Sains Malaysiana 41(5)(2012): 611–615

A Simple Automated System for Hall Effect Measurements

(Sistem Automasi Ringkas untuk Pengukuran Kesan Hall)

ARIFFIN ABAS, S.A. HALIM, Z.A. TALIB & Z.A. WAHAB

ABSTRACT

This project deals with the development of a computer interfacing technique for the study of Hall effect. A stepper motor with resolution of 0.1 mm was used to move a pair of permanent magnet backward and forward against the sample. The General Purpose Interface Bus (GPIB) card together with a digital nanovoltmeter and teslameter using serial port siri RS232, interface were used to measure the potential difference and magnetic field strength, respectively. Hall effect for $YBa_2Cu_{3-x}Ti_xO_{7-\delta}$ *system (x=0.00, 0.01, 0.03 and 0.05) showed positive sign Hall coefficient showing that the material is a hole type carrier at room temperature. Parameters such as Hall coefficient and charge carrier concentration were also display on the front panel of Lab View programming.*

Keywords: Charge carrier concentration; Hall coefficient; Hall effect

ABSTRAK

Projek ini berkaitan dengan pembangunan teknik antaramuka untuk mengkaji kesan Hall. Sebuah motor pelangkah dengan resolusi 0.1 mm digunakan untuk menggerakkan sepasang magnet kekal ke hadapan dan belakang terhadap bahan ujian. Kad kegunaan am antaramuka bas (GPIB) bersama dengan nanovoltmeter dan teslameter menggunakan port siri RS232, masing-masing digunakkan untuk mengukur beza keupayaan dan kekuatan medan magnet. Kesan Hall untuk sistem $YBa_2Cu_{3-x}Ti_xO_{7-\delta}$ *(x=0.00, 0.01, 0.03 dan 0.05) yang telah dikaji menunjukkan sistem adalah didominasi oleh lohong pada suhu bilik. Parameter seperti koefisien Hall dan ketumpatan pembawa cas juga dipaparkan pada panel hadapan program Lab view.*

Kata kunci: Kesan Hall; ketumpatan pembawa cas, koefisien Hall

INTRODUCTION

The objective of this paper was to setup a simple automated system to measure the Hall effect in $YBa_2Cu_{3-x}Ti_xO_{7-\delta}$ system at room temperature. The Hall effect V_H was observed when a magnetic field (B) was applied at right angles to a sample of material carrying an electric current (I). Hall effect (or Hall voltage) that appears across the sample is due to an electric field which is it right angle to both the current and the applied magnetic field (Edward 2006). Hall voltage can then be expressed as:

$$V_H = \frac{BI}{nqd} = \frac{R_H BI}{d}, \quad (1)$$

where is the thickness of the sample, q is the charge and n is the charge carrier concentration.

The quantity $R_H = \frac{1}{nq}$ or $n = \frac{1}{qR_H}$ (2)

is called the Hall coefficient.

The Hall voltage is directly related to the magnetic field and the drift current, and it is inversely related to the thickness of the sample. A plot of Hall voltage (V_H) as a function of magnetic field (B) at constant current will have a slope given by:

$$Slope = \frac{R_H I}{d} \text{ or } R_H = \frac{(Slope)d}{I}. \quad (3)$$

From (3), the slope of dependency V_H vs. B is defined, in particular, by the Hall coefficient R_H. This R_H carries information about majority electron or holes concentration.

INSTRUMENTION AND SOFTWARE

The Hirst Tesla meter model GM08 was used to calibrate the magnetic field and connected to a personal computer (PC) via Serial Port (Kai 2009). The drive board with PCI 6025E card through opto isolator circuit and stepper motor with a resolution of 0.1 mm were used to move a pair of permanent magnet neodymium-iron-boron (Nd-Fe-B) backward and forward against the sample (Basil 2011, Kalman (1995). The opto isolator circuit was used to amplifier 5 to 12 V from DAQ Card PCI 6025E to make stepper motor work and also serves as a protection circuit for any excess current, which could backflow into PC in any case of short circuit or current spikes. All the apparatus were controlled by LABVIEW programming (Lisa & Jeffrey 1997) to acquire the data. The sample with four points probe is as shown in Figure 1. Two wires are connected to a Keithley current source model 224 of 100 mA and the other wires were connected to Keithley nano voltmeter model 2182 to a PC via General Purpose interface Bus (Sumathi 2007) to measure the Hall effect potential. In order to have good electrical contacts silver paint was used. The schematic of the setup is shown in Figure 2.

