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Some applications using simple low cost infrared light sources

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ABSTRACT

The present work examines the possibility to use homemade miniature infrared (IR) sources in spectroscopic applications. Simple useful IR applications were studied using IR sources made from in-expensive available materials. Different liquids absorptions of broadband IR radiation were compared. The effect of frying time on vegetable oil changing properties is one of the applications described. Olive oil adulteration with in-expensive vegetable oils such as corn oil was studied as a useful simple to perform test. Industrially, the dependence of color dyes concentration on IR absorption was also studied. These applications are discussed in view that further improvement on such experiments could lead to the construction of a portable handy useful testing system.

KEYWORDS

Miniature infrared sources;
Spectroscopic applications;
Vegetable and olive oils;
Color dyes.

INTRODUCTION

Spectroscopy is an important identification research tool in many sciences, for example in chemistry, physics, astronomy and many other related fields. The type of source used determines the nature of the spectroscopic application. Wide range of infrared sources are available and or can be constructed; when designing such sources; large spectral ranges and different working temperatures are desired to get a well-characterized and trustable source[1]. In spectroscopy experiment, absorption, emission and or scattering of electromagnetic radiation by atoms or molecules do take place[2], since the incident radiation is having different IR frequencies; some of the frequencies of the IR light passed through a sample (as an example, organic compound) are absorbed while other frequencies are transmitted through the sample. Plotting percent absorbance or percent transmittance against frequency gives the so - called IR spectrum[3]. To transform a given data from a source; a signal is taken from detector through a processing system that converts it to spectral form[4]. IR spectrum is a good method for identifications of mixture components[3] or, the concentrations of specific liquids and gases can also be measured using IR absorption[5]. Beer-Lambert law describes the un-attenuated radiation intensity given by a source as: $I = I_0\, e^{-\alpha t}$,Where I, is the un-attenuated radiation intensity, I_o is the intensity before absorption, t is the path length and α is the absorption coefficient at a particular wavelength unit. The law explains the IR gas detection based on absorption[4].

This work is intended to perform simple IR spectroscopy experiments to some applications in diverse areas using home made easy to prepare and handle IR sources. In-expensive, simplicity and short time record of the spectrum are of the many advantages usually sought[6] in spectroscopy experiments. Although, many studies are carried out with sophisticated IR sources with encouraging results[7,8]; our main concern is to run experiments with IR sources constructed from readily available materials. Miniature, IR sources were constructed from fecralloy sheet to supply pulsed mid-IR thermal radiation to be used in the open air and is based on alternating heating and self-cooling of a thin metal alloy. Details of the theory involved can be found somewhere[9]. In order to reach low warm-up and cooling time an electrically modulated black-body is used in its smaller size[10]. In This case these sources are treated as a black body radiators, with thermal emissivity $\varepsilon=1$ and thermal pulses frequency expressed as[11]: $f = (8\varepsilon\sigma T^{3}) / (c_p \rho d)$, where, σ is a constant ($\sigma=5.67\times10^{-8} Jm^{-2}K^{-4}s^{-1}$), c_p is the specific heat of the material, ρ is the metal's foil density and d is its thickness.

EXPERIMENTAL

Figure 1, Shows the complete experimental system. The IR source was powered by square wave taken from a power function generator to achieve the self-cooling process. IR detection was possible using IR pyroelectric detector having silicon window area=16.49mm^2.

