Wafer manipulating robots – design, programming and simulation

ADRIAN FLORIN NICOLESCU, GEORGE ENCIU, ANDREI IVAN, GEORGIA CEZARA AVRAM, DAN ANDREI MARINESCU
Machines and Production Systems
Politehnica University of Bucharest
313 Splaiul Independentei, district 6, Bucharest
ROMANIA
afnicolescu@yahoo.com, enciug@yahoo.com, andrei.mario@yahoo.com, cezara.avram@yahoo.com, marinescud85@gmail.com
http://www.pub.ro

Abstract: - The paper presents achievements made in original works performed by authors in the field of virtual prototyping atmospherical wafer manipulating robots and specific application for atmospherical wafer manipulation tasks. There are succesively presented virtual prototypes of a four degrees of freedom SCARA robot type for wafer atmospherical manipulation, and wafer processing equipment including atmospherical operation area, peripheral equipment for wafer storage and above mentioned robot, as well as specific software modules for robot manual control and teach-in and real time robot programming and simulation.

Key-Words: - wafer, robot, virtual prototyping, programming, simulation

1 Introduction

This paper presents the results of research and development activities performed by the authors regarding the wafer manipulation robots and their specific applications.

Considering the fact that the wafers are important components in electronic equipment – being used in structures such as microprocessors, memories, integrated circuits, etc – their precise manipulation and manufacturing represents an important issue. Because there are operations that require high accuracy and repeatability, as well as small payloads, wafer manipulation is an ideal task for light robotic equipment [1].

Robot type – operation method	Process stages in which the robot is involved
Vacuum environment	Physical and chemical vacuum deposition, wafer transfer and loading/unloading into processing equipment
Atmospherical environment	Wafer loading/unloading; wafer slicing and polishing; wafer introduction in transfer room

Table 1 – Types of robots used in wafer manipulation and processing, according to the environmental conditions

The semiconductor-type electronic components can be processed in two different environmental conditions: atmospherical and vacuum. According to these conditions, different types of robotic manipulators are used, as shown in Table 1, Fig. 1 and Fig. 2.

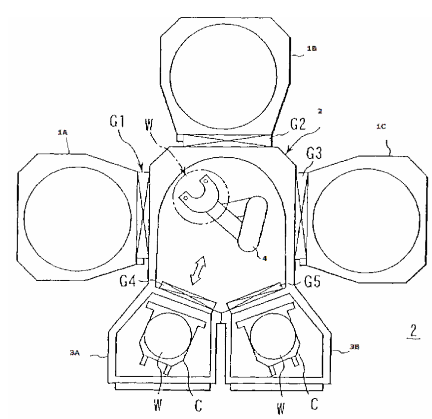


Fig. 1 – Wafer manipulating robotic system for vacuum environments

To exemplify wafer manipulating robot using in above two mentioned environments, two specific applications are presented in Fig. 1 and Fig. 2.

The system illustrated in Fig. 1 is a vacuum processing system including three processing vacuum chambers (1A, 1B, 1C) coupled with a transfer chamber (2) through the valves G1, G2, G3. The transfer chamber is also coupled with two chambers (3A, 3B) in which the boxes containing wafers are stored. The vacuum operating robot, placed in the transfer chamber, takes a wafer from a box and moves it to the corresponding processing chamber (it can also transfer wafers between processing chambers if needed).

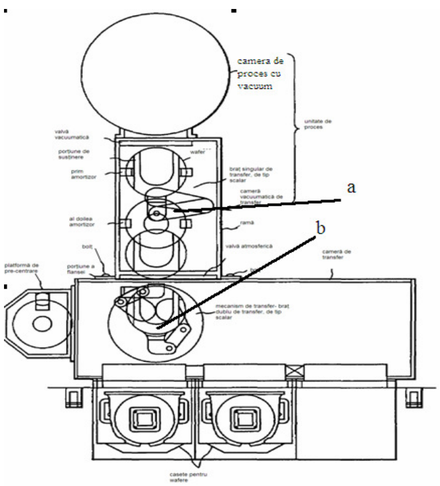


Fig. 2 – Wafer manipulating robotic system with atmospherical transfer chamber

The system illustrated in Fig. 2 is provided with an atmospherical transfer chamber. It contains a vacuum processing chamber for pickling operations, a vacuum transfer chamber (with a vacuum operating robot) and an atmospherical transfer chamber (including an atmospherical operating robot). The first two (vacuum) chambers constitute a module attached to the third (atmospherical) chamber. The atmospherical transfer chamber also includes the boxes containing wafers to be manipulated.

