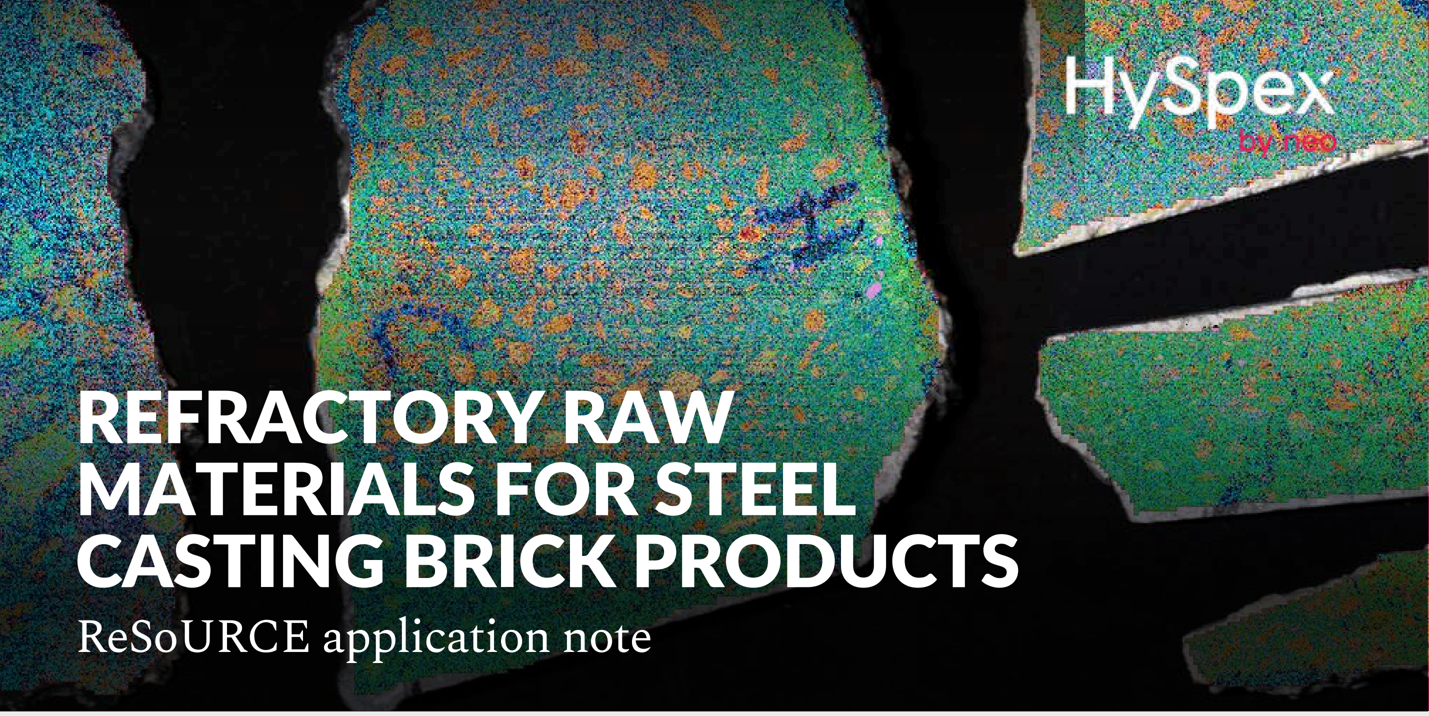

HySpex by neo

REFRACTORY RAW MATERIALS FOR STEEL CASTING BRICK PRODUCTS

ReSoURCE application note

SEPTEMBER 2024

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The EU-funded ReSoURCE project aims to increase the recovery of spent refractory bricks. The main components of these bricks include startegic raw materials such as magnesium oxide (MgO), corundum, bauxite, spinel or graphite. Innovative technologies for recycling processes such as hyperspectral imaging for automated sorting will be a key to reaching these goals.

