A Concept of Collision Prevention during Micro Assembly in a SEM Chamber

Al. Cvetanovic[a] , An. Cvetanovic[b], M. Soucek[c] D. Andrijasevic[a], W. Brenner[a]

[a] *Institut of Sensors and Actuator systems, Vienna University of Technology, Floragasse 7/2, A-1040 Wien*
[b] *Integrated Mycrosystems Austria, Viktor Kaplan Straße 2, A-2700 Wiener Neustadt*
[c] *Tomeckova 3, CZ-63800 Brno*

Abstract

This paper presents a concept for avoiding collisions during micro assembly processes in the chamber of a Scanning Electron Microscope (SEM). The focus is the phase during which a micro gripper approaches the specimen holder and the phase during which the micro components positioned on it are picked up. Although the position of the gripper tips should be known exactly, the current design of equipment in the SEM chamber does not allow an assessment of the position in the z-direction (vertical axis). This uncertainty of relative positions causes a high risk that tips of micro grippers could break if they collide with the specimen holder, because the operator has no information about the distance. Mounting of an additional camera on the existing tweezers-gripper module is proposed for the purpose of providing information about the distance between micro gripper and micro component. The working principle is based on evaluation of the fictive distance (to the virtual image) between the approaching gripper tips and their mirror image on the reflecting holder.

Keywords: collision avoidance, micro assembly, SEM

1. Introduction

Assembly of micro components can be realized under the optical microscope but in a SEM chamber.
The assembly in the SEM chamber has its application in cases where a great resolution(ability of a microscope to distinguish between two objects, depends from the wavelength of the energy source that is used for specimen image) depth of field(area in front of and behind a focused subject in which the image appears sharp) as well as large working distance (distance from the front lens element of the objective to the closest surface of the specimen surface when the specimen is in sharp focus) is needed.

Nevertheless, there are a lot of restrictions concerning manipulation of micro components, its positioning and orientation in the given system. Due to the fact that there is no possibility of observing the approach of the micro gripper to the micro components in the z-direction in the SEM chamber, collisions occur often. In this paper we dealt with the problem of collision between the gripper and the specimen holders or stage with protective cover. [1a], [1b]

2. Existing equipments for micro assembly in SEM chamber

The system used for micro assembly at the Institute of Sensors and Actuator Systems consists of a module with tweezers and micro gripper (Figure 1, detail 1 and 2) and a protective cover (Figure 1, detail 3) that protects micro components on the specimen holders from the suction during the formation of a vacuum. Due to the fact that there is no possibility of observing the approach of the micro gripper to the micro components in the z-direction (vertical axis) in the SEM chamber, collisions occur often. Figure 1 shows the view of the CCD camera mounted inside the chamber.

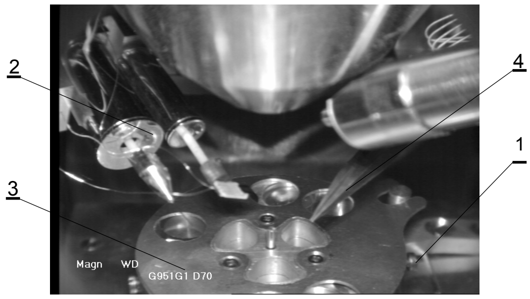

Fig. 1 View of the CCD camera inside the SEM chamber.

The stage with specimen holders (Figure 1, detail 4) could be tilted to 45° but it is not enough to avoid the break between the gripper and the specimen holders.

Figure 2 shows the image when the electron beam is on. As can be seen, confirming whether the wire is horizontally or vertically positioned or the distance between the micro gripper and the holder is not possible. The operator drives the micro gripper down but has no information about the vertical distance to the specimen holder and the gripper breaks after colliding with the stage or specimen holder.

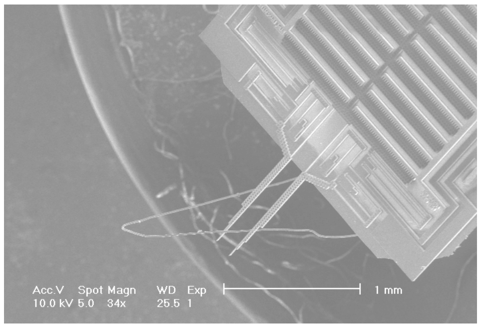

Fig. 2 Wire 10 μm on the specimen holder

3. Different potential solutions for solving the collision

In order to prevent the collision a distance sensor and micro camera have been considered.