However, due to specific internal design and specific mounting of vacuum operating robots and atmospherical operating robots, the project has been developed only for a single robot type (the atmospherical operating robot) and appropriate processing equipment (shown in Fig. 2), the rest of the paper presenting exclusively this approach.

2 The robotic manipulator designed for atmospheric environments

For wafer manipulation in atmospherical environment, a SCARA-type robotic manipulator with four degrees of freedom has been developed, first as a virtual prototype using the CATIA software. Fig. 3 illustrates a perspective view of the designed atmospherical operating robot with internal components exposed [2].

The robotic arm is sustained by a support that includes the partial assembly generating first (rotation) degree of freedom for the robotic arm system, and a vertical extending column (second degree of freedom for the robotic arm system), as shown in Fig. 3. The base rotation is performed through a spur gears and timing belt system, and the vertical translation is performed through a ball-screw system (see Fig. 4).

The robotic arm system also includes three elements linked by rotary joints (through timing belt systems – see Fig. 5): first and second links of the articulated arm respectively the end-effector orientation system. The last element of the robotic arm system is a (vacuum operating) ceramic end-effector special dedicated for wafer manipulation (see Fig. 6).

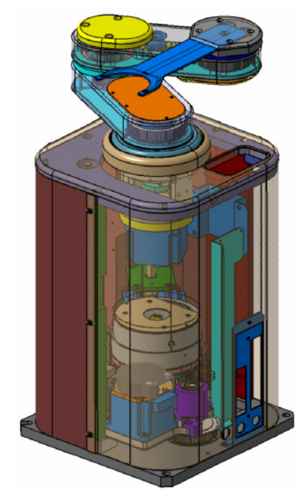


Fig. 3 – SCARA-type robot designed for wafer manipulation in atmospheric environment

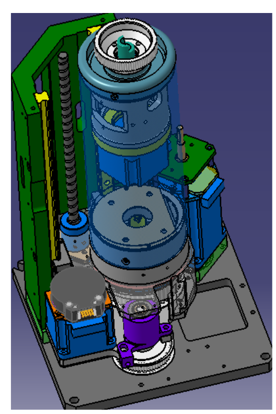


Fig. 4 – Base rotary/vertical sliding system

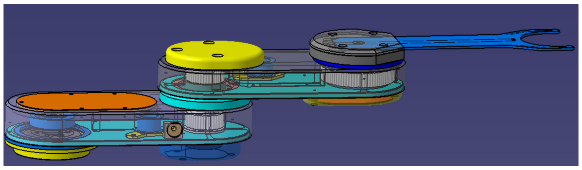


Fig. 5 – Robotic arm elements

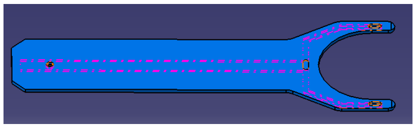


Fig. 6 – Robotic arm system end-effector

3 The wafer processing system – design and simulation

As a second step in present approach, the virtual prototype of the wafer processing system has been developed (see Fig. 7). It includes the following elements:

- a wafer storage modular system including three boxes containing wafers (see Fig. 8), placed on special supports (see Fig. 9);
- an atmospherical transfer area;
- an atmospherical operating robot, having a base translation system allowing multiple workstation operation (including a slide, a driving motor and a pair of rails and a rack-pinion system – see Fig. 10);
- the valve that connects the atmospheric transfer chamber with the vacuum transfer chamber.
- a pre-alignment system for wafer orientation (see Fig. 11);
- the vacuum processing system including a (non-represented) vacuum operating robot;