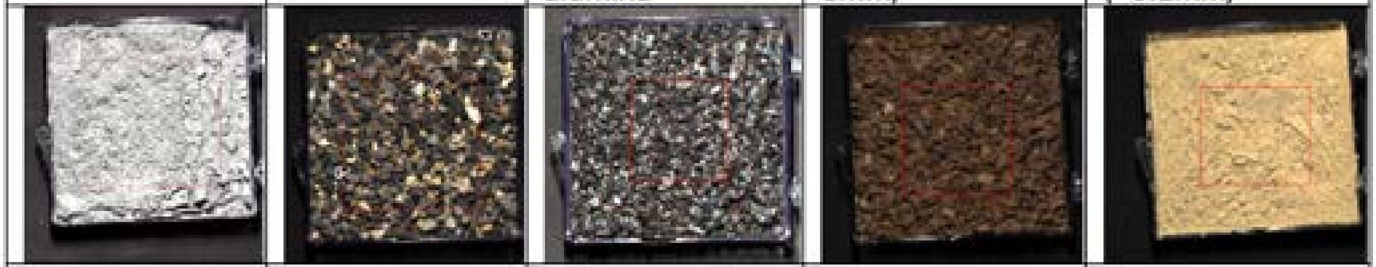
The global leader in the refractory business RHI Magnesita (RHIM) is coordinating the ReSoURCE project with the aim of evolving sensor-based automated sorting combining HySpex hyperspectral imaging cameras as well as laser-induced breakdown spectroscopy (LIBS) equipment from LSA GmbH, Fraunhofer ILT and InnoLas Laser GmbH in an optimized sorting system.

Consortium partners such as the Montanuniversität Leoben, SINTEF AS, Crowdhelix and CPI, are carrying out targeted product development, mapping possibilities outside of the refractory industry while assuring transparency with a life-cycle assessment to ensure an improvement of the entire process chain within this project.

Spent refractory bricks from steel casting ladles (SCL) and cement rotary kilns (CRK) as well as the raw materials used by RHIM have been investigated using HSI in the Hyspex lab facilities.

Table 1 shows the SCL raw material samples. The brick components white fused alumina, sintered MgO, recycled MgO-C, graphite, fused MgO, brown fused alumina, bauxite and Al-powder were scanned using a VNIR-1800 and SWIR-384 cameras from HySpex.

Al-powder	Bauxite	Brown-fused alumina	Fused-MgO (1-3mm)	Fused-MgO (<0.1mm)
Graphite	MgO-C-recycled	White fused alumina	Sintered MgO (1-3mm)	Sintered MgO (<0.1mm)



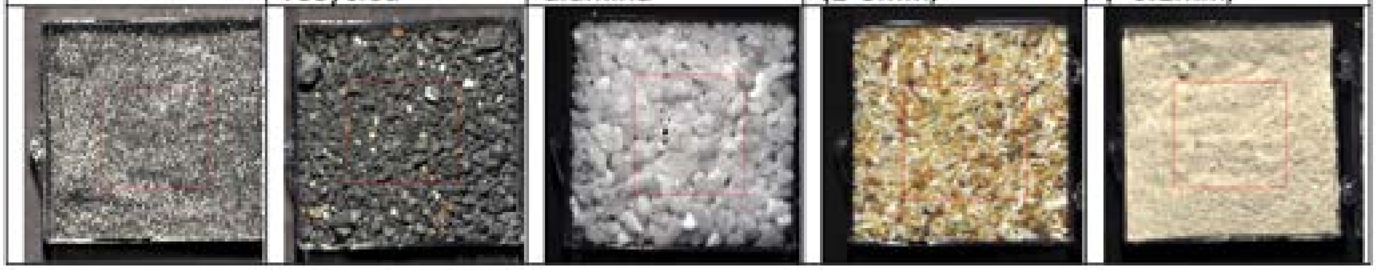


Table 1: SCL raw materials, true-color RGB based on VNIR image. Not all grain-sizes for each material is represented here.

In this application note a focus will be put on the raw materials for producing SCL bricks. Spectra for the SCL raw materials are plotted in Figure 1.

