MICROPROCESSOR CONTROLLED FOUR-AXIS GONIOMETER

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A four-axis vacuum goniometer for application in ion beam channeling is described. It has three axis of rotation and one translation stage for movement in horizontal direction. The error reproducibility has been found to be less than one step. The microprocessor controlled goniometer is driven by vacuum stepper motors that are located within the vacuum chamber. The control of four stepper motors may be executed either from the front panel of control unit or from the host computer across the serial port. The sample can be heated up to 900° C.

I. INTRODUCTION

To investigate the location of impurity atoms and nature and depth distribution of lattice disorder channelled Rutherford backscattering spectrometry (RBS) is widely used technique [1]. An use of the channeling effect impose the certain requirement both on the divergence of ions beam and on the precision orientation of the studied crystal target. Moreover, one must be able to vary the position and the orientation of the sample during the experiments within a wide angle range. Therefore a goniometer must be used which combines a wide angular range with the ability to move in very small steps about rotation axes. It is also important to execute all manipulation with crystal in automatic mode. The above considerations have led us to the design the microprocessor controlled goniometer described in the following.

II. THE GONIOMETER MECHANISM

A schematic diagram of the four-axis goniometer is shown in fig.1. The goniometer includes three independent motor driven angular rotations and one transverse Y-translation of the target stage. It is also necessary to allow for movement to another spot on the sample surface if damage occurs as a result of the irradiation.

The goniometer occupies the space of 240 mm diameter with height of 240 mm. It is mounted vertically on the bottom flange of a target chamber. The distance of the centre-line of the three axis from the top surface of the bottom flange is 185 mm. The vacuum stepper motors with the step of 3 deg. are placed inside a vacuum chamber. For the ease of installation of each axis and the inspection of the functionality and precision of the mechanical parts the reference scales for each movement are provided.

The first rotation takes place about the vertical axis Z, indicated in fig.1 by angle α and has the range of -10 to +70 deg. with a step of 0.004 deg. The stepper motor M1 drives the sample holder around Z-axis via two pairs of spur gears (Fig. 1, position 2 and 3) and worm and wheel assembly. These gears displace the motor rotation axis and the worm and wheel assembly (pos. 4) then drives the body of goniometer head (pos.17) around the Z-axis directly. The gear ratio of the reduction gear (pos. 2,3,4) is 750.

The second rotation, angle in the fig. 1, involves a tilt of target about the Y-axis and has the range of -20 to + 90 deg. with respect to the vertical with a step of 0.006 deg. The drive from stepper motor M2 to the Y-axis is realised via the worm and wheel assembly (pos. 6) and the pair of displacement spur gears (pos. 5). The gear ratio of the reduction gear (pos. 5,6) is 540.

The third rotation occurs about the surface normal (the azimuth angle β) and has the range of 360 deg. with a step of 0.028 deg. The sample is pivoted around X-axis by the stepper motor M3 through the worm and wheel assembly (pos.7) with the gear ratio of 108.

Besides the rotations there is a possibility for shifting the sample along the horizontal axis Y. This movement is implemented by means of the stepper motor M4 through the micrometer screw (pos. 8). One can shift the sample in this horizontal direction over a distance of 25 mm with a step of 0.004 mm and with an accuracy of 0.01 mm.

The accuracy of the reading and setting with aid of indicated scales for axes Z and Y have the magnitude not a worse than 0.025 deg. and for X-axis has one not a worse than 0.05 deg.

One sample with the diameter up to 80 mm or 21 samples of 10x10 mm^2 may be placed on the target holder. However, as comes out of possible horizontal motion, only the circle of 50 mm diameter can be investigated. The goniometer construction allows also another type of target holder to be used if necessary. For instance, to heat the sample the target holders with direct resistive heating are used. The sample with size up to 20 mm may be placed on those type of holder. The temperature to which a sample may be heated is limited by the heat loss from the oven and sample to its surroundings and may be reached up to 900 °C.

To compensate for difference in target thickness the additional manual control is included. This adjustment can be as large as 9 mm.

