A LOW COST AUTOMATIC SYSTEM FOR ANELASTIC RELAXATIONS MEASUREMENTS

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ABSTRACT

A modified system for automatic collection of data of internal friction and frequency is devised utilizing an inverted torsion pendulum. This system is based on velocity method instead of traditional method of amplitude decrease of free vibrations. The time intervals are obtained through the reflection of a He-Ne laser beam, traversing two photodiodes separated by a known distance. An interface was developed which receives a signal of these photodiodes, amplified and takes it to a clock. The temperature is obtained by a digital multimeter and through a GP-IB type interface. A computer program was devised which reads simultaneously temperature, internal friction and frequency. We are also presenting some spectra obtained in our laboratory for metallic materials using the constructed system.

1. INTRODUCTION

The internal friction method is widely used in physical metallurgy to investigate anelastic relaxation and microplasticity in solids. The free vibration method is one of the major methods for measuring low frequency internal friction in solids. There are three types of torsion pendulum developed for low frequency free vibration decay, i.e., the normal torsion (or Coulomb type), inverted torsion, and, Collete pendulums. Among these torsion pendulums, the normal torsion pendulum came into being first. It consisted basically of a inertia member (e.g., a horizontal bar) suspended from a wire specimen and, therefore, seemed somewhat simple to copy the setting arrangements of the galvanometer suspension apparatus [1]. Since then it became a dominant method for awhile to measure the low frequency internal friction in solids. Subsequently, there were many refined forms for this kind of pendulum [2-6] including Kê's work in 1947 [2] in which the effort was made by this pendulum to measure anelastic relaxation internal friction but limited only to metals (the anelastic relaxation internal friction in solids was first highlighted by Zener in 1948 [7] but was systematically theorized by Nowick and Berry in 1972 [8]). In the normal pendulum, the tensile load exerted on the sample by the weight of the inertia member (which is necessary to lower or change the system vibration frequency) is rather high and will inevitably lead to the undesired tension of an investigated sample or the torsion modulus of the sample. This will inevitably lead to serious error during an internal friction measurement over a wide temperature range which, on the other hand, however, is required for the measurement of activated energy associated with relaxation internal friction or for monitoring any material structure change. For this consideration, most torsion pendulums presently used in materials science are changed to be operated in the "inverted" configuration. The sample is located below the inertia member which hangs on a tin suspension wire (called a torsionally weak suspension wire) of low damping. In doing so, only a very small force on the sample s needed in order to keep the system straight and the pendulum can perform without any inertia weight suspended at the end of sample. Usually, the suspension wire is made so thin that its torsional rigidity can be neglected with respect to that of the sample.

The torsion pendulum constructed by Kê [2] and particularly its modification (the inverted torsion pendulum) [8] are the most usual devices for low frequency measurements (0.1 - 100 Hz), by which the decrease in amplitude at constant vibration frequency f may be registered within a distinct range of temperatures. The main objective for improving internal friction measurements in the low frequency range is to automate the torsion pendulum.

The measurement of the damping of a torsional pendulum is generally achieved by observation of the decrease of the oscillation amplitude. Where damping is high, the visual observation of successive amplitudes with an optical lever presents few problems to the patient observer, apart from possible eye fatigue. However, when air damping is removed for increased sensitivity by enclosing the pendulum in an evacuated chamber, the decrease of the oscillation amplitude may be reduced, requiring long times for the measurements. Accurate visual observations, moreover, become difficult above 2 Hz.

A more rapid determination of the decrease of the oscillation amplitude, consist in the observation of the decay in velocity in successive transits across the equilibrium position. In the present work, we propose the application of an apparatus that greatly simplifies and improves measurements of the angular velocities and the oscillations periods of the pendulum.