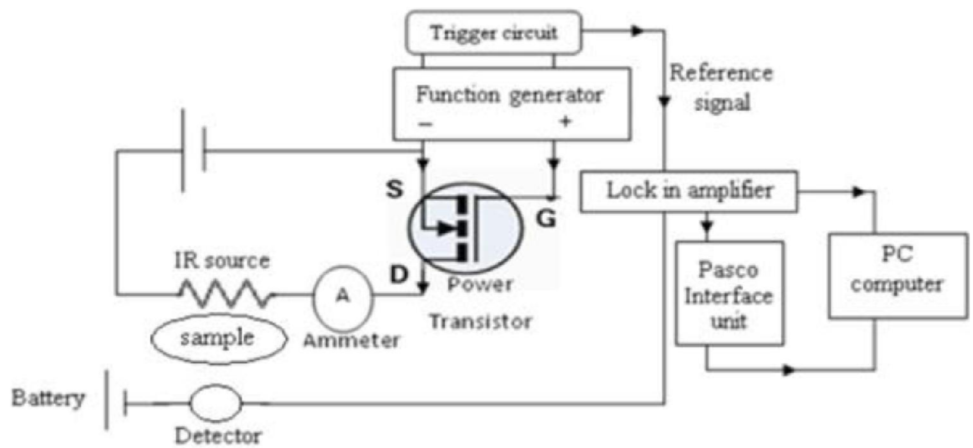

Figure 1 : Schematic showing the complete experimental set up.

Fecralloy foils, consist of Fe (72.6%), Cr (22%), Al (4.8%), Si (0.3%) and Y (0.3%), with a resistivity of 134 $\mu\Omega$cm and thermal conductivity of 11.5 $Wm^{-1} K^{-1}$[9],

IR sources

The IR sources were constructed mainly using a sheet of Fecralloy. This alloy is composed of Fe-Cr-Al steel containing "yttrium" at the following percentages: (Fe72.8/Cr22/Al 5/Y 0.1/Zr 0.1) with foil thickness 25 μm. The most versatile of the alloys that is suitable for use over wide range temperatures up to 1300°C. The "yttrium" Y can be used up to (0.3%) is the key to its longer high temperature life, having greater oxidation resistance[12]. The optimum temperature for our experiment was ~ 900 °C, or when filament is heated to dull red, the melting point of the alloy is ~1380 °C. The alloy was cut to different dimension ribbons and formed in the required shape that suits the experimental set up as shown in Figure 2.

The source in its most simple form is shown in Figure 2b, although other sophisticated shapes can be constructed according to the need Figure 2c and d.

Another useful source was constructed from readily available light bulb by just removing its glass envelope as shown in Figure 3.

Another source was constructed from Nichrome wire, it is consisted of nickel–chromium having a room temperature resistivity of 1.5×10^{-6} Ω.m, 10cm long and cross sectional area 4.2×10^{-8} m^2 has a resistance of 4.3 Ohm was used to perform an IR, 4 turns helix source,3.5 cm long, 0.25cm radius.

All types of sources were powered by a square wave delivered by a power function generator. Full details of their studied characteristics are reported in[13]. The maximum emitted power was found to be in the forward direction as shown in Figure 4.

