Instruments and Experimental Techniques, Vol. 44, No. 5, 2001, pp. 698–699. Translated from Pribory i Tekhnika Eksperimenta, No. 5, 2001, pp. 134–136.

LABORATORY TECHNIQUES

In situ Conductance Measurement of Surface Phases on Silicon by the Four-Probe Method

I. A. Belous*, O. V. Utas, D. A. Tsukanov***, and V. G. Lifshits*****

** Vladivostok State University of Economics and Service, ul. Gogolya 41, Vladivostok, 690600 Russia*

*** Far East State University, ul. Sukhanova 8, Vladivostok, 690600 Russia*

**** Institute of Automation and Control Processes, Far East Division, Russian Academy of Sciences, ul. Radio 5, Vladivostok, 690041 Russia*

Received February 21, 2001

Abstract—The experimental chamber, automation system, and method for measuring the conductance of surface phases on silicon are described. This chamber is intended for measuring the conductance of superthin films and surface phases on single-crystal silicon substrates by the four-probe method under ultrahigh vacuum conditions (10^{-10} Torr). The system is controlled by a computer and contains 12-bit analog-to-digital and digital-to-analog converters. The measurement error is ≤0.5%. The measurement rate is 10 points/s.

The four-probe method for measuring the conductance of semiconductor materials [1] requires no ohmic contacts with the sample. To apply this method, the sample only needs to have a flat surface whose linear sizes exceed those of the probe system.

To measure the conductance of surface layers in situ under ultrahigh vacuum conditions, we have manufactured a four-probe head in the form of a vacuum module. It is based on a DN100 flange equipped with a silphon allowing one to move the probe head in a direction perpendicular to the sample. The probes are made of tungsten and sharpened by the electrolytic method. The holder for the probe head is made of stainless steel. As insulation, we use ceramics, and connecting wires are made of preliminarily degassed copper.

The system for conductivity measurements by the four-point probe method includes a precision direct current (dc) amplifier and an L-154 analog-to-digital converter (ADC) and digital-to-analog converter (DAC) board (L-Card company, Moscow). The L-154 board inserted into an IBM PC/AT computer contains a 12-bit ADC and DAC. We can apply up to 16 measured voltages via a multiplexer to the ADC input. The dc amplifier [2] connected to the current probes and ADC is intended for increasing the input impedance of the system up to several GΩ and matching the levels of the signals taken from the probes to the ADC sensitivity. The amplifier, with a differential input and output, is based on two КР140УД25Г operational amplifiers [3]. The circuit design makes it possible to decrease the common-mode signals of this circuit by ~100 dB in comparison with that having an asymmetric input [2]. The gain is set at 20, since the maximum voltage taken off the sample is 50 mV, and the maximum ADC input voltage is 1.024 V. The current is applied to the sample directly from the DAC output via the precision resistor R. To measure the applied current, the voltage drop across the resistor is applied to the second input of the ADC–DAC board, and the current is calculated by the computer. The control program written in the Borland C++ language outputs the measured results to a display in real time in graphical, in text form, and as a file; it also calculates the conductance taking into account all correction coefficients and root-mean-square errors.

The ultrahigh-vacuum chamber is equipped with optics for low-energy electron diffraction (LEED), two holders for samples, Al source, and viewing windows.

The surface layer formation was observed by the LEED method while viewing a crystalline structure of the surface.

As substrates, we used rectangular monocrystalline silicon wafers ($19 \times 5 \times 0.45$ mm) with a surface orientation of (100) and a resistivity of 50 Ω cm.

To form an atomically pure silicon surface, the silicon substrate was annealed in ultrahigh vacuum at 1200°C [4]. As a result of the annealing, a 2×1 superstructure was observed by using the LEED method. This corresponds to the formation of a Si (100) 2×1 surface phase.

At a substrate temperature of about ~600°C, aluminum was evaporated onto it from a source. According to a phase diagram for aluminum on Si (100) [4], a Si (100) with a (4×12)-Al surface phase is formed under these conditions. This is also observed by using the LEED method. The aluminum coating in this surface phase is about 0.45 monolayers. Further annealing of the substrate at a temperature of 1200°C results in evap-

0020-4412/01/4405-0698$25.00 © 2001 MAIK “Nauka / Interperiodica”