The user interface of the LABVIEW programming is as shown in Figure 3. The user interface is divided into three parts i.e. pre-setup system, monitoring system and data acquisition system. The pre-setup system consisted of four features: *Test selection menu* for the user to select either to choose Hall effect experiment or to move stepper motor; *Offset voltage* (Brandley 2007) for the user to provide initial voltage so that the LABVIEW program will automatically fix this voltage as offset voltage; *Dimension* for providing the length, thickness and width of the sample; *File selection tool* that permits a user to store the acquired data. The monitoring system was a *motor indicator* which indicates the distance between two permanent magnets. The data acquisition consists of *Parameter of the experiment* that display the values of the Hall coefficient and charge carrier concentration; *Magnetic field and voltage reading* that display of the magnetic field strength and Hall voltage reading; *Graph* to display the Hall voltage as a function of the magnetic field.

RESULTS AND DISCUSSION

The automation system written using Lab View programming has been successfully developed. The data from teslameter and nanovoltmeter via serial port and GPIB, respectively were automatically saved for further analysis and automatically plotted in real time. The superconductor sample tested was the $YBa_2(Cu_{3-x}Ti_x)O_{7-\delta}$ or Y-Ba-Cu-O. The Hall measurement for this system (Y-Ba-Cu-O) doped with titanium showed positive Hall coefficient for all doped with at room temperature as shown in Figure 4. This result agrees with previon reports (Da Luz et al. 2009; Pao et al. 1997).

