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A method for fast and contactless control of raw materials

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Abstract

A technique for quality control of ceramic materials is proposed based on the surface photo-charge effect. The method is demonstrated and studied in the case of controlling the chemical composition of bricks. Presented experimental results show that samples with different compositions invoke distinctly different electronic signals specific to sample's composition. In particular, it is revealed that the response signal is a function of the percentage of coal slurries added to the brick raw material for energy efficiency. The quality measurements using the proposed technique are express and contactless, and can be performed under the production conditions of brick firing. The obtained results indicate that the described technology could be extended to control the production quality of other raw materials.

Keywords: B. Impurities; D. Traditional ceramics; E. Sensors; Quality control

1. Introduction

In many industries, there is a need for constant monitoring of the chemical composition of the feedstock material from which a product is made. This is necessitated by the technological requirements for maintaining a high-quality product, and for preventing possible sabotage attempts, possibly by disgruntled employees or competitors. In our research, a technology was developed that can implement control during production. This report is focused on the mechanism to monitor the chemical composition of materials for the manufacture of ceramics and, in particular, bricks. This production has huge energy consumption. To reduce the energy consumption of the product, combustible waste materials such as coal slurries are added to the raw material. When bricks are inserted in the furnace, the coal slurries ignite and burn. This way, the bricks are self-baked and a serious environmental problem is solved since there are large quantities of coal sludge requiring specific storage measures. A constant monitoring of the quantities of combustible additives is needed; otherwise the quality of the bricks will deteriorate.

Different methods exist for control of the chemical composition of such materials. For example, X-ray diffraction and mass spectrometry were used by Andrés et al. [1] for physicochemical characterization of bricks. Laser-induced breakdown spectroscopy is an effective method for studying powdered samples, in particularly for the production of materials for bricks and tiles [2,3]. Neutron activation analysis [4] often finds its place in materials science and manufacturing technology. Alia et al. [5] have applied Fourier-transformation Raman spectroscopy and X-ray fluorescence spectrometry for quality control of clays. Belozerova [6] has examined the soil mineral component by X-ray electron probe. The X-ray diffraction, photoacoustic spectroscopy and electron paramagnetic resonance can also be used for soil characterization [7]. Dielectric permittivity measurements have also been successfully applied in studying clay minerals, granular samples and soil–water mixtures studies [8,9]. These methods exhibit certain disadvantages. They are either too slow and complicated or too expensive, being in general not suitable for continuous monitoring under production conditions.

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Our research has shown that for monitoring of the chemical composition of the material the so-called surface photo charge effect (SPCE) can be used. The essence of SPCE consists in the finding that the interaction of any solid with electromagnetic field results in occurrence of induced alternating electric signal with the same frequency as that of the incident field [10]. The SPCE represents generation of an alternating voltage when a solid interacts with a modulated electromagnetic field. The potential difference between the irradiated sample and the common ground of the system is measurable and is dependent upon many factors. The measurement of the voltage is rapid, contactless, and can be performed in-situ under production conditions with rather inexpensive equipment. The name surface photo charge effect has been kept for historical reasons.

Possible mechanisms causing SPCE are proposed and analyzed [10,11]. A detailed theoretical interpretation of the SPCE has not been developed yet. Several hypotheses, regarding the mechanism of the SPCE in various types of solids, were proposed:

- for conductors, the incident radiation, decaying in the medium depth leads to the generation of a force directed perpendicularly to the illuminated surface and redistributing the charges in the conducting medium;
- for non-conducting media, the incident radiation leads to redistribution of the charges, accumulated into surface energy states;
- the incident light redistributes dipole molecules absorbed on the surface of the dielectrics;
- photo desorption or surface sputtering induced by the incident radiation.

The above hypotheses cannot be regarded as complete or determinative. The explanation of the SPCE will probably require further investigation. It is possible to seek an explanation, within a theory dealing with field–matter interactions. The approach can involve quantum-mechanical, semi-classical and statistical considerations on the interaction of an electromagnetic field with the surface of a material, which may be a metal, a semiconductor or an insulator. Density functional theory (DFT) including external electromagnetic fields effect is one of the possible approaches considered at present as capable to offer reliable description of SPCE physical mechanisms.

2. Material and methods

The SPCE is a very fast effect: for example, an irradiation with 20 ns laser pulse results in a signal response which reproduces precisely the waveform of the incident pulse. As the experiments have shown, the arising of a signal from a solid after electromagnetic irradiation is a universal feature of solids. SPCE has been measured in the frequency range from1 Hz to 1 GHz, infrared, visible and the beginning of ultraviolet. Our hypothesis is that the effect exists in the whole frequency range of the electromagnetic radiation. SPCE can be induced only by modulated incident radiation. The lack of response upon non-modulated field is an evidence that the detected signal is induced by the SCPE. Since the electron properties of the solid are influenced by the incident electromagnetic radiation, one can expect that excited changes will provoke measurable SPCE signals. In this way, with all other conditions fixed, it is possible to detect changes in the solid properties. Experimental studies show that the sensitivity of the proposed method is high. An important feature of SPCE is its significant dependence on the specific properties of the irradiated samples. This fact reveals opportunities for a fast and contactless analysis, not only of solids, but also of liquids and gases e.g. foods [10,12].

As mentioned above, one of the features of SPCE, which is discussed in this article, is that every solid generates a specific electric signal. The amplitude and the phase of this signal depend on the chemical composition of the solid. In this study we monitor the amplitude. This means that we could quickly and without any physical contact, monitor the composition of a variety of samples. Quality control is carried out by checking whether a set of samples of interest always generate the same signal.

A schematic diagram of the experimental setup for SPCE observation we have used in our research is shown in Fig. 1. Here (L) is a source of incident radiation. The radiation was modulated by using a modulator (M). We have constructed these two details using standard modules and elements. The studied sample is placed in the measuring arrangement (S). In this particular setup the latter represents a small vessel in which two electrodes are mounted. The vessel was placed in a shielded chamber which had an optical window. For this purpose a transparent conducting film of SnO_2 was deposited on the glass plate. The film of SnO_2 was used for electromagnetic interference prevention. Mechanical device always fixes the samples in the same position to avoid errors caused by displacements. The signals measured are in the nano- and micro-volt scale and were 20 dB amplified by the preamplifier (A). The preamplifier type 233-7 manufactured by Unipan Scientific Instruments is usually used in our experiments. The detected signal had very low amplitude,

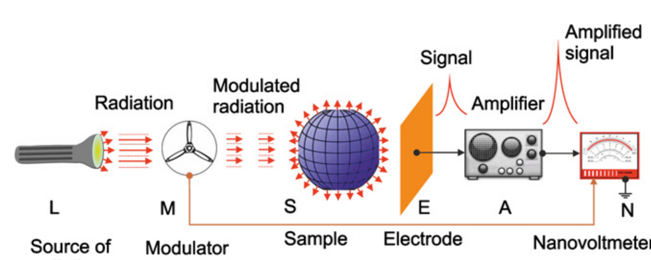

Fig. 1. Experimental setup for SPCE observation: L—source of radiation; M—opto-mechanical modulator; S—measuring structure; E—electrode; A—high impedance amplifier; N—lock-in nanovoltmeter.