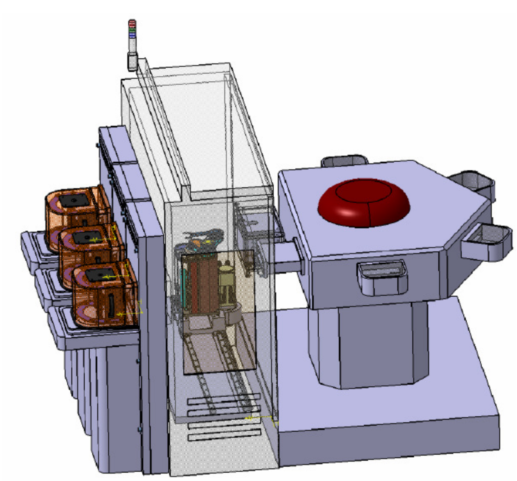


Fig. 7 – The designed wafer processing system

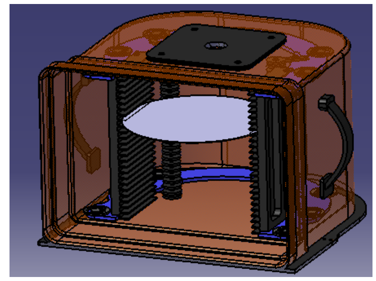


Fig. 8 – Wafer storage box

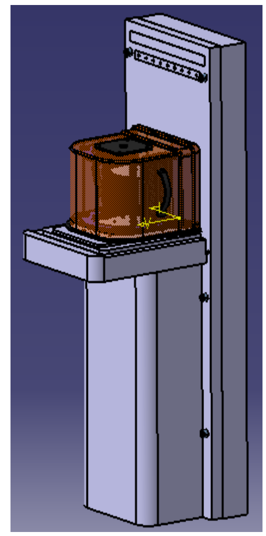
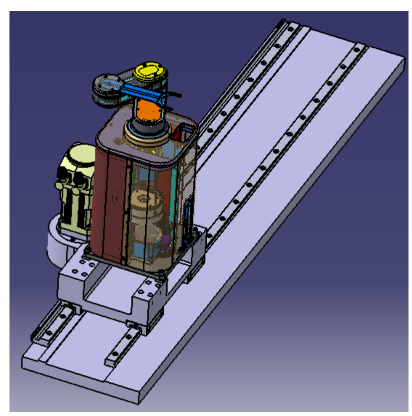


Fig. 9 – Support for wafer storage box



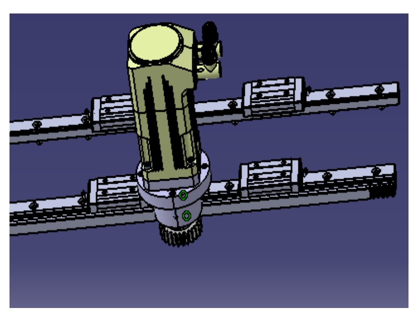


Fig. 10 – The sliding system for the manipulating robot

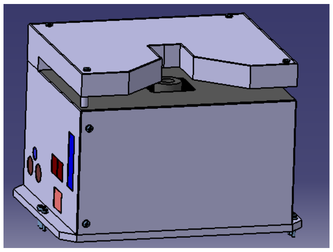


Fig. 11 – Pre-alignment system for wafer orientation

In order to fully illustrate the operating principles and the functionality of the atmospherical robotic arm system, a simulation has been made using the virtual prototype of the processing system developed in the CATIA environment and the DMU Kinematics software module (see Fig. 12). This simulation shows how a multi-transfer operation of the wafers between the wafer storage system, pre-aligner and the valve that connects with the vacuum processing system is performed by the atmospherical operating robotic arm [1],[2].