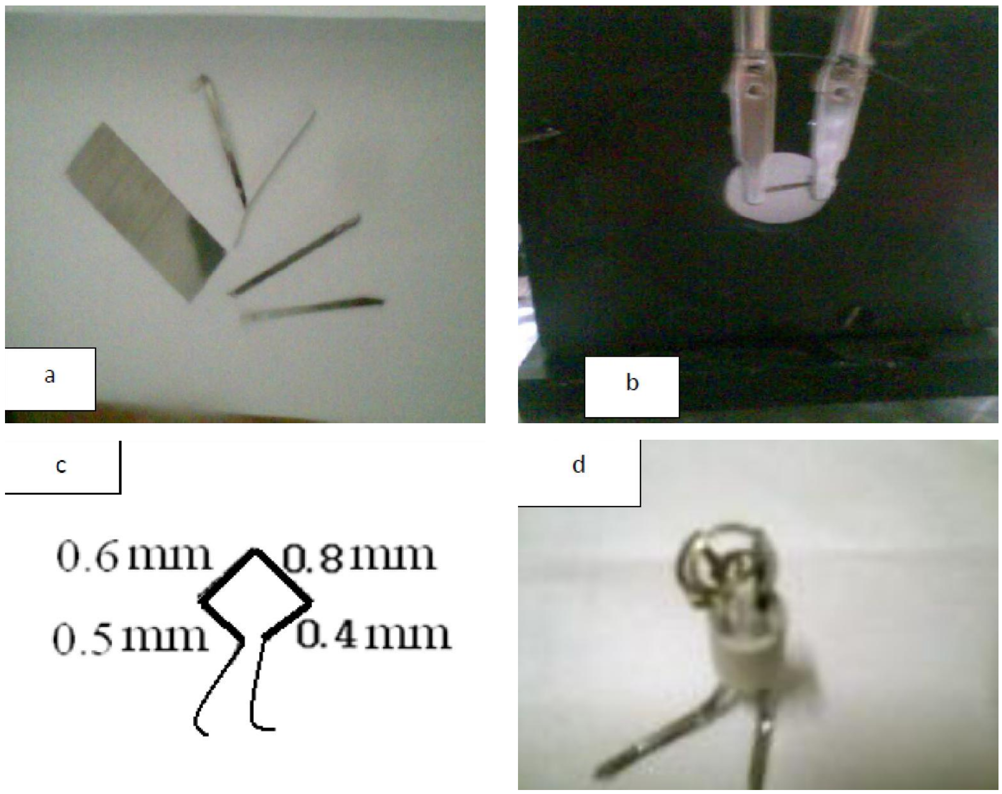

Figure 2 : a-Fecralloy sheet and the cut off IR sources elements; b- IR source element as connected into circuit; c-IR Rhombic source; d- Sophisticated IR source.

Samples

Commercial samples such as oils and dyes were bought from local shops and used. In those applications; the same sample volume was allowed to be absorbed by a piece of filter paper ($3x3cm^2$) and used as a sample carrier in front of the IR source.

EXPERIMENTAL RESULTS AND DISCUSSION

Liquid absorption of IR radiation

The same area ~20 mm^2 of the wetted filter paper was subjected to IR radiation from the IR source which was located ~10 mm from the front side of paper, the detector was initially located at 20mm from the other side, the samples are subjected to a broad band of IR radiation in the range 2-15 μm, since no IR filters were used between the sample and the source.

The transmitted infrared radiation through samples was examined; results of the characteristics curves for liquid samples: sesame seed, black cumin, Olive, oils and glycerin and water are shown in Figure 5.

Figure 3 : A miniature IR source constructed from a 2.5V lamp by removing its glass envelope.

It's found from the graph that the transmitted intensity is dependent on the type of used material. More transmitted intensity means less absorbance by the liquid, the chemical structure is the limiting factor for the absorbed and transmitted infrared radiations. For example, the sesame oil has the smallest viscosity compared to other liquids used, so it allowed radiation to be transmitted easily, i.e. larger intensity goes through.

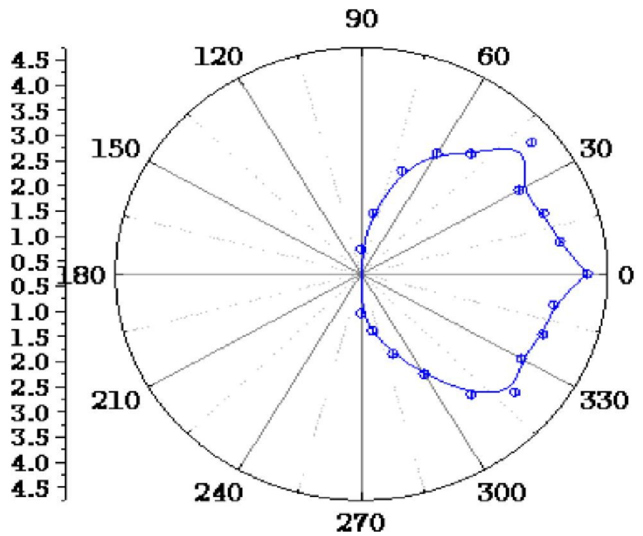

Figure 4 : Dependence of IR intensity on the angle between the vertical axis to the foil and detector.