2. EXPERIMENTAL EQUIPMENT

Among the several existent techniques for the study of anelastic relaxation that involve the decay of the free vibrations of the system, one of the more used is the torsion pendulum. A schematic diagram of the torsion pendulum used for us is shown in the fig. 1. The sample (A) is placed in the inferior part of the pendulum, attached by two chucks (D), one in the body of the pendulum and another in the extremity of the connecting rod (E). The other extremity of the connecting rod is called to a counterweight (J) through a suspension wire, to maintain the connecting rod and the sample stretched out, even so non-strained. In order to obtain a variation in the frequency of oscillation of the pendulum, we placed two weights in an inertia bar (I). The displacement and variation of weights, allows that the pendulum oscillates with frequency in the interval of 0.1 to 10 Hz, approximately. The initial displacement of the pendulum is made by two driving coils (H) activated externally and controlled by the microcomputer.

A laser beam is reflected from a mirror installed on the torsion pendulum (K). As the pendulum oscillates, the beam passes over two photodiodes symmetrically located about the equilibrium position, 40-mm apart. The distance between the mirror and the plane where these photodiodes are located is 4.5m, as it can be seen in the fig. 2. The laser beam activates the photodiodes sending a signal to a Schmidt Trigger unit. This unit delivers a pulse which the duration is the time spent by the laser beam to traverse the distance between the two photodiodes.

In order to obtain the temperature variation, a heating element (B) and a reservoir for liquid nitrogen (C) were placed around the sample. The temperature measurements were madden by a copper-constantan thermocouple.

The vacuum in the system is made through the entrance (G), in which is connected a system with a turbomolecular pump.

3. THE VELOCITY METHOD

When a torsion pendulum is deflected to an initial angle θ_o and is then allowed to perform small amplitude oscillations, the solution of the equation of motion is [8]:

$$\theta(t) = \theta_o \exp(-\gamma t)\cos(\omega t) \quad (1)$$

where: $\theta(t)$ is the angle of deflection from the equilibrium position (see Fig. 2), γ is the damping factor and ω is the angular frequency.

Taking ratio of angular velocities $(d\theta/dt)_{max}$ for two more successive oscillations, then:

$$\frac{\left(\frac{d\theta}{dt}\right)_{max}(t = nT)}{\left(\frac{d\theta}{dt}\right)_{max}(t = 0)} = \exp(-\gamma nT) \quad (2)$$

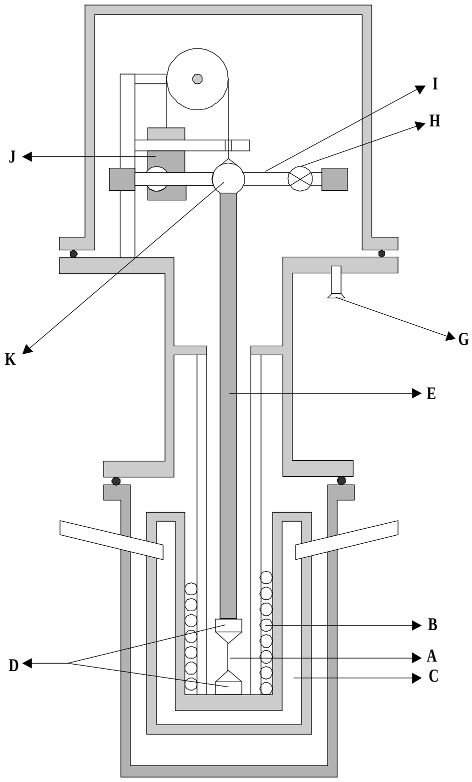

Figure 1 – Schematic diagram of the torsion pendulum.

Hence

$$\gamma = \frac{1}{nT}\log_e \frac{\left(\frac{d\theta}{dt}\right)_{max}(t = nT)}{\left(\frac{d\theta}{dt}\right)_{max}(t = 0)} \quad (3)$$

or

$$Q^{-1} = \frac{\gamma}{\pi} \quad (4)$$

Equation (4) is used to compute Q^{-1}, once the values $(d\theta/dt)_{max}$ are determined and stored in the microcomputer memory. No matter if we take of angular velocity (maxim) or linear velocities about equilibrium position.