Because there are specific conditions in the SEM chamber, the sensor that could be integrated has to fulfil the following requirements:

- contactless principle of work
- no magnetic field which could deflect or spread the electron beam
- no glue which could evaporates
- high sensitivity to
- very small dimension
- simply mounting and use

As it is very difficult to find a really adequate sensor and time consuming to modify some, we have decided to use a micro camera. It is low priced,, simply to manipulate and to install and when equipped with a housing, completely compatible with the SEM chamber.

3.1. Specimen holders coating

In order to achieve optimum results the specimen holders are coated with a conductive, reflective material. Micro gripper and micro component reflect (image) on the specimen holders and the approach can be inspected in detail because we can see when the gripper nears the micro component in the mirror (Figure 3).

The coating material is aluminium; the material has to be conductive because of the SEM's principle of image generating. Both the micro gripper's image and its mirror image have to be sharp.

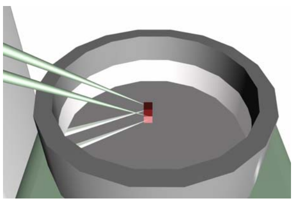

Fig. 3 Micro gripper and its mirror image on the aluminium coated specimen holder

4. System for prevention of the collision between micro gripper and the stage - analysis of the depth of the field

The most important thing considering the place of the camera positioning is compromise between magnification and the depth of field.

The draft of the system is shown on Fig. 4. It is not proportional so that the whole system can be shown.

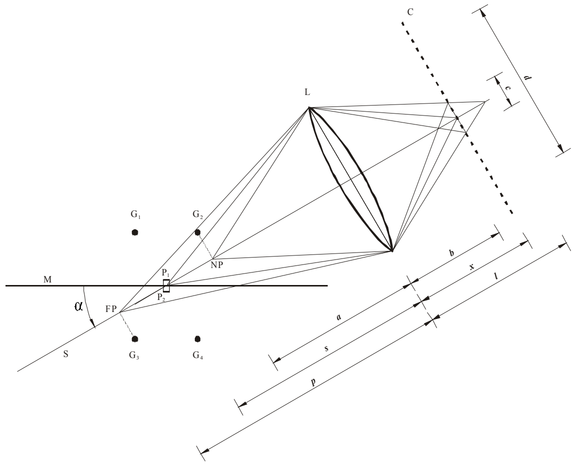

Fig. 4 System for collision prevention [1]- [6]

System parts and symbols:

G_1, G_2 – micro gripper fingers
G_3, G_4 – micro gripper mirror image
P_1 - micro component
P_2 – micro components mirror image
M – mirror
S – symmetric axis of the optical system
C – plain of the CCD chip of the camera
c – size of the single cell of the CCD chip. It is the maximum permissible circle of confusion (to calculate a camera's depth of field one needs to know how large a circle of confusion can be considered to be an acceptable focus)
d – lens diameter
NP –object G1 projection to the symmetric axis of the system. Lower boundary of the area that has to have satisfying depth of field (near point)
FP – object G3 projection to the symmetric axis of the system. Upper boundary of the area that has to have satisfying depth of field (far point)
L – lens. Because of the simplification, only one lens is shown and its parameters are defined as parameters of the equivalent lens for the system of the lens used in the experiment.
a - distance from the near point NP to the symmetric axis of the lens
b - distance from the mirror image of the near point NP to the symmetric axis of the lens
p - distance from the far point FP to the symmetric axis of the lens
l - distance from the mirror image of the far point FP to the symmetric axis of the lens
s – distance from the micro component of the lens symmetric axis
x - distance from the mirror image of the micro component of the lens symmetric axis
α – slope of the symmetric axis of the optical system to the mirror plain

Working principle of the system is as follows: the distance between the micro gripper's finger and its mirror images is twice the distance between the micro grippers and the mirror. Important is that the satisfactory depths of field the furthest object (G3) and the nearest object (G1) have to be sharp reproduced (focused image in the area of the determined depth of field).