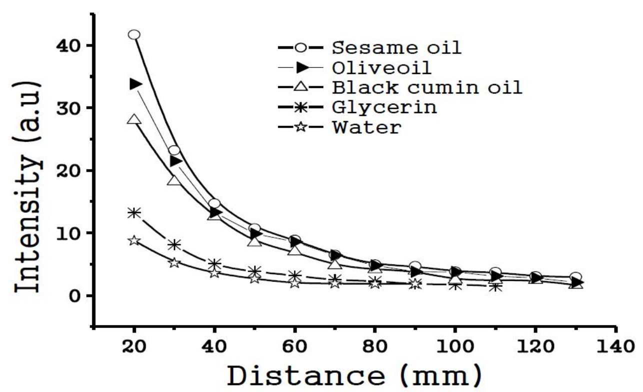

Figure 5 : Transmittance of broadband IR radiation through different liquid samples.

Black cumin oil has a larger viscosity than the sesame oil so its curve is shifted downward, the glycerin has the largest viscosity of all and this will block the infrared from going through the paper to the other side where the detector is, hence, the absorbed radiation will be large. Water's infrared absorption found to be the highest as water is easily permeated through the sample carrier fibers. Using liquids in this way will simplify the transmission of the infrared through the sample carrier paper; those liquids that will permeate the pores and fiber of the filter paper greatly attenuate the IR radiation.

In fact two effects must be at work, firstly the type of material decide the amount of IR radiation absorbed, and the other properties of material by which the filter paper be opaque or otherwise determine the level of attenuation. In this way one can use these types of liquids absorbed by filter paper to get more or less IR attenuation. This allows the possibility of differentiating different types of liquids using a simple experiment depending on detecting the transmitted infrared radiation through liquids. We can see the possibility of such application as quality control in production lines in factories to monitor drinks and beverage final specifications.

Effect of heating time on oil properties

No doubt that oil properties change with heat, i.e. Different oils have temperature limitations after which their properties degrade. This is also related the number of times oil has been used for frying specially in those restaurants and factories that used vegetable oil many times for frying before discarding it. In this work oil samples were heated for different time intervals and its IR absorption studied. Results are shown in Figure 3, in which boiling temperatures are used. Increasing time will not increase temperature since heat energy will affect oil components at constant boiling temperature.

Knowing the frying time of a vegetable oil is very important; since it affects the properties and the chemical structure of the oil and can be harmful for human consumption. The work here is not intended to determine the exact frying time after which degradation occurs, but rather establish the basis for a further study to be combined with an analytical study of change on oil components with heating time. The desire is to establish an experiment that simply indicates the effect of heating time on the oil in terms of its infrared absorption. Figure 6 shows the effect of heating vegetable oil for certain periods of time on its ability of IR absorption. It's clear that IR transmission increases with heating time; that is increasing the heating time resulted in transparent oil due to the general change in the oil properties.

It is found that heating vegetable oil up to ½ an hour does not affect the transmitted infrared spectrum much, but using this same oil for ¾ hour has increased the transmitted intensity by a factor of 1.2, compared to that of unheated oil. Hence a calibration can be established to act as a guide for the threshold heating time after which oil properties began to change. Improving this method can be useful in designing a portable handy tester useful for detecting the threshold deterioration limit of the used oil in which it stays hazard free.

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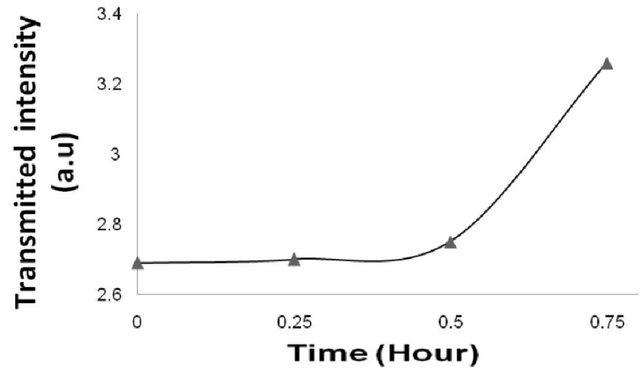

Figure 6 : Effect of heating time on corn oil absorption of infrared radiation.