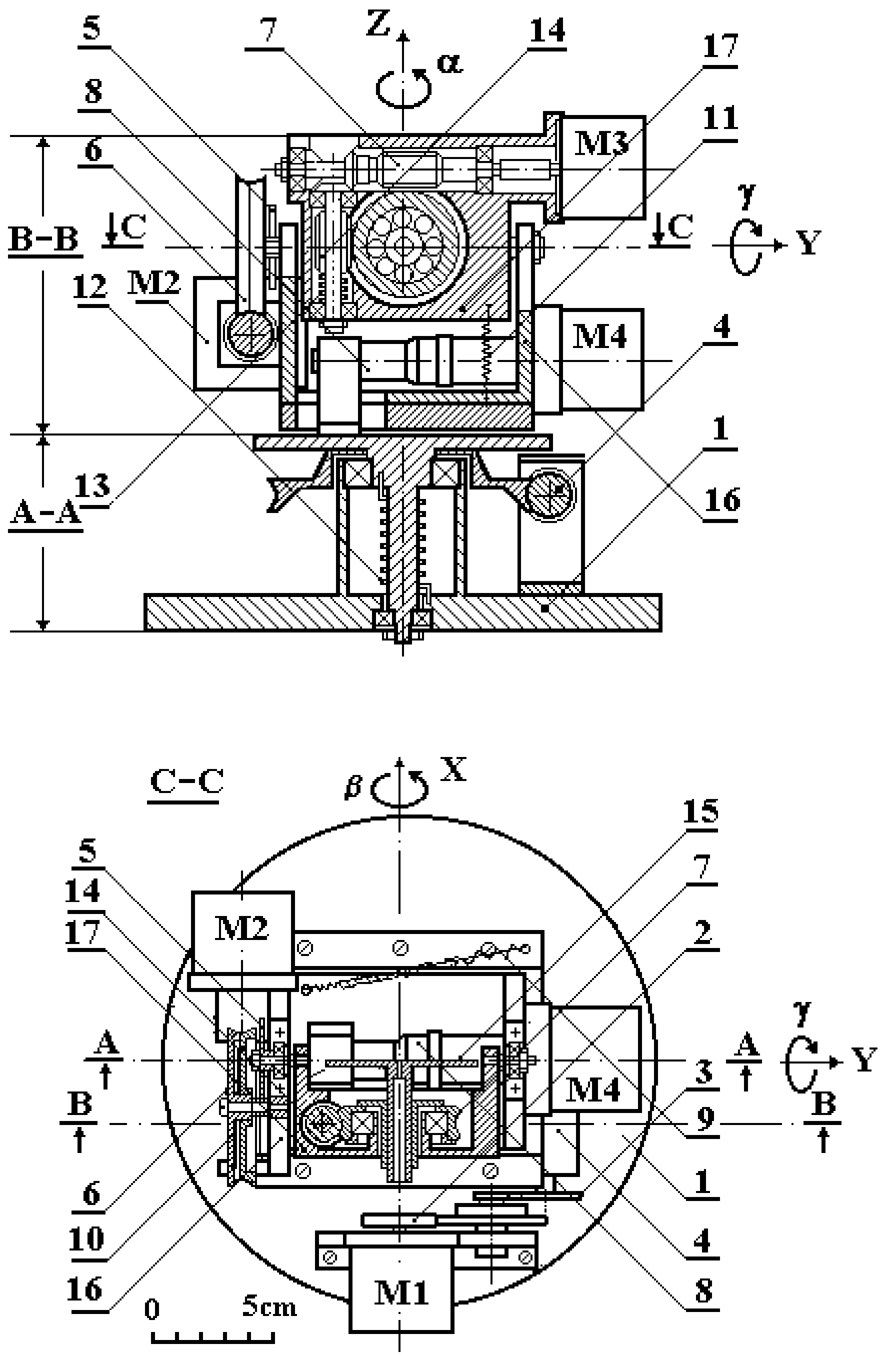

Fig.1. Schematic diagram of the goniometer.

M1,M2,M3,M4 - stepper motors; 1 - the basis of the goniometer; 2 and 3 - two pairs of spur gears; 4 - worm and wheel assembly; 5 - displacement spur gears; 6 - worm and wheel assembly; 7 - worm and wheel drive; 8 - micrometer screw; 9, 10, 11, 12, 13 - anti-backlash springs; 14 - anti-backlash worm; 15 - target holder; 16 - basic support bracket of goniometer head; 17 - body of goniometer head.

All construction parts of the goniometer including ball bearings are made of stainless steel, the gears and worm wheels are made of bronze. As a gear lubricant the molybdenum disulphide is used.

III. CONTROL UNIT AND TEST RESULTS

To control the four stepper motors of goniometer the microprocessor based control unit was designed. Motors may be selected and operated either from the front panel switches or from host computer across the serial port, i.e. the control unit based on autonomy microprocessor performs the all control and exchange operation [2]. That kind of solution enable one to simplify the control algorithm of goniometer and to organize easily the inspection of the motors temperature, the the motors movement in the given limits, the display of angle and translation magnitudes, the connection with host computer.

Single-step or multiple-step operation with a controlled acceleration, retardation and preset repetition numbers are available. For the sake of excluding the error condition during the control of goniometer and to keep the axes co-ordinates in the storage there is the non-volatile memory and data protections in case of power turn off or any of supply voltages decreases under the limiting level. To exclude the data losses in case of power failure the check of data integrity and authenticity in internal RAM of control unit is carried. The setting of the initial co-ordinates is fulfilling from the front panel with the aid of automatic time switch within limits 0 and 9999 steps.

In the manual mode the all function of control unit is supported by the monitor subprogram stored in the internal ROM of control unit. The subprogram carries out a display on the indicators the co-ordinates and the state of the control unit. The operation beginning of selected motor is taking place only after the special command.

The remote control set up with the suitable switch on the front panel. In this mode the host computer is able to read the memory contents of control units and to set the rotation direction and the step number of acceleration and operating of the motor and also to put the selected motor into the operating and the stopping.

The reproducibility of the goniometer, developed for the target chamber of Ion Beam Laboratory at STU (Bratislava) [3], were tested by an optical method using a diode laser fixed on target holders. These measurements showed, that the settings on all three axes were reproducible to less than one step.

IV. CONCLUSION

The near surface analysis technique of RBS combined with channelling demands the user of a goniometer with a wide angular range that is also capable of being moved over small angles in an accurate series of steps. The microprocessor controlled goniometer described here fulfils these requirements. The goniometer construction allows to investigate the samples with the diameter up to 80 mm or up to 20 mm with the heating.

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