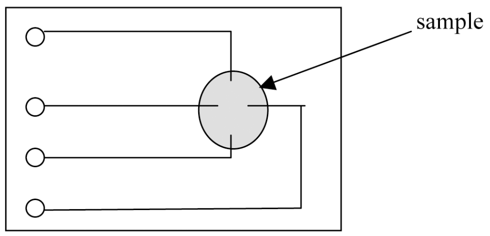

FIGURE 1. Sample holder with four point probes for YBCO sample

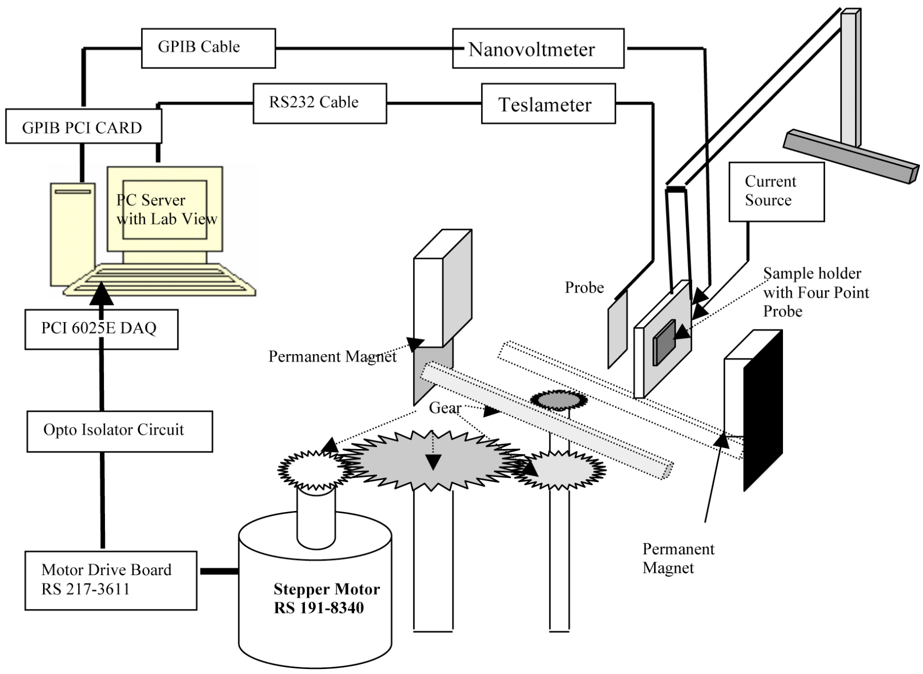

FIGURE 2. Schematic of the experimental setup

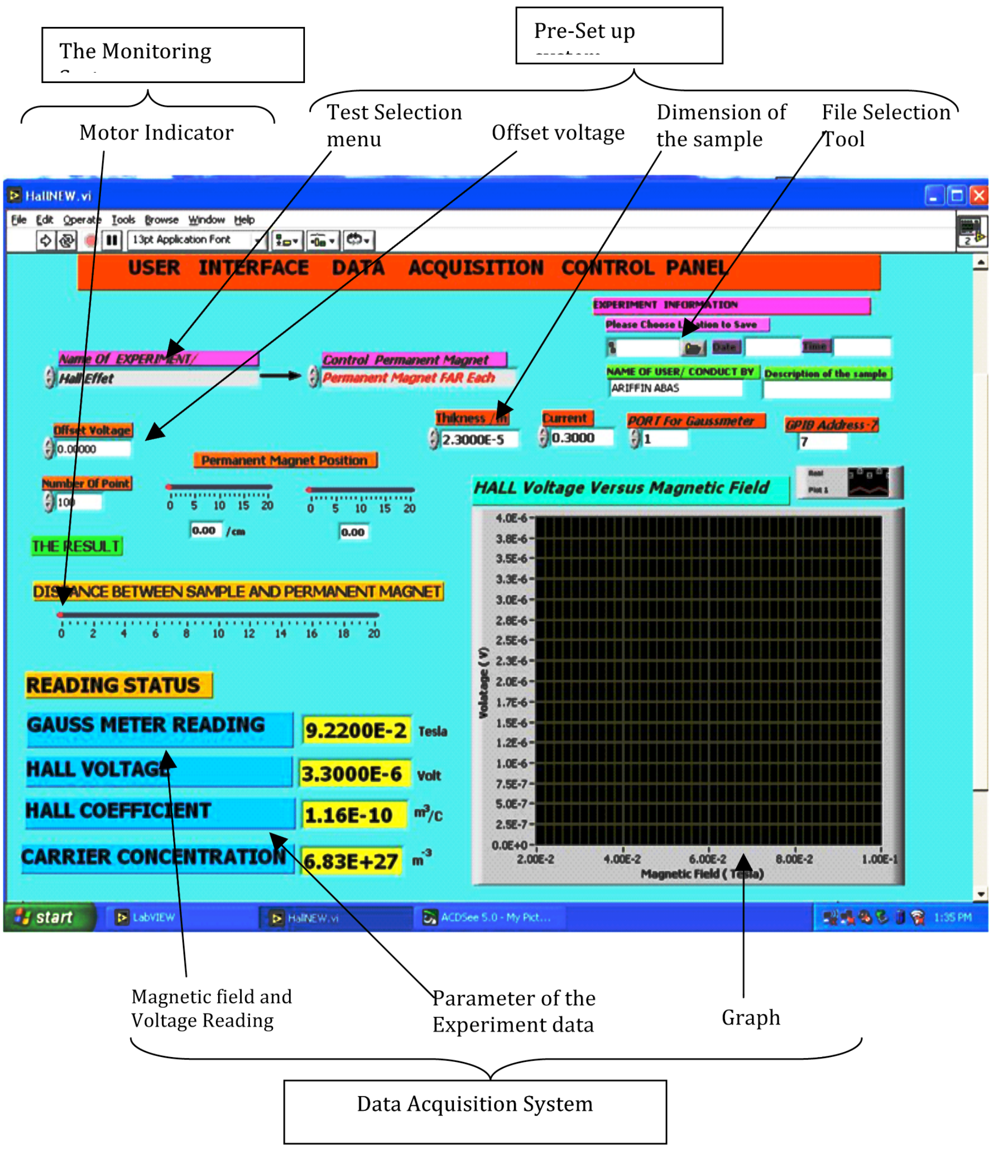

FIGURE 3. User interface

The Hall coefficient and charge carrier density obtained by using (1)-(3) and automatically calculated and displayed in the front panel user interface through Lab View programming are as shown in Figure 1.