IR absorption by different dye concentrations

Effect of dye concentration on IR absorption was studied. Different dye concentrations in water were used. The different solutions were applied to dye certain area of cloth by the same amount of dye. The cloth pieces dyed in the different dye concentrations were then examined in the same way as the above. Figure 7 Illustrates the effect of dye concentration on IR absorption.

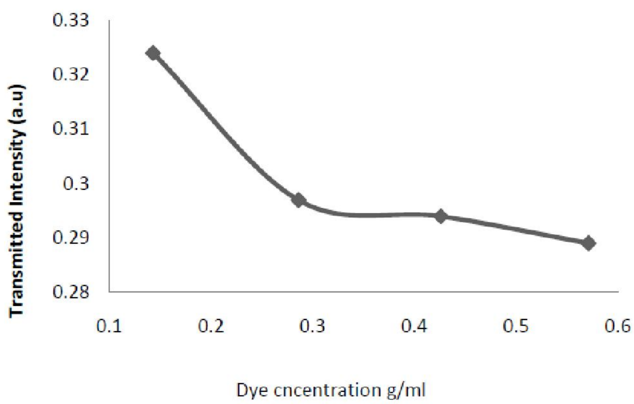

Figure 7 : Dependence of transmitted infrared radiation on dye concentration.

It is clear that as the dye increases the transmitted infrared flux decreases; molecules of dye will fill in the spaces of the cloth; obstructing or absorbing the IR radiation, this will obviously decrease the transmitted infrared radiation. Simple application of this sort can act as a guide along the production line in fabric factories to ensure the standard painting of fabrics.

Detection of olive oil adulteration with vegetable oil

Olive oil is a valuable healthy material and is a target for adulteration by inexpensive oils. In this work; olive oil was mixed with vegetable oil at different ratios: 1:1 up to 10:1; the effect of increased ratio of adulteration on IR transmittance was studied by detecting the transmitted infrared radiation, results are shown in Figure 8.

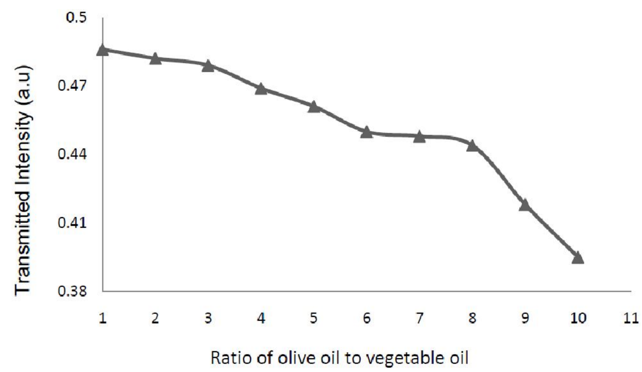

Figure 8 : Effect of mixing corn oil with olive oil at broadband IR absorption.

As the ratio of olive oil to vegetable oil increases, i.e. adulteration is less, relative absorbed intensity decreases. It is known that olive oil absorption in this region of IR band is higher than corn oil as the results indicates. This method proved useful, easy to handle and inexpensive to discover olive oil adulteration. Hence, a conclusion is drawn this simple no time consuming method is useful for olive oil authentication.

CONCLUSION

In this work some applications carried out successfully using homemade miniature IR sources. The types of experiments performed and the simplicity the results being achieved indicate the vitality and splendor of these homemade IR sources. The diversity of fields of applications employed such as: industry, agriculture and health add to the advantages of the sources used. The opportunity is available for portable easy to handle measuring devices using such IR sources. The level of sensitivity can be enhanced depending on the type of application in question by using sophisticated sensitive equipment. Even though, in a crude measurement many applications could be carried out to the satisfaction of the experimenter.

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