The time interval is inversely proportional to the maximum angular velocity $(d\theta/dt)_{max}$.

Pulse-duration data, corresponding to the maximum velocities, are taken in hexadecimal and converted to decimal representation. The data are collected in the direct sense of the laser beam and in the reverse sense. They are either stored on a floppy disk or processed directly for the Q^{-1}, calculations according to the relation (4).

4. INTERFACE CIRCUIT

The device of data acquisition consists of a microcontrollated circuit, based on a Intel 8751

microcontrollator [9,10], a circuit of sensor using triggers Schmidt Trigger or window comparator, a circuit of serial communication and an external control for a driving coil.
For the operation, it is necessary an IBM-PC or compatible microcomputer with a serial output free, the external sensors (in the case two photodiodes) and the pendulum system.
The full control of the measure process is made by the microcontrollator, that is, for its time, connected to a PC by a serial cable, from where it receives several commands to begin the measurement.
To excite the oscillation, a synchronized driving current is passed through the driving coils. The block Schmidt Trigger impedes that interference from ambient light happens, among another. Schmidt Trigger is connected to the microcontrollator, that makes the data collection and after the sampling end, it sends them to the microcomputer through the serial door. After the measure, the PC receives the obtained data and it processes them through specially developed software in Pascal and Visual Basic language.
The software to measure the temperature dependence of internal friction is implemented as follows: the initial, final and step temperature are imputed; the device of data acquisition is connected; the number of cycles is imputed; the heating rate is defined. The temperature is measured; the sample is heated to a given temperature at a given rate; the data are collected; the internal friction in the direct sense and in the reverse sense are determined. The temperature, the mean internal friction (the mean value of the internal friction in a direct and reverse sense) and frequency are storage. The block diagram for the interface circuit is shown in Fig. 3.

5. MEASURING EXAMPLES

To illustrate the accuracy of the apparatus, some results are reported in figs. 4 and 5. Fig. 4 is an example of a very well known Snoek peak obtained with this apparatus in a polycrystalline tantalum sample (1.3-mm diameter for 50-mm length) with oxygen in solid solution, measured with frequency of 2.7 Hz and heating rate of 1.1 K/min. A Snoek peak due oxygen is observed at 440 K. The maximum value for Q^{-1} is 1.5 x 10^{-3}.
Figure 5 shows the internal friction and frequency measurement for a $Bi_2Sr_2CaCu_2O_{8+\delta}$ sample (4.0 x 3.0 x 45-mm^3). Two peaks are observed. The low temperature peak is due to the movement of additional oxygen in the ab plane in the 2212 structure and the high temperature peak is related to orthorhombic to monoclinic (O-M) phase transformation.

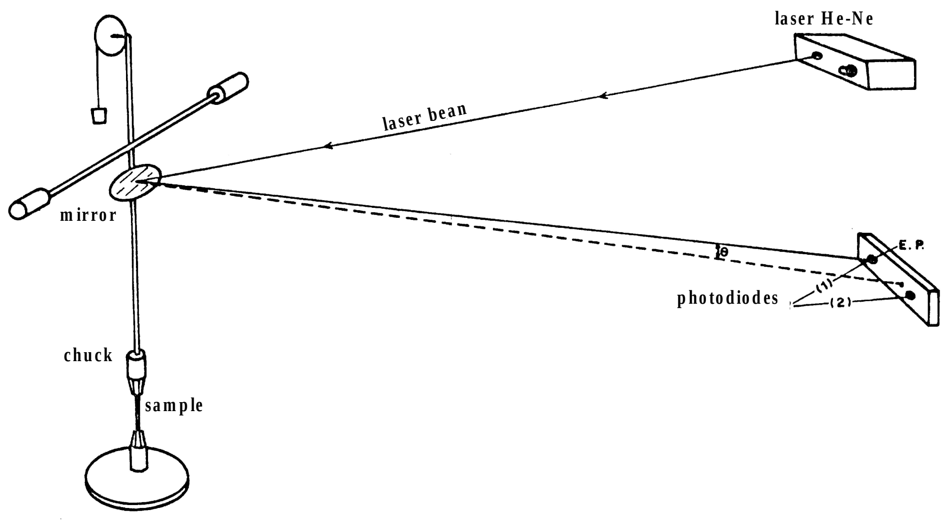

Figure 2 - General view of torsion pendulum equipment.

