THERMOLUMINESCENCE 3D EQUIPMENT

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ABSTRACT: *In this paper we describe a thermoluminescence 3D equipment developed in our laboratory which can automatically measure and display a 3D graph, i.e the dependence of the intensity I of the thermoluminescence signal on the sample temperature T and the wavelength λ of the emitted signal simultaneously. The temperature range varies linearly from chamber temperature to 400°C and the wavelength range is 350-600 nm, which is matched with the frequency response of the used photomultiplier tube. The equipment works automatically and after about 8 minutes the 3D graph will be displayed. With this equipment one can get basic informations in thermoluminescence studying.*

I. Introduction

Thermally stimulated luminescence (TSL) has been interested researchers for its applications in dosimetry, dating and studyings of point defects in solids [1,2]. Recent years this field is intensively developed in some institutes and universities in Vietnam.

Since 2000, the department of solid state physics of University of Natural Sciences in Hochiminh City has a project in studying of thermoluminescence for its mentioned above applications. This project is developed in two parallel directions: the preparation of thermoluminescence materials (LiF: Mg, Cu, P; $Li_2B_4O_7$...) and equipments for measuring the characterictics of these materials .

In the experimental aspect, it is necessarily to develope the equipments which can perform three basic measurements: The dependence of thermoluminescence signal on the temperature of the sample– called the glow curve. The spectrum characteristics of the signal at a fixed temperature and as possible the simultaneously dependence of the signal I on the sample temperature T and the wavelength λ (frequency). This is the thermoluminescence 3D graph and finally the temperature dependence of thermostimulated current (TSC) .

In our laboratory, we have developed an equipment which can record the glow curve [5], so in this paper we report the development of an another instrument which can automatically record the 3D graph.

II. Presentation of the methodology

The glow curve measurement is a basic one in thermoluminescence study. It gives informations of the depth of traps and dynamic characteristics of thermoluminescence signal but no informations of recombination centres. For this it is necessarily to measure the signal spectrum. The spectrum measurement is in principle the same as for the other kinds of luminescence. The distinction however, in this case we are faced with transient emissions: the thermoluminescence is not fixed, it changes during the temperature rising .

There are two methods of measuring the 3D thermoluminescence. The simplest and straightforward one is the measuring of the spectrum of the signal at a fixed temperature, then repeating many times the same measurement at other temperatures. By collecting of the data from each measurement we can get a 2D-array of data so each column of this array represents the spectrum of the signal at a fixed temperature and each row is the dependence of a narrow band of the spectrum on temperature. From this 2D-array we can get the thermoluminescence 3D graph [3] .

Practically, we have to expose and heating the sample many times - a time waste and tedious work. Additionally, this can make changes in the distribution of traps and recombination centres in the measured sample .

Resonably, it should be risen the temperature only once (and therefore an unique sample exposure!). However, in this case we are faced with the fast scanning difficulties of the monochromator .

Normally, in thermoluminescence the sample temperature rises linearly in time ($T=T_o + \beta t$) in which T_o is the initial temperature and β is the temperature rate ($^oC/s$). In this method, each spectrum scan corresponds to a rising temperature range ΔT. Of course, as possible as, it should be minimized ΔT. The simplest case is the fast scanning of the monochromator and a second method is using an interferometer or multiplexing method, i.e the use of a diod array to detect all the wavelengths simultaneously. Based on the conditions of our laboratory we choose the former method.

1. ***Choosing the temperature rate*** β

With the fast scanning of the monochromator, the temperature rate must be as low as possible. The low temperature rate however, considerably reduces the signal intensity so a not too low temperature rate must be chosen. In our equipment the temperature rate is about $1^oC/s$. So with the innitial temperature of 30^oC and the final temperature of 400^oC, the whole measurement takes about 400s.

2. ***Choosing of monochromator scanning rate***

The spectrum range was chosen from 350nm to 600nm which matches the frequency response of the used PMT and therefore with a total of 48 scans, each scan must be performed in 400/48s, i.e of about 8s.

Nowaday, due to the low cost of personal computer we should like to develop a computerized equipment.

III. Instrument descriptions

The block diagram of the 3D equipment is shown in Fig.1. As be seen in the figure, it has four principal blocks.

1. ***Heating block***

The function of the heating block is to rise temperature linearly in time. It contains a closed cylindrical temperature chamber with 14,5cm diameter. In the box there is a resistive planchet that heat up as a result of the passage of current through it. The samples to be measured in the form of single solid specimens, pellets or powders suported on a small metallic discs are placed directly on the resistive planchet. The planchet itself is a thin metal strip made of nickel-chrome. A thermocouple welded directly on the back side of the planchet measures the temperature of the sample.