$$\frac{1}{l}+\frac{1}{p}=\frac{1}{f} \qquad (1)$$

$$\frac{1}{s}+\frac{1}{x}=\frac{1}{f} \qquad (2)$$

$$\frac{1}{a}+\frac{1}{b}=\frac{1}{f} \qquad (3)$$

From similarity of triangle (Figure 4) can be written:

$$\frac{c}{d}=\frac{l-x}{l} \qquad (4)$$

$$\frac{1}{l}=\left(1-\frac{c}{d}\right)\frac{1}{x} \qquad (5)$$

(1) and (2) into (5)

$$\frac{1}{f}-\frac{1}{p}=\left(1-\frac{c}{d}\right)\left(\frac{1}{f}-\frac{1}{s}\right)$$

$$p=\frac{dsf}{cs+f(d-c)} \qquad (6)$$

$$\frac{c}{d}=\frac{x-b}{b} \qquad (7)$$

$$\frac{1}{b}=\left(1+\frac{c}{d}\right)\frac{1}{x} \qquad (8)$$

(2) and (3) into (8)

$$\frac{1}{f}-\frac{1}{a}=\left(1+\frac{c}{d}\right)\left(\frac{1}{f}-\frac{1}{s}\right)$$

$$a=\frac{dsf}{-cs+f(d+c)} \qquad (9)$$

The next equation represents distance between NP and FP from the lens. Now can be calculated the depth of field in the same way as its difference:

$$p-a=dof=\frac{dsf}{cs+f(d-c)}+\frac{dsf}{cs-f(d+c)} \qquad (10)$$

[1]- [7]

Analysis this equation to the value s would give us information about the micro component's distance from the lens axis and in this way the depth of field can be defined. The term "lens" are related to the equivalent lens, result from the combination two or more lenses (micro camera lens and magnification lenses).

Due to the complexity of this equation we have designed dependence of depth of field from the focal distance of the lens and the distance between micro components from the lens. Figure 5 is obtained on the basis of the equation (9) and shows the distance at which the micro camera has to be positioned to obtain a satisfactory depth of field

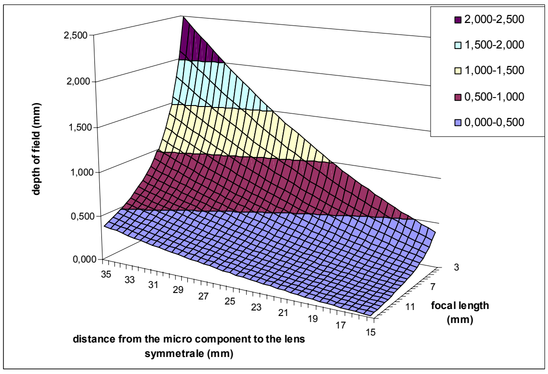

Fig.5 Depth of field depending on the focal length of the lens and the distance micro camera-micro component

Our system has two or more lenses, depending on the size of the micro component. It is necessary to calculate the focal length of the equivalent lens. The depth of field is function of the equivalent lens' focal length, the distance between micro component and lens, the lens diameter (aperture size) and the size of the CCD chip's single cell. We had five different lenses and the depth of field could be calculated by combining them.

It is supposed that, for use in order of magnitude one hundred to ten µm, a 500 µm depth of field provides a satisfactory image because both of the micro gripper and its mirror image are reproduced sharply. From the Fig. 5 follows that, for the lens focal distance 4 mm, d=3mm (equivalent lens as combination of two lenses f_1=25mm, d_1=12mm and f_1=7mm, d_1=3mm) the micro camera had to be at 25 mm to the micro component because this permits a depth of field 500µm.

4.1. Experimental verification

The optimum distance between camera and lens was controlled by means of the set up (Fig. 6)

The whole system represents an adjustable microscope and provides experimental verification of the calculated results. The lenses (Fig.6 detail 1) can be moved along the linear guide (Fig. 6 detail 2) and also combined. The platform with the micro camera (Fig. 6, detail 3) can be moved in the same way as the platform with the micro component (Figure 6, detail 4). The focal length of the equivalent lens, magnification and depth of field are changed.

