Micrometer Precision of Miniature Pattern with a Shape Memory Alloy Stage.

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ABSTRACT

Keywords:
SAM stage;
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Joule effect;
Peltier effect;
Subpexilic;
Command.

In most cases, the stage with piezoelectric actuators, in particular the SAM stage, represents an interesting alternative to the classic manual stage. Because it has the advantages of high precision, a significant possibility of miniaturization, and above all the simplicity and ease of development of these contactless sensors. This article demonstrates that, with proper design, we can make and develop a SAM stage able to track and manipulate a high-precision coded pattern. This pattern is used to measure and track the movement of a miniature target placed below a vision system (optical microscope and camera). This technique is particularly interesting when a contactless sensor is necessary, and especially to avoid the disturbance of miniatures targets that have a high sensitivity to external excitations.

1. Introduction

The miniaturization of mechanisms and microelectromechanical systems (MEMS) require reliable and precise handling (1). Microscope object manipulators consist of several micro-positioning stages which are generally based on automatic or manual controlled systems (figure 1a).

The microscope stages have imperfections that prevent the vision system from achieving the required micrometric precision.

And to minimize these imperfections, we propose in this article a new technique of two-dimensional measurement thanks to a contactless position sensor which consists of two systems:

- Image acquisition system (camera and lens) linked to image processing software capable of extracting position and dimension information.

- SAM stage and a coded pattern (2,3,4) which constitutes the system of manipulation and tracking of the miniature target (figure 1b).

Therefore, this article is divided into three sections. the first section explains, based on the illustrations, the operating principle of the AMF stage as well as the method of measurement by this technique. the behavior of SAMs is explained in the second section. and finally, the third section presents the control and command system of the SAM stage.

2. Presentation of the microscope stage

The manual stage replaces by a stage manipulated by SAM bars in-plane (XYR). The SAM stage performs micrometric movements thanks to the expansion and contraction of the SAM bars; this process is controlled by an electric current

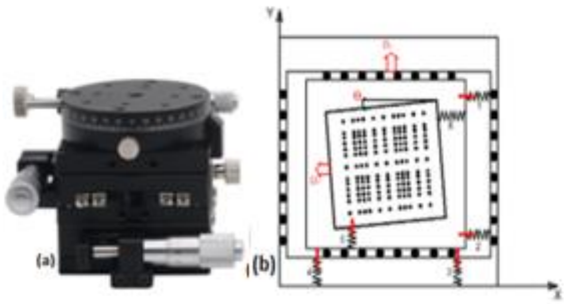

Figure 1: a) 3 axis XYR manual positioning stage. (b) simplified diagram of a 3D stage manipulated by ASM bar.

The goal is to obtain a system capable of superimposing the pattern (figure 2a) on an image of a MEMS (figure 2b) or a miniature robot (6) to obtain subpexilic measurements on the image (figure 2c).

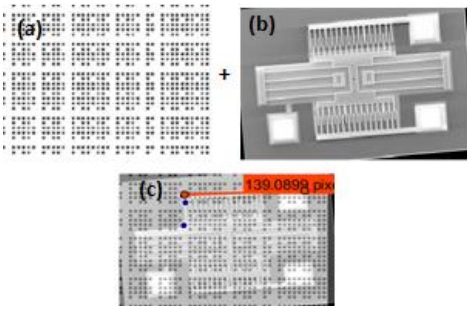

Figure 2: Principle of measuring and tracking the movement of a MEMS with the coded pattern.

3. SAM behavior modeling

In this study we adopt the model of Tanaka which was the first to propose representing the thermomechanical behavior of shape memory alloys during direct austenite-martensite and inverse martensite-austenite phase transformations by the following one-dimensional relationship (5):

$$\Delta\sigma = E(\xi)\Delta\varepsilon + \Phi(\Delta T) + \boldsymbol{\Omega}(\boldsymbol{\xi})(\boldsymbol{\Delta\xi} \qquad (1)$$

4. SAM bar deformation command

The simplified convection heat transfer model (1) determines the rate of heating and cooling due to ramp electric current passing in the wire is defined as:

$$mc_p \frac{dT(t)}{dt} = \nu I - h_c A_c[T(t) - T_a] \qquad (2)$$

Where $\boldsymbol{m}$ is the mass of the wire; c_p is the specific heat capacity; h_c is the heat convection coefficient; $\boldsymbol{T_a}$ is ambient temperature; I is the current flow; v is the potential difference across the wire; $\boldsymbol{A_c}$ the wire convective surface.

The exploitation of the two thermomechanical effects; the Joule effect and the Peltier effect in order to control the bars of the stage as shown in figure 3

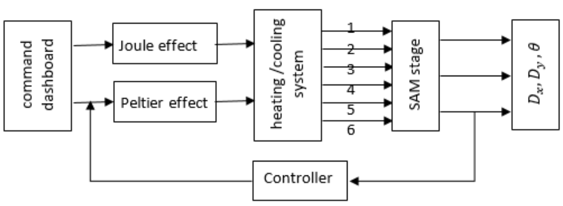

Figure 3: Command and control of the SAM stage.

Obtaining certain displacements is done by inducing the appropriate bars. The following table shows the bars excited (expansion or contraction) for each displacement.

Table 1: The SMA bars excited according to the desired displacements.

desired displacement	bars excited
$D_x, -D_x$	$(1,2), \overline{(1,2)}$
$D_y, -D_y$	$(3,4), \overline{(3,4)}$
θ	$(6, \overline{5})$
$-\theta$	$(\overline{5}, 6)$

5. Conclusion

We have proposed in this article a new SAM stage. These stages seem to be preferred candidates for applications that require contactless sensors, high precision, and large working ranges.

In the future, it is interesting to work on increasing the precision of these stages thanks to the use of high sensitivity SAMs to the small variations in the electric current.

6. References

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