Since the resistivity of the planchet is very small, it can be driven only through a secondary coil of a transformer. In order to rise the temperature, the inputs of the transformer are driven by a variac. A stepper motor, driven by software, turns the variac. By appropriate changes of the stepper motor speed we can get the expected temperature rate. Fig.2 represents a temperature rising with a rate of 2° C/s.

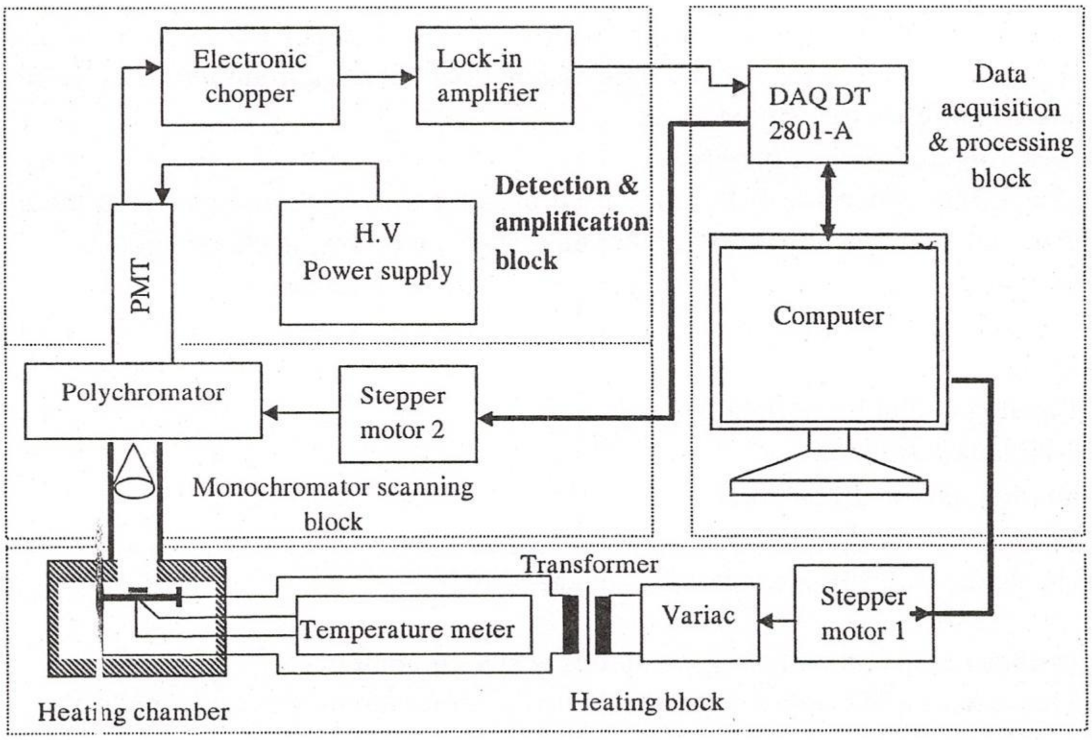

Fig.1 *Block diagram of the thermoluminescence 3D equipment.*

2. *Monochromator scanning block*

In our equipment ,we use a polychromator with a diffracted grating which has Δλ=20nm. A second stepper motor is used for the scanning purpose. The spectrum range from 350 nm to 600 nm was chosen to match with the photomultiplier tube (PMT) which is used to detect the thermoluminescence signal.

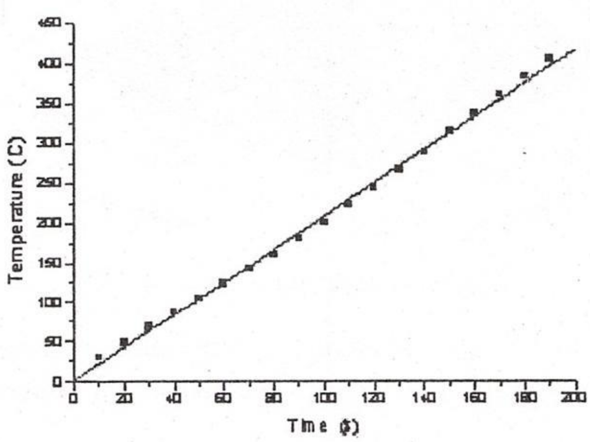

Fig.2 *A temperature rising with a rate of 2 °C/s .*

3. *Detection and amplification block*

Since the thermoluminescence is very weak in comparision with other normal light sources, its detection in a narrow spectrum range (~20 nm) must be taken with care. A light collection system is introduced. It contains a glass tube coated with aluminium in order to reflect all diverging lights and collect them to a lens which makes a focus beam at the slit of the polychromator. The signal from the polychromator is directed to the PMT, the output signal of which is converted in ac signal by an electronic chopper before its entrence to a lock-in amplifier. At the output of the lock-in amplifier the signal amplitude is sufficently large before its entrence to the next block .