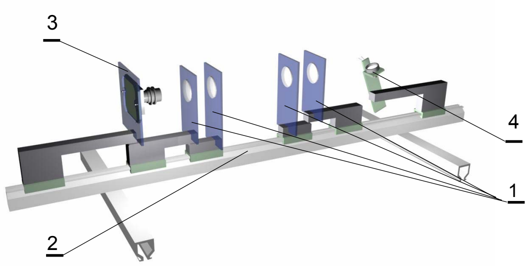

Fig. 6 Set up for experimental analysis of the depth of field

A compromise between the needed magnification and a satisfactory depth of field represents an optimum result.

Figure 7 shows the mirror image on the coated specimen holder in the dark with a infrared source of light, the condition that dominates in the SEM chamber. A sharp image of both the micro gripper and its mirror image that confirms the results of the calculation are obtained.

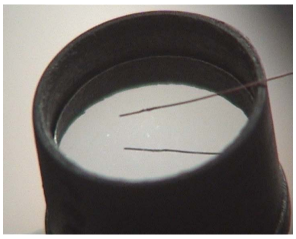

Fig. 7 Wire 50 µm, and its image on the aluminium coated specimen holder

5. Mounting

Micro camera will be mounted on the existing tweezers module and driven by three piezomotors (Figure 7, detail1). The two-part platform (Figure 7 detail 2) can be rotated on two planes, which enables coarse adjustment while three piezomotors are used for fine adjustment.

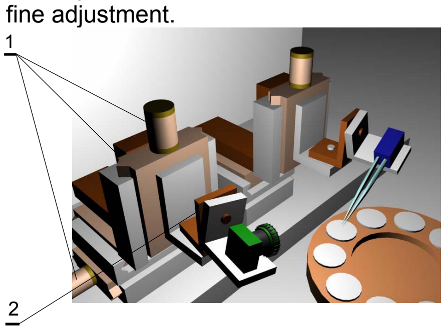

Fig. 8 Micro camera mounted on the tweezers module

The whole system is screwed onto the SEM chamber's interior and will be controlled both manual and by Lab View.

Acknowledgements

This work was supported by FP6 MarieCurie Research Training Network "Advanced Methods and Tools for Handling and Assembly in Micro technology - ASSEMIC", funded by the European Commission, Contract no. MRTN-CT-2003-504826. Also, this work was carried out within the framework of the EC Network of Excellence "Multi-Material Micro Manufacture: Technologies and Applications (4M)".

References

[1a] S. Fatikow, J. Seyfried, St. Fahlbusch, A. Bürkle und F. Schmoeckel, A Flexible Microrobot-Based Microassembly Station, Journal of Intelli-gent and Robotic Systems: 135-169, 2000.

[1b] Al. Cvetanovic, An. Cvetanovic, D. Andrijasevic, I.Giouroudi, W. Brenner "A Novel Protective Cover in Assembling of Micro Components in a SEM Chamber", The Second IEEE Conference on Automation Science and Engineering (IEEE-CASE), October 8-10, 2006, Shanghai, China

[1] Hansma, Paul K. 1996. View Camera Focusing in Practice. Photo Techniques, March/April 1996, 54–57.

[2] Larmore, Lewis. 1965. Introduction to Photographic Principles. 2nd ed. New York: Dover Publications, Inc. / http://en.wikipedia.org/wiki/Depth_of_field

[3] Merklinger, Harold M. 1992. The INs and OUTs of FOCUS. / http://en.wikipedia.org/wiki/Depth_of_field

[4] Ray, Sidney F. 2002. Applied Photographic Optics. / http://en.wikipedia.org/wiki/Depth_of_field

[5] Shipman, Carl. 1977. SLR Photographers Handbook. Tucson: H.P. Books. ISBN 0-912656-59-X [2] Singh B. In: Liu B (Ed.) Probability maps (2nd edn). Springer, Berlin, 1988, pp 154-187.

[6] Ruck MJ., High-resolution spectroscopy of late-type stars., D.Phil. Thesis, University of Oxford, UK, 1994.

[7] Dr Dragisa Ivanovic, Vlastimir Vucic "Fizika II", Naucna Knjiga, Beograd 1984., 423-429.