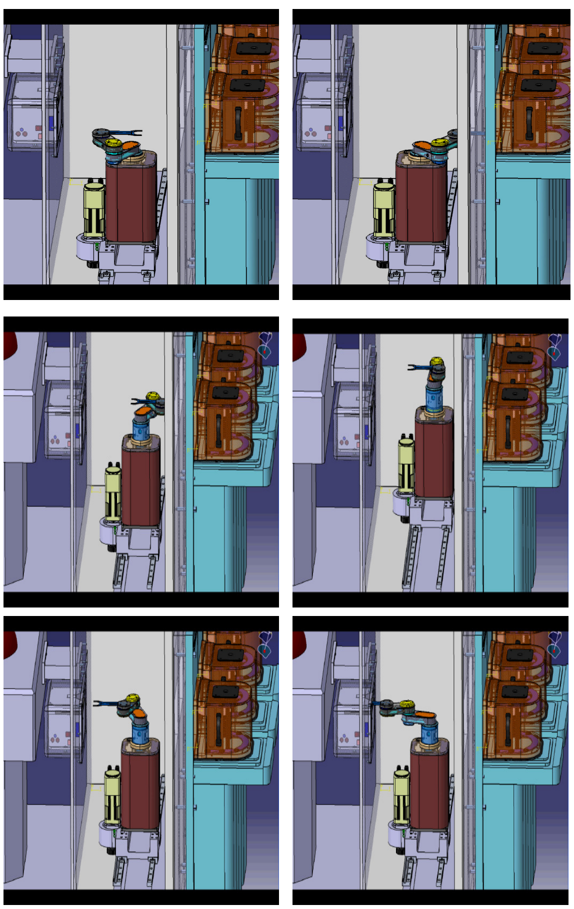


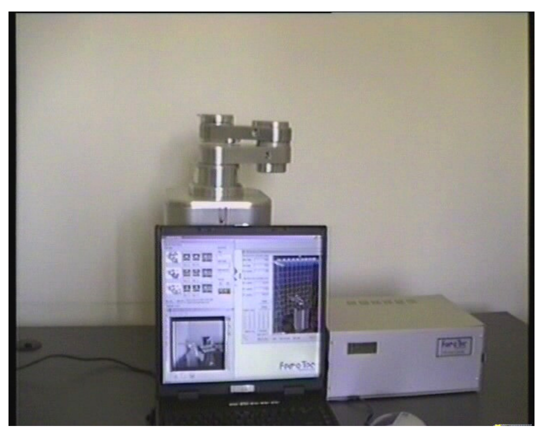
Fig. 12 – Captures from the simulation of the wafer manipulation process

As seen above, the robot picks a wafer from a storage box, it introduces the wafer into the pre-alignment system in order to be correctly positioned on robot's end-effector and then transfers it to the vacuum chamber. Finally, the robot returns to the initial position, and a new cycle begins from a different wafer location of the storage system.

4 Robotic arm system programming

Following virtual prototyping pf the atmospherical robotic arm system, physical (real) robot operational unit has been made in cooperation with Japan and China private companies. As well, the robotic arm system information unit has been designed and its prototype manufactured in a Romanian private company (see Fig. 13). Finally, a software package for robot teach-in and offline programming and simulation (see Fig. 14, Fig. 15, Fig. 16, Fig. 17) has been developed in partnership with above-mentioned Romanian private company.

a) b)



c)

Fig. 13 – The robotic arm system: a) atmospherical operating robot unit; b) robot informational unit (the dedicated robotic controller); c) full system (including the notebook running the simulation and programming software)

The ROBOPACK software is designed for command, control and programming of industrial robots performing wafer manipulation operation. This software package includes:

- an user friendly main graphical interface in English language (see Fig. 14) [3];
- advanced 3D simulation/visualization window (see Fig. 15) [3];
- an editor for the robot's application teach-in and offline programming using an originally developed robot language (see Fig. 16) [3];
- a virtual teaching pad needed in teach-in command of the robot and key-points teaching (see Fig. 17) [4];

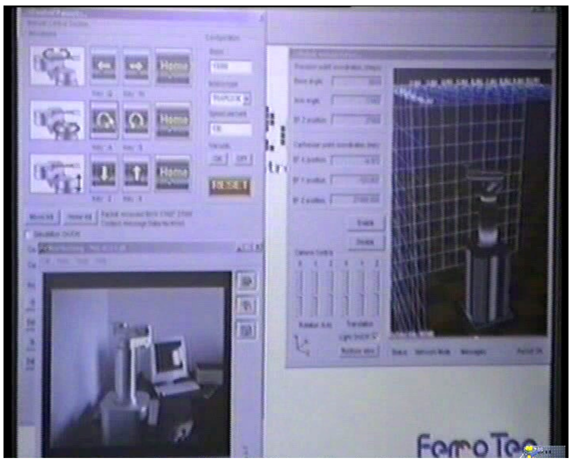


Fig. 14 – The main graphical interface

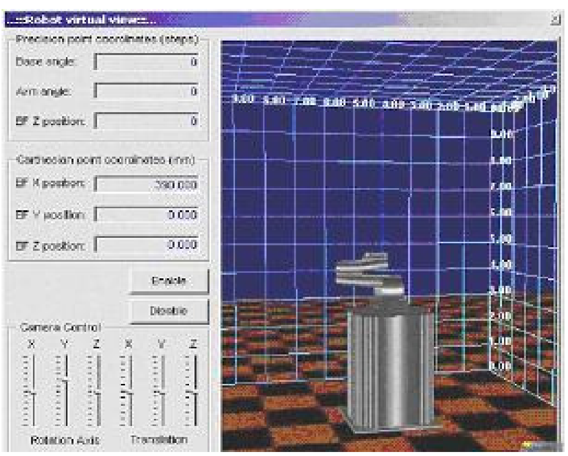


Fig. 15 – 3D simulation/visualization window

The virtual teaching pad can directly control the robot's movements, being able to command movement on each axis of the robot, to set movement direction, movement speed and acceleration values, to memorize key-points, etc.