4. Processing and controlling block

A Data Acquisition Card (DAQ) is used in order to sample and converse the analog signal to a digital one. This DT 2801-A DAQ board has the following characteristics:

- 16 single ended channels of analog inputs for A/D conversions.
- Two DIO ports with two 8-bit registers. We can use these ports to drive the stepper motors.
- 01 analog output for peripheral device.
- 12-bit data resolution .
- Sampling rate of 10,000 S/s.

The software we used to control the whole equipment is LabVIEW, version 5.1 for its powerful in signal acquisition, processing and displaying.

IV. Discussions of results and characterictics of the equipments

Fig.3 represents a 3D graph of Al_2O_3:C which was measured by our equipment .

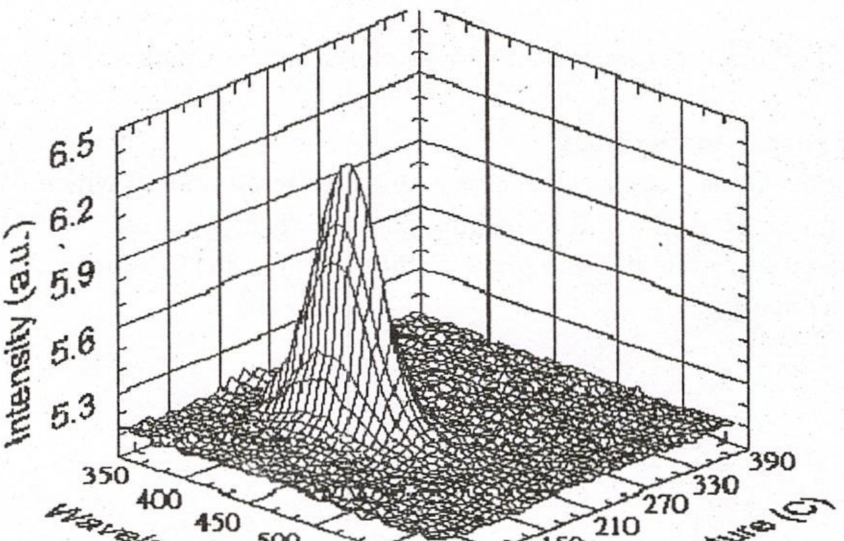

Fig.3 *A 3D graph of Al_2O_3:C .*

One can see in Fig.3, the Al_2O_3:C spectrum is distributed in a range from 370 to 520 nm and has a peak at 420 nm and 170°C. These results are in accordance with those early reported [4].

The main advantage of our equipment is that the recording of 3D graph is taken automatically. After the sample placing in the heating chamber, with an unique mouse clicking at the RUN button in front panel of our LabVIEW program, the equipment works automatically. After 8 minutes the 3D graph of the sample will be diplayed in the monitor of the computer and the equipment automatically returns to the initial state for the next measurement .

With this equipment we can save time and espectially exclude the repeatings of sample exposure and heating.

This equipment however, has some limited features. Due to the mechanical inertia of the stepper motor and polychromator we cannot scan the polychromator faster than 8s for each scan in order to reduce the temperature difference at the beginning and ending of each scan. In our equipment this difference is about 8°C. In addition, the sensitivity of this equipment is also low, which makes difficulties in recording low exposed samples. In order to improve the signal to noise ratio, it is necessarily to replace the present old PMT by an another one which has lower dark current and better spectrum characteristics .

V. Conclusions

With this 3D equipment we can make almost basic measurements in thermoluminescence study. The TSC measurement is a more complexity one but we hope that it will be developed in our laboratory in a no far future.

HỆ THIẾT BỊ ĐO VÀ HIỂN THỊ ĐỒ THỊ 3 CHIỀU CỦA HIỆN TƯỢNG NHIỆT PHÁT QUANG

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TÓM TẮT: *Trong bài báo này chúng tôi mô tả một hệ thiết bị được xây dựng tại phòng thí nghiệm của Bộ môn vật lý chất rắn. Hệ thiết bị có thể đo đạc và hiển thị đồ thị 3D của tín hiệu nhiệt phát quang, tức là đồ thị biểu diễn đồng thời sự phụ thuộc của cường độ I của tín hiệu vào nhiệt độ T và bước sóng λ của ánh sáng do mẫu phát ra. Nhiệt độ của mẫu được nâng tuyến tính từ nhiệt độ phòng đến 400℃ còn giải tần số làm việc từ 350 đến 600 nm. Toàn bộ phép đo và ghi hình 3D được tiến hành một cách hoàn toàn tự động trong khoảng thời gian 8 phút sau khi nhấp chuột lên nút RUN ở front panel của chương trình LabVIEW. Hệ thiết bị cho phép đo được các thông tin cơ bản trong nghiên cứu hiện tượng nhiệt phát quang.*

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