DEVELOPMENT OF MICROCONTROLLER BASED INSTRUMENTATION FOR LOW DOSE IMPLANTATION

K. Suresh, K. Saravanan, B.K. Panigrahi, K.G.M. Nair,
Materials Science Group, Indira Gandhi Centre for Atomic Research, Kalpakkam - 603 102, Tamilnadu, India.

Abstract

In experiments like ion implantation based ion track formations, the sample is implanted to low doses of the order of 10^{10} ions/cm^2, limiting the ion beam currents to be less than 1-5 x 10^{-12}A. However the standard current integrators available are not sensitive to very low currents, causing an unacceptable high level of error in dose measurement. Hence a low dose implantation measurement system has been developed. It consists of a very sensitive low current preamplifier with full scale input 1nA/100pA, a standard current integrator, a microcontroller based interface circuit, which are connected to a personal computer(PC) through USB. Two types of the software are developed for the system : the microcontroller firmware using C and windows based virtual instrument programs using LabVIEW 7.0. Necessary precautions associated with pA level measurement like rigidly fastened good quality cables, low ripple DC power supply, shielding, close mounting of the preamplifier to the sample are adopted. After necessary calibrations with an ECIL make low current source, the system has been put into regular use. Design and development details, salient features are discussed in this paper.

INTRODUCTION

Particle Accelerators and Ion implanters play an important role in the field of materials research in a wide ranging applications from doping of semiconductors to simulation of neutron damage in materials. In these applications, the characteristic changes in the materials due to ion beam irradiation, apart from other factors, depend on the ion beam dose (fluence). The ion beam dose measurement is commonly done by employing an ion beam current integrator which measures the ion beam induced current and subsequently integrates the ion beam current digitally to obtain the accumulated charges.

Low fluence ion implantation has interesting applications for the fabrications of electronic devices. Low fluence ion implantations have been extensively employed for dilute magnetic semiconductor, precise doping in semiconductor materials, nanostructures prepared via ion track of high energy ion irradiation, etc. However monitoring and controlling the ion beam current and flux are the difficult and challenging tasks in these processes because of sub-nano ampere currents involved in the low fluence ion implantation experiments. To study the nanostructures prepared via ion track of high energy ion irradiation, we have established a very low ion beam current (few 10^{-12} A) measurement setup at Materials Science Group, IGCAR.

MICROCONTROLLER BASED INSTRUMENTATION

Figure.1 shows the block diagram representation of the microcontroller based instrumentation for low dose implantation setup. The setup consists of a very sensitive low current preamplifier with full scale input 1nA/100pA, a standard current integrator(model 556 of Danfysik) , a PIC16F877 microcontroller based universal interface circuit, which are connected to a personal computer(PC) through USB. The popular PIC16F877A, a 8-bit high performance FLASH microcontroller from the Microchip® PIC family, is chosen after taking into account of its price, performance and rich peripheral set as well as the availability and ease of use of software development tools. Internal Flash program memory guarantees fast and easy re-programmability.

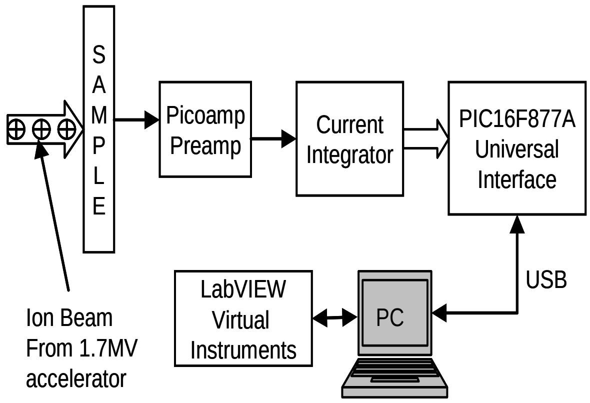

Figure 1: Microcontroller based pA measurement setup

Hardware Description

The heart of the set up is a sensitive current to voltage converter preamplifier with two selectable gains of 100 pA/V and 1000 pA/V with outputs of 10 V for an input current of +/- 1μA/100 pA or +/- 1μA/pA. Improved accuracy of low current measurement is realised in the preamplifier by using a feedback ammeter with an operational amplifier (transimpedance amplifier) to convert the input current into a voltage. Some of the important features of the preamplifier include low burden voltage (<200μV), good accuracy of 1%, fast settling time. As noise can significantly affect the accuracy of the low current measurement, several precautionary noise reduction techniques are used. Some of them are shielding, using special cables to reduce tribological effects, rigidly fastened cables to reduce cable movement and vibration in the setup, avoiding leakage current through contaminants like dirt, grease, fingerprints, or solder flux. The ac line noise is reduced by coaxial cable. The amplified current output of the preamplifier is fed to a model 556 current integrator which further amplifies and does digital integration to provide the fluence in the form of discrete pulses. The current integrator is interfaced to a universal interface circuit to enable PC based automated low fluence measurement.

The universal interface circuit is centered around the popular PIC16F877A and a USB to universal asynchronous receiver transmitter (UART), first in, first out (FIFO)controller, DLP2232. The analog and digital outputs of the ion beam current integrator (model 556 from Danfysik, Netherlands) like voltage representing the beam current and current range, charge counts form the core inputs to the universal interface circuit. Necessary signal conditioning circuitry consisting of non-inverting amplifier or unity-gain buffer, a voltage divider, and a RC low pass filter, is used between the interface and the current integrator. For implementing the USB protocol, we have used a cost-effective, microcontroller-based method in the form of a DLP-2232 module from M/s.DLP Design. Two pins TX and RX of hardware UART of the PIC16F877A are used with TXBD and RXBD of DLP2232M to realize the bidirectional USB communication. The DLP-2232M module employs a versatile dual USB UART/FIFO chip, FT2232C,which converts a single downstream USB port into two input/output (I/O)channels that can each be individually. configured to work in as many as seven modes such as an UART interface, a FIFO interface, etc. Two types of the software are developed for the setup : the microcontroller firmware using C using CCS C compiler and windows based virtual instrument programs using LabVIEW 7.0.

Tests and Results

The measurement set up extensively tested by feeding bipolar currents ranging from sun pA to 1000 nA from an ECIL make low current source and a multifunction calibrator source, model 5018 from M/s Time Electronics. The current values measured interface by using the 556 integrator output were compared with the similarly measured values using a standard electrometer K6517 from M/s Keithley Inc. and found to be in good agreement.

For testing the microcontroller counters, TTL pulses with frequency in the range of 0–2 KHz from a standard wave form generator were fed to them and the count readout were monitored over a fixed period of time. The charge count measurements done with a constant input current over a fixed period of time and the deduced charge/pulse factor agree well with the manufacturer's specifications.

After necessary calibrations with the ECIL make low current source, the set up has been put into regular use . A 6 MeV Si^{5+} ion beam from the 1.7 MV Tandetron accelerator (HVEE, The Netherlands) was used for ion implantation of SiO_2/Si and quartz samples with various fluencies at a vacuum of 4×10^{-7} mbar. The implantations were performed at room temperature. The beam diameter is 10 mm. The implantation ion fluence, beam current and integrated counts are tabulated in Table 1. The implanted samples were characterized by scanning electron microscopic analysis.

Table 1: Implantation dose, ion beam current, integrated counts and typical implantation duration

Fluence (ions/cm2)	**Beam current (pA)**	**Counts**	**Implantation duration (sec)**
1×10^{10}	3	630	2100
5×10^{9}	3.2	315	945
1×10^{9}	3	63	210
5×10^{8}	2.9	30	100

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