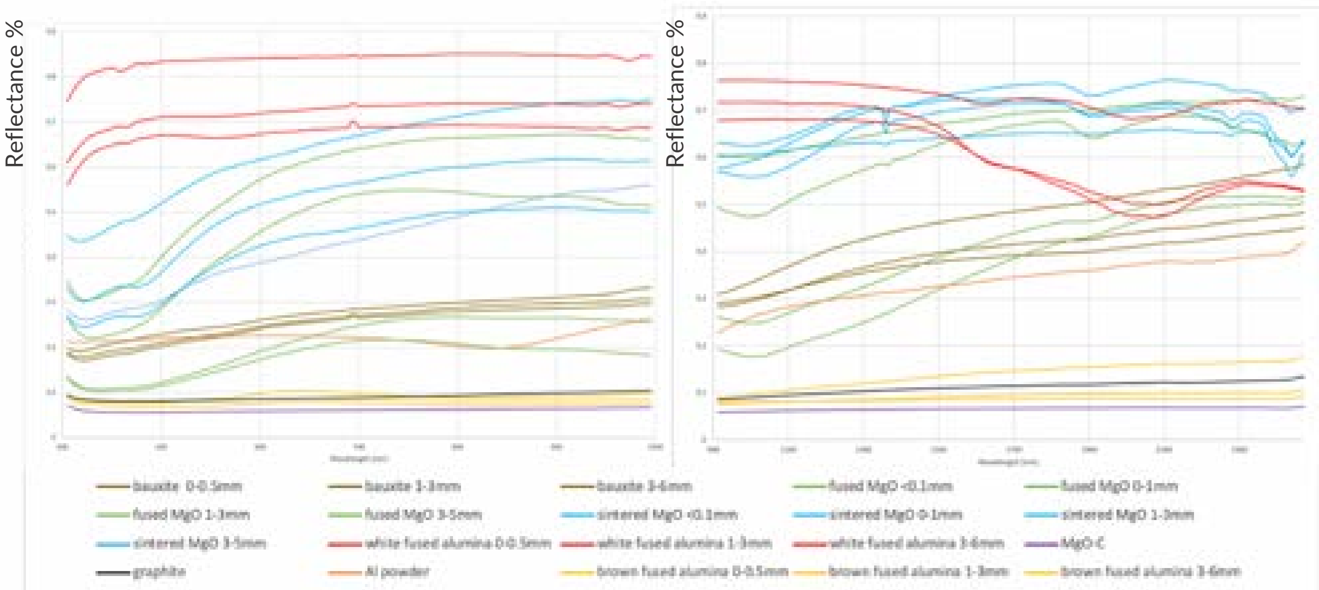
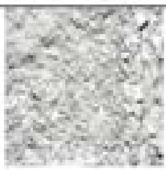
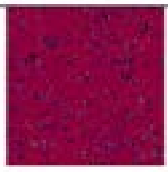
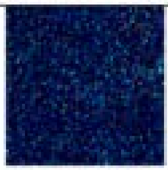
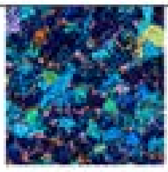
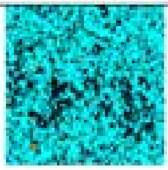
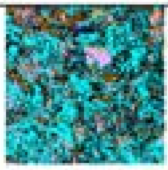
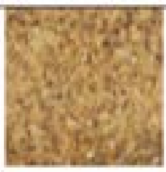
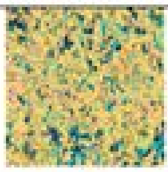