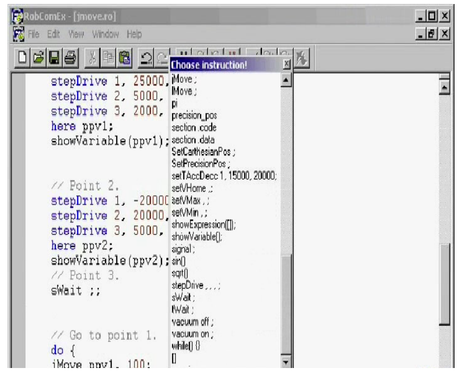


Fig. 16 – The editor for the robot's application programming

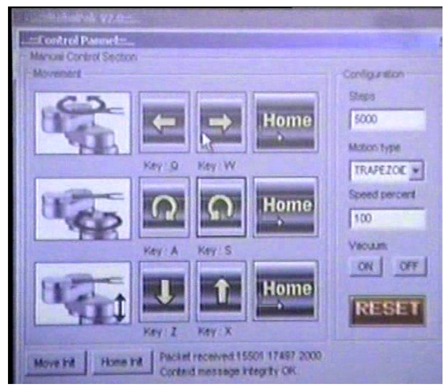


Fig. 17 – The virtual teaching pad

During manual control and teach-in, the visual interface of virtual teaching pad (see Fig. 17) works with real information supplied by the position transducers mounted on each robot axis [5], [6].

Similarly, the advanced 3D visualization / simulation software (see Fig. 15) is able to realize the virtual simulation of a program based on:

- programming information for the case of offline programming and simulation procedures [3], [4], as well as
- real robotic system information supplied by the position transducers mounted on each robot axis, in case of robot manual control, teach-in or real task / program executions [5], [6].

As result, the overall programming and simulation software allows a real time visualization of robot movements in both simulation procedure and real task / program execution.

The programming language is useful for both robot teach-in programming and offline programming. It includes user friendly instructions and commands, usually to be selected from predefined pull-down menu, and inserted directly to the program, and as well the capability to directly

ISSN: 1790-5117

ISBN: 978-960-474-135-9

edit specific commands / instructions / introducing numerical values by direct typing.

For complex programming task the advanced 3D visualization / simulation software can be easily configured for including in the work scene peripheral equipment or different other objects that need to be correlated with robot functionality.

5 Conclusions

The paper presents achievements made in original works performed by authors in the field of virtual prototyping atmospherical wafer manipulating robots and specific application for atmospherical wafer manipulation tasks.

There were successively presented virtual prototypes of a four degrees of freedom SCARA robot type for wafer atmospherical manipulation, and wafer processing equipment including atmospherical operation area, peripheral equipment for wafer storage and above mentioned robot, as well as specific software modules for robot manual control and teach-in and real time robot programming and simulation.

References:

[1] X2. Nicolescu, A., *Industrial Robots Implemented into Robotic Manufacturing Systems (work in progress in Romanian)*, EDP Publishing House, 2009

[2] X1. Nicolescu, A., *Industrial Robots (in Romanian)*, EDP Publishing House, 2005

[3] X3. ROBOPACK programming and simulation software, *Operating manual*

[4] X4. ROBOTEACH virtual teaching pad, *Operating manual*

[5] X5 Iliescu, M. Brinduş, C, Nuţu, *"Signal Processing's Importance in Manufacturing of a Special device,* WSEAS Transactions on Signal,

[6] X6 Iliescu, M. Rosu, M. Spânu, P. *Signal Processing – Key Element in Designing an Accurate Machining Forces Measuring Device*, 8th WSEAS, International Conference on Signal Processing, Robotics and Automation (ISPRA '09), pag. 234-239, ISBN 978-960-474-054-3, ISSN 1790-5117, Cambridge , UK , February 21-23, 2009