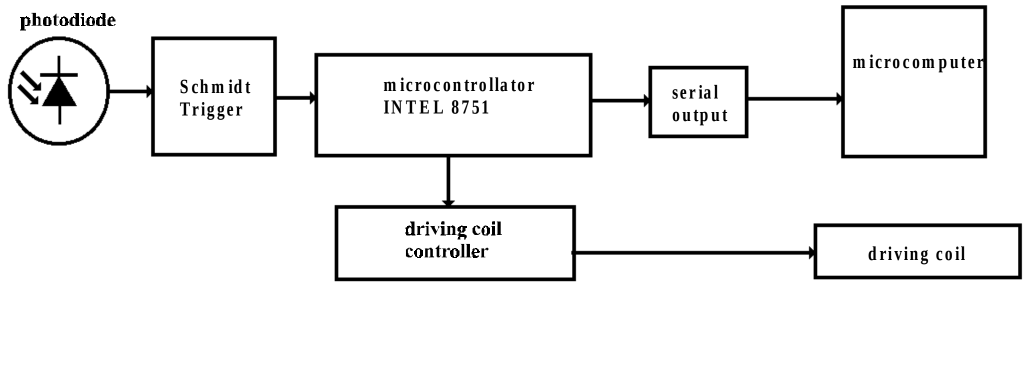

Figure 3 - Block diagram of the electronic interface for velocity and frequency measurements.

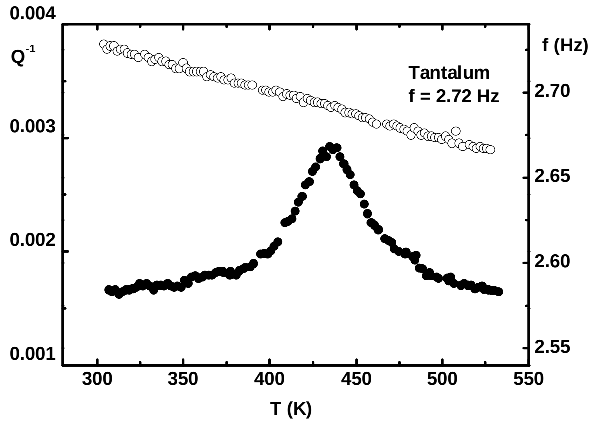

Figure 4 - Internal friction and frequency for a tantalum sample with oxygen in solid solution.

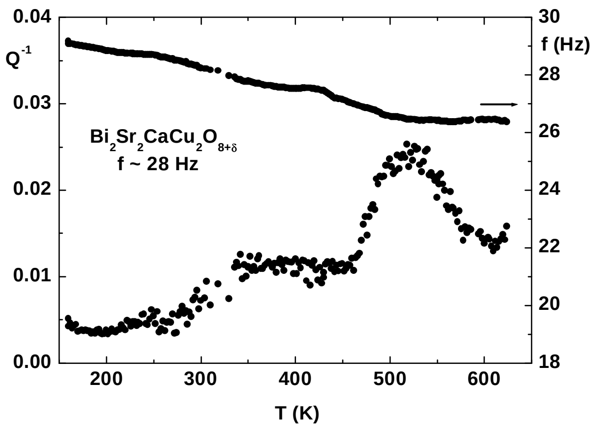

Figure 5 - Internal friction and frequency measurements for Bi-based superconductor sample.

6. SUMMARY

A low cost fully automated internal friction and frequency measurement system was constructed.

The instrument makes possible quick and reliable measurements of Q^{-1} as well frequency measurements with very few oscillations of the pendulum.

This, in turn, permits internal-friction measurements over small temperature intervals during heating or cooling within rates of 1 K/min.

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