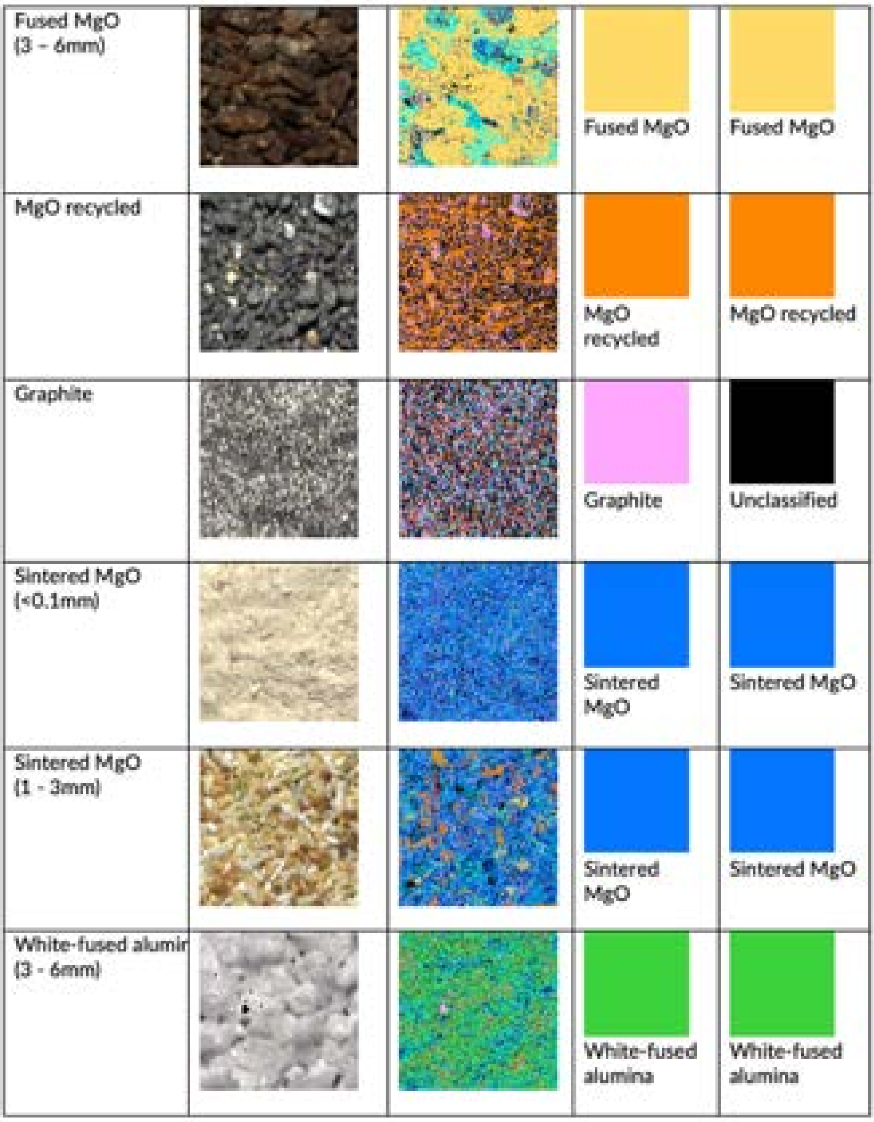
Figure 1: SCL raw material spectra in the VNIR (left) and right (SWIR). Spectra plotted in reflectance. X-axis: wavelength in nanometers, from 940 to 2500nm; Y-axis: reflectance [%] scaled from 0-1

Based on these raw materials a PLS-DA classification model was trained using Prediktera's Breeze software. The VNIR model was trained based on 9 subsamples per brick. The balanced training dataset comprises 40 samples while testing was done on 59 samples. For the VNIR training dataset the overall class was predicted with 82.5% accuracy, whereas the testing dataset was predicted at an overall accuracy of 86.4%. In the VNIR, the most challenging samples for accurate prediction are MgO-C recycled, graphite, brown fused alumina and bauxite.

A PLS-DA classification model was trained on the raw material spectra both for the VNIR and SWIR separately. In the VNIR case, both the classification based on the pixel-class majority and the object average spectrum show acceptable results. Comparing the VNIR- and SWIR-based prediction, the VNIR case seems superior for predicting the recycled MgO-C and brown fused alumina classes. For both sensors, the classification of pure graphite powder does not seem possible. An excerpt of the VNIR prediction results of the different raw materials is shown in Table 2.

Table 2: VNIR-based prediction results for some of the raw materials for SCL bricks. From left to right: the sample name and grain size, where relevant; the true-color RGB, the pixel-based classification, the class predicted based on pixel-class majority (pixel count) and the class predicted based on the object's average spectrum.

Sample	Image	Pixel-based prediction	Class prediction based on pixel-class majority	Class prediction based on average spectrum
Al-powder			Al-powder	Al- powder
Bauxite (0 - 0.5mm)			Bauxite	Bauxite
Bauxite (3 -6mm)			Bauxite	Bauxite
Brown-fused Alumina (0 – 0.5mm)			Brown-fused alumina	Brown-fused alumina
Brown-fused Alumina (3 - 6mm)			Brown-fused alumina	Unclassified
Fused MgO (0 - 1mm)			Fused MgO	Fused MgO



Based on these results, a classification model based on VNIR hyperspectral data for SCL bricks' raw materials seems possible. The model could possible be improved further by adding more samples to cover the full range of variation expected in these input materials.

