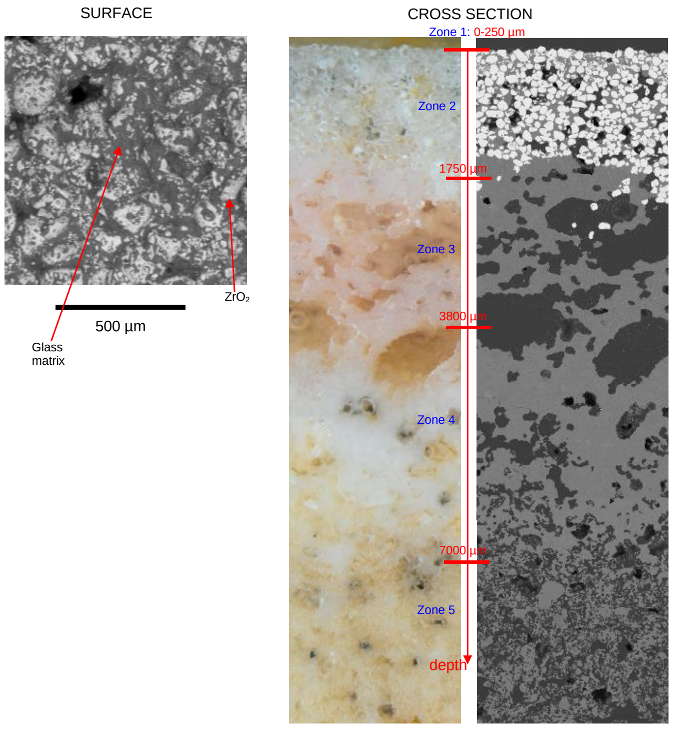

Figure 2. Surface and cross-section microstructure of the JM26 wall refractory operating at 1185ºC for 5 years.

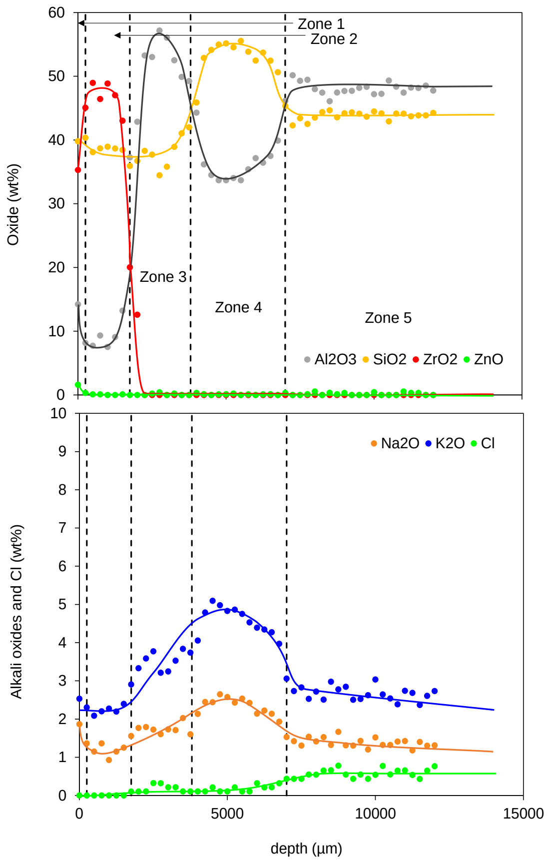

Figure 3. EDS depth profiles of the attacked JM26 wall refractory.

### 3.2 Wall refractories operating at different temperatures for 5 years.

The JM23 and JM26 wall refractories, conveniently installed in the different kiln modules according to their temperature, were studied. Some of the results are summarised in Figure 4.

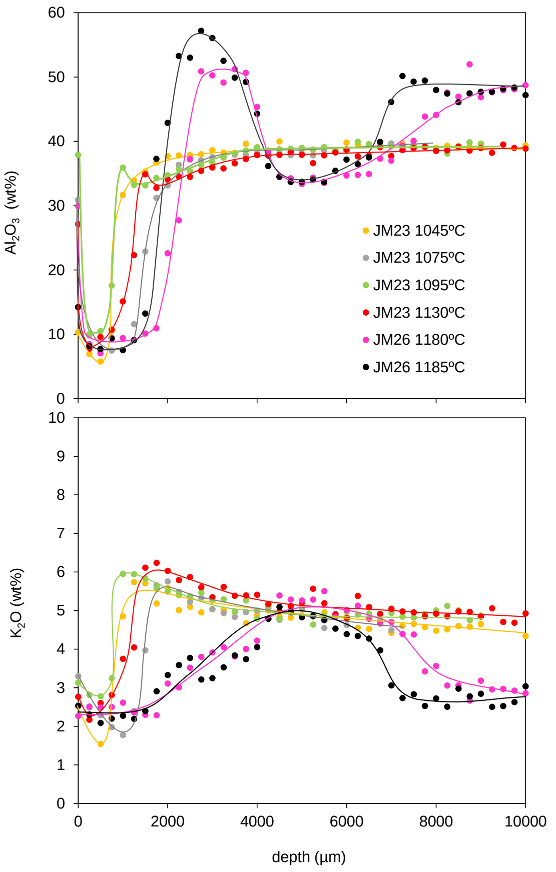

Figure 4. Variation of $Al_2O_3$ and $K_2O$ (wt%) with depth in refractories installed at the different modules for 5 years.

## 4 SUMMARY AND CONCLUSIONS

A layer of zinc and magnesium aluminate crystals containing chromophores ($Fe_2O_3$ and $Cr_2O_3$) and tin oxide is formed on the surface of the refractories installed in the low-temperature modules.

Except for the refractories installed in modules working at low temperatures (<950ºC), a $ZrO_2$-rich surface layer was observed. This material (protective coating) was applied after installation of the refractories, to reduce its attack

The refractories working at temperatures above 1100ºC showed a highly sintered pinkish zone in contact with the $ZrO_2$-rich layer. It consisted of corundum crystals embedded in a silicoaluminous glass matrix containing $Na_2O$ and $K_2O$. Its thickness and colour intensity increased with temperature.

All the refractories showed inward penetration of alkali oxides ($Na_2O$ and $K_2O$), at distances greater than 10 mm. The penetration of alkali oxides was higher in JM23 refractories than in the JM26, even though the working temperature of the latter was higher than that of the former. This is explained by their different chemical and mineralogical composition.

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