The titanium (Ti^{4+}) ions are expected to replace the Cu^{2+} ion in the superconductor. The additional electron contributed by Ti ions are expected to fill mobile holes in the CuO_2 planes thereby increasing the Hall coefficient (still positive sign) as shown in Figure 5(a) and the charge carrier density (n) decreased as shown in Figure 5(b) because Hall coefficient, $R_H \alpha \frac{1}{n}$. The Hall coefficient (R_H) and the charge carrier density for pure YBCO system are 8.55×10^{-9} m^3/C and 0.75×10^{27} m^{-3}, respectively at room temperature (Table 1). These values are in the same order of magnitude

TABLE 1. The Hall Effect result for $YBa_2(Cu_{3-x}Ti_x)O_{7-\delta}$ sample

$YBa_2(Cu_{3-x}Ti_x)O_{7-\delta}$ Thickness= (1.4690 ± 0.0001) mm Current supply = 100mA	Hall coefficient R_H (m^3/C)	Carrier Density n (m^{-3})
0.00 (Pure)	8.55×10^{-9}	7.54×10^{26}
0.01	1.58×10^{-7}	3.92×10^{25}
0.03	6.42×10^{-7}	9.74×10^{24}
0.05	1.13×10^{-6}	5.56×10^{24}

as compared with 3.7 × 10^{-9} m^3/C and 1.1 × 10^{27} m^{-3} respectively reported by Yong et al. (1987).

In this paper, the apparatus that used in the experiment to measured Hall Effect are simple, easy to handle and gave result to the previous reports.