Derived from this model, one of the used SCL bricks was classified showing an abundance of classified white fused alumina on the surface as well as identifying MgO-recycled and fused MgO in addition to graphite (Figure 2). Taking into account that graphite is prone to misclassification, this compares to the high value of Al2O3 found in the sample (92%) via X-Ray Fluorescence (XRF), along with the MgO content of around 5%.

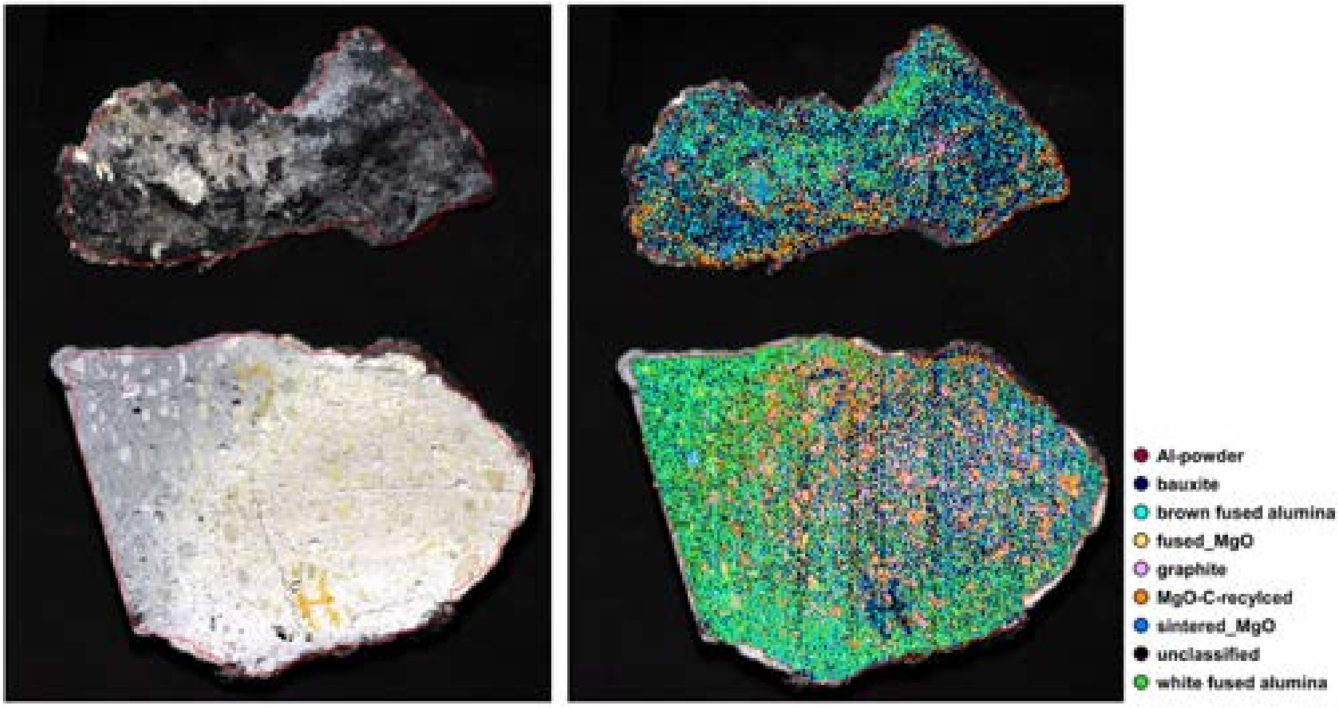


Figure 2: Used brick type 5, alumina concrete, classified on a pixel-basis using the SCL raw materials classification model.

This feasibility study is part of the Horizon-Europe funded ReSoURCE project which investigates how hyperspectral imaging can help to identify and classify refractory materials for energy-efficient recycling.

HySpex offers a varied selection of turn-key solutions for mining and raw material-related studies as well as other scientific and industrial applications. Visit www.hyspex.com or contact us at hyspex@neo.no to discuss your application and requirements with our specialists. The samples and expert input were provided by RHI Magnesita. For more information about the project see https://www.project-resource.eu/

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