Directional Reflectance of Dry and Wet Rock Samples in the Thermal Infrared Band

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Some rock samples are studied in their dry and wet conditions. Their directional reflectance is measured by means of developed experimental technique for bi-directional backscattering measurements in the Institute of Electronics - BAS. The differences of the moisture absorption ability and surface roughness of the selected limestone and anorthosite samples show a variety of correlations. These observations can be useful for the field of thermal remote sensing, when the viewing angle and atmospheric conditions must be considered to calculate the true temperature of the observed terrestrial objects and to recognize them.

Introduction

Thermal Infrared (TIR) remote sensing, which investigates objects' temperature requires certain assumption about the emissivity of the terrestrial surfaces. However, the emissivity can greatly change with the surface condition of the emitting material. The emissivity depends strongly on the surface roughness, the surface oxidized film, water content, and so on. For this reason, emissivity values in the literature usually lack information on data reliability and the measurement uncertainty is not clear for most measurement methods [1].

Some active emissivity measurement techniques are based on the energy conservation law [2] which is expressed by the equation

(1) $\alpha + \rho = 1,$

where α and ρ are correspondingly absorption and reflectance of the opaque body. This means that by measuring the reflectance ρ of an opaque surface one can evaluate its absorption α. The latter quantity equals the emissivity ε according to the Kirchoff's law, i.e.

(2) $\varepsilon = 1 - \rho$

Using this relation, we have applied an active measurement of the spectral hemispherical emissivity in ref. [4,5], where we evaluate the emissivity ε of the body by measuring the hemispherical reflectance ρ of its surface. Such approach is based on the assumption that the object has a Lambertian (diffuse, isotropic) reflecting surface. As the reflected light is collected in almost all directions excluding that of specular reflection, for the objects with strong portion of the specular reflection the results will be misleading. To overcome this problem, an experimental set up has been developed [3] that allows to measure the scattered by the surface light in all directions and to select a sample with Lambertian surface, for reliable measurement of its emissivity applying the method reported in Ref. [4,5].

As a next step of our study, we applied the bi-directional back scattering measurement technique [3] over dry and wet rock samples.

Experimental

The developed in the Institute of Electronics at the Bulgarian Academy of Sciences experimental set-up for assessment the degree of Lambertian scattering in the TIR band of 8-14µm is shown in Fig.1. It is utilized to measure the backscattered energy from the sample's surface. The surface is oriented at different zenith angles θ measured from the normal $\boldsymbol{N}$ of the surface to the incident light. Ceramic infrared source heated to 1100°C provides TIR emission and the investigated sample is illuminated by a parallel infrared light beam from the source.

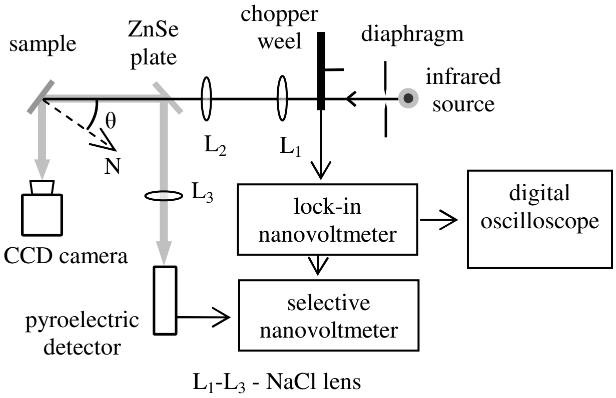

Fig.1 Scatterometer layout.

The diaphragm D is used to reduce the beam radius to 3.5mm. The lenses L2 and L3 collimate the beam, thus increasing its density. NaCl lenses are used because of their high transparency in this spectral band. An important element of the set-up is a ZnSe plate, inserted at 45° to the beam. It transmits 60% of the light beam in the forward direction, but at the same time reflects a part of the backscattered from the sample light. This light is collected and measured by a pyroelectric detector PLT222 through the lens L3.

The detector PLT 222 uses a lithium tantalate pyroelectric element. This material provides high voltage responsivity and a uniform spectral response in the (0.3-25) µm range. In order to detect the scattered energy and to enhance the signal to noise ratio, the light source radiation is amplitude modulated at 33Hz by a chopper wheel. The signal from the detector is selectively amplified at the modulation frequency, lock-in detected and recorded by a digital oscilloscope. The measured data are processed by a PC. The CCD camera allows positioning of the sample scattering spot exactly over the rotating axis and estimation of the spot dimensions.

