A possibility for utilization of biowaste through synthesis of garnet pigments of CaO-Fe2O3-SiO2 system

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Introduction

The aim of the present work is to synthesize garnet ceramic pigments from waste raw materials and study the possibilities for their application in the silicate industry.

The present study was carried out with rice husk obtained from treatment of Krasnodarski 424 brand of rice grown in Bulgaria. The rice of this brand has 17.8 % husk. They are arc-shaped and the following dimensions: length – about 8 mm, width from 2 to 3 mm and thickness from 0.10 to 0.15 mm. The husk contains 74.5% organic matter (cellulose, hemicellulose and lignine) and water; the rest is inorganic matter consisting of 20% SiO_2 and 5.5% mixture of the following oxides: CaO, Fe_2O_3, MgO, Al_2O_3, Na_2O, K_2O, MnO_2, as well as traces of Cu and Pb. The husk oxidation was carried out at the following temperatures: 500°C, 600°C, 650°C, 700°C, 850°C, 1000°C and 1200°C. The color of the oxidized residue depends strongly on the burning temperature. Up to 500°C, the ash was almost black since the organic matter had not been burnt totally yet. At temperatures about 600-700°C, the initial rice husk sample turned into grey-white ash of varying intensity due to the presence of non-oxidized carbon in it while at higher temperature the product obtained was microcrystalline white ash with high content of SiO_2 due to full release of carbon.

Fig.1 Photos of rice husk: a) raw and b) oxidized

Two firing temperatures: 1000°C and 1100 °C with isothermal soaking of 2 hour have been chosen for the production of garnet ceramic pigments, type $3CaO.Fe_2O_3.3SiO_2$ (andradite). As a raw materials were used $CaCO_3$ and Fe_2O_3, as a sources of CaO and Fe_2O_3 of respectively, and as a source of silica rice husks oxidized at 650 0C were added.

Table 1.
Composition of oxidized ash obtained at 1000°C

Component Quantity, mass. %	
SiO_2	94,47
Fe_2O_3	1,32
K_2O	1,08
MgO	1,03
Al_2O_3	0,98
CaO	0,62
MnO_2	0,49
Na_2O	0,01
Cu	traces
Pb	traces

The analyses of the composition of rice husk ash (RHA) showed that, due to the full oxidation of the carbon organic matter at temperatures above 800°C, the solid residue was almost pure SiO_2 with small amounts of other inorganic oxides. Table 1 shows the composition of the oxidized powder.

Results & Discussion

Figure 2 shows the technological scheme for the synthesis of pigments of the garnet pigments of the $CaO-Fe_2O_3-SiO_2$ system, andradite type.

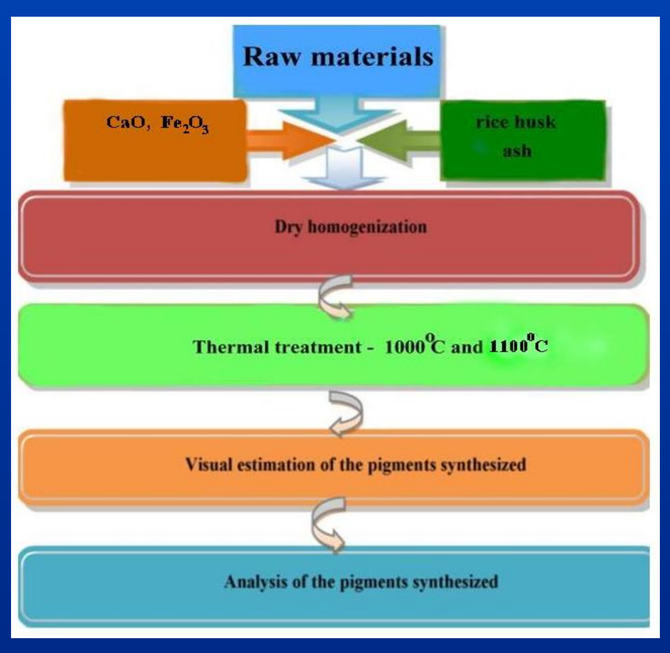

Fig. 2 Technological scheme for synthesis of garnet pigments of the CaO-Fe2O3-SiO2 system

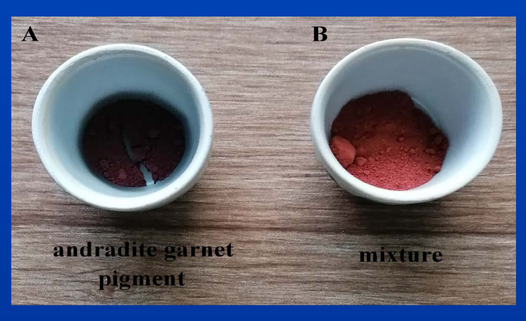

Fig.4 Photos of: A) garnet pigment, B) initial mixture

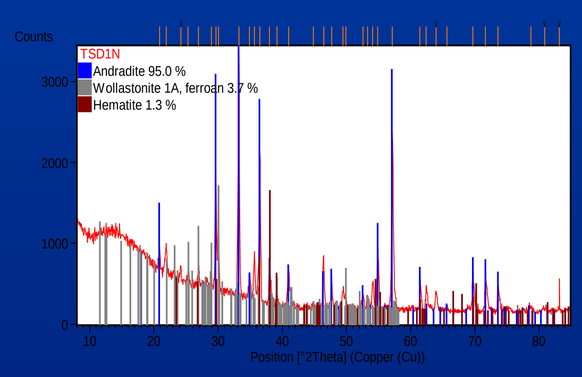

Fig.3 X-ray diffraction patterns of pigments in the system containing a main phase of andradite

Table 2. The color of the pigments was determined by using a Lovibond Tintometer RT 100 Color spectrometer

sample	colour	L	a *	b *
RH 1 / 1000°C		46,99	5,87	10,81
RH 1 / 1100°C		43,15	4,92	9,96

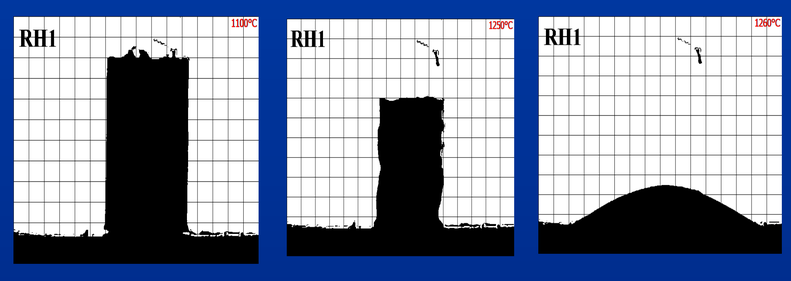

Fig. 4 Hot-stage microscopic analysis of composition RH1 at temperatures of 1100 ° C, 1250 ° C and 1260 ° C

Conclusions

The synthesis of andradite garnet pigments of $CaO-Fe_2O_3-SiO_2$ system by utilization of biowaste (rice husk) was demonstrated. The rice husk ash obtained by burning rice husk in air at 1000°C was found to contain predominantly SiO_2 (94.47 mass.%). The pigments were synthesized at a final firing temperatures of 1000 °C and 1100 °C. It was demonstrated that the best results were obtained with the pigments synthesized at 1000^0C – a* = 5.87, b* = 10.81. It was established that the garnet pigments synthesized can be used in glazes for faience tiles.

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