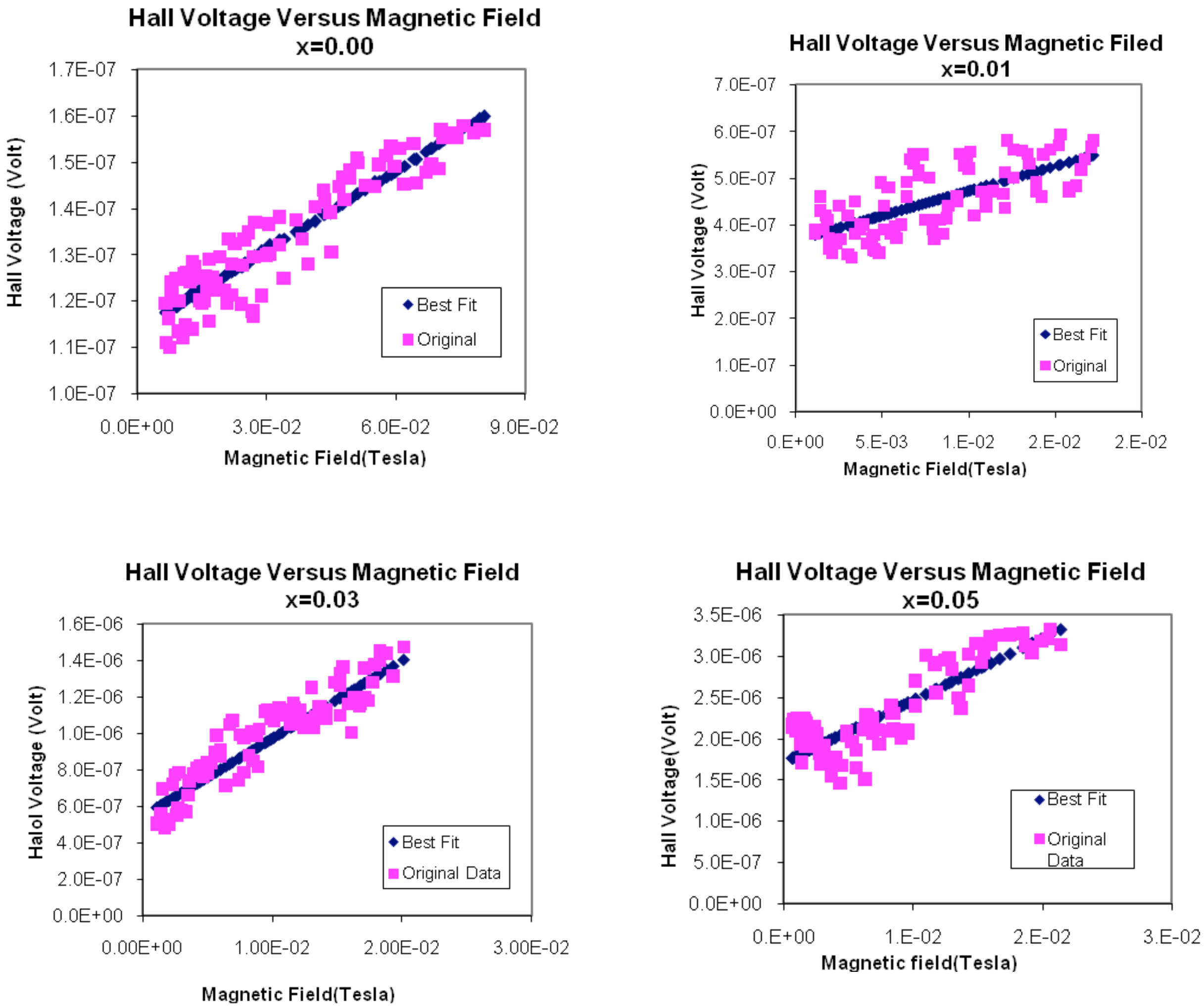

FIGURE 4. Hall Voltage as a function magnetic field for $YBa_2 (Cu_{3-x}Ti_x) O_{7-\delta}$ system

(a)

(b)

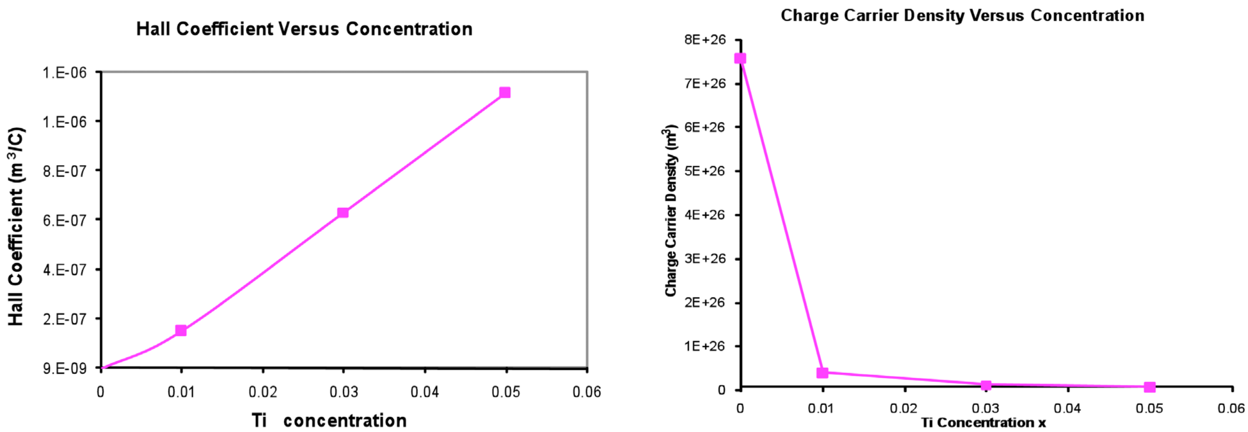

FIGURE 5 (a) Hall coefficient as a function of titanium concentration for $YBa_2 (Cu_{3-x}Ti_x) O_{7-\delta}$ system and (b) charge carrier as a function of titanium concentration for $YBa_2 (Cu_{3-x}Ti_x) O_{7-\delta}$ system

ACKNOWLEDGEMENT

This work was supported by the Ministry of Higher of Education of Malaysia and Research Universiti Grants (RUGS), Universiti Putra Malaysia, Serdang Selangor, Malaysia.

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Ariffin Abas , Z.A.Talib & Z.A.Wahab
Department of Physics
Universiti Putra Malaysia
43400 Serdang Selangor, D.E.
Malaysia

S.A. Halim*
Institute of Mathematical Research (INSPEM)
Universiti Putra Malaysia
43400 Serdang Selangor, D.E
Malaysia

*Corresponding author; email: ahalim@science.upm.edu.my

Received: 29 June 2011
Accepted: 29 November 2011