The conventional definition of moisture content is based on the amount of water within the pore space between the grain when a soil or rock material is dried to a constant mass at a temperature between 105 and 110°C, expressed as percentage of the mass of dry soil. This loss in weight due to drying is associated with the loss of the free water.

For some rocks in addition to free water that is available, there may exist crystallized water within the structure of minerals that is released at these drying temperatures. As suggested by Fookes(1997), to identify this type of soils and rocks, comparative test should be carried out on duplicate samples taking the measurement of moisture content by drying to constant mass at between 105 and 110°C and at a temperature not exceeding 50°C until successive weighing shows no further loss of mass. The significant difference should indicate that interparticle water is present. This water exists as a part of solid particles and should be excluded from the calculation of moisture content. The releasability of this additional water varies with mineral types and in some cases results in highly significant differences in moisture content between different testing temperatures.

Results and discussion.

In this section we consider the measurements of bi-directional reflectance of two different rock samples in dry and wet condition. The first one, presented in fig.2 is a sample of limestone - sedimentary rock, taken from Rodopi Mountain, situated in South Bulgaria. The pure mass of the sample is 24.008g weighed out after drying to a constant mass in a drying oven at 80°C. By soaking till achieve a constant mass it weighs 25.262g that corresponds to 5.2% water content capability. In room condition we measured 0.67 % of free water content.

The backscattering measurements of the limestone sample show that with increasing its water content to constant level, the directional back scattered energy decreases about twice according to the room condition, but its directional reflectance doesn't change significant. We find the measured scattering distribution near the Lambertian (ideal diffusive) surface, that makes the sample appropriate for additional spectral emissivity measurement [4,5].

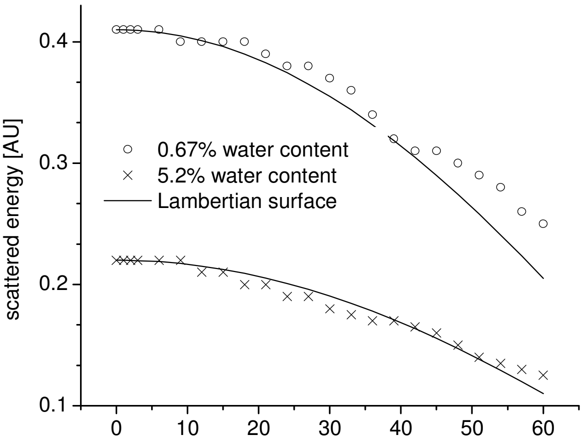

Fig.2 Limestone backscattering

A good example for a rock sample with a pronounced specular(mirror-like) reflectance is shown in Fig. 3. Anorthosite is an intrusive igneous rock characterized by a predominance of plagioclase feldspar. The sample has a smoothly sawed surface and after soaking the water makes a film on it. After measurement of the wet sample we find a big rise of the specular component.

These experimental results show that the proposed method for determination of the diffusive properties of natural surfaces can be applied for selecting samples with Lambertian surfaces for an accurate measurement of their emissivity with the method described in [4,5]. This methodology has also a potential for designing and building of practical device suitable for field applications.

This study is of importance for thermal remote sensing, where emissivity data is used to calculate the true temperature of the observed objects and to recognize them [8,9]. Also the infrared scattering ability of widely used surfaces represents great interest in heat transfer study.

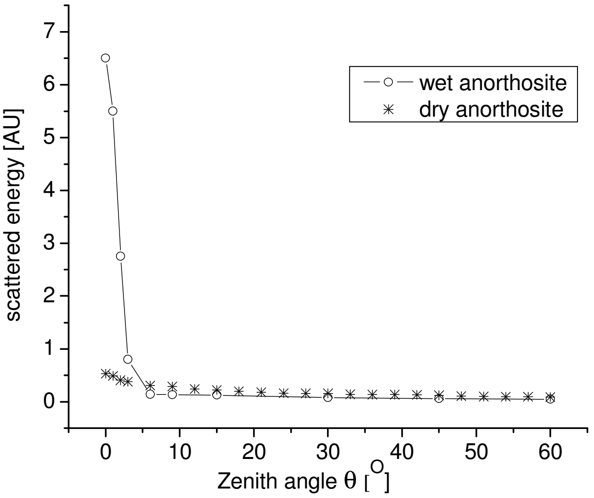

Fig.3 Anorthosite backscattering

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