Mechatronics 21 (2011) 1272–1278

Contents lists available at SciVerse ScienceDirect

Mechatronics

journal homepage: www.elsevier.com/locate/mechatronics

# Long term thermal drift study on SPM scanners

F. Marinello [a,*], M. Balcon [a], S. Carmignato [b], E. Savio [a]

[a] DIMEG, Dip. di Innovazione Meccanica e Gestionale, University of Padua, Italy
[b] DTG, Dip. di Tecnica e Gestione dei Sistemi Industriali, University of Padua, Italy

ARTICLE INFO

*Article history:*
Available online 24 August 2011

*Keywords:*
Thermal drift
Scanning probe microscopy
Scanner
Temperature

ABSTRACT

Scanning Probe Microscopy (SPM) imaging process is inherently slow, and commonly suffers from instrumental drift. According to experience, drift is a time dependent phenomenon and therefore it influences measurement results obtained using the instruments for long periods of time, e.g. when high resolution imaging is performed by taking many profiles. Evaluation and control of actuator drift is an important issue for high accuracy measurements. In particular, a better probe positioning can be obtained through characterization of the scanning system's metrological performance, and distinguishing systematic and stochastic behavior components. In this work, a new approach is proposed to study long term thermal phenomena, correlating them to SPM scanner drift distortions evaluated using calibrated reference samples. Long term drift evaluation is then cross-correlated to thermal analyses carried out in parallel by means of an infrared-camera. Eventually, it is discussed how the investigations here presented may be used to improve the instrument set-up in order to reduce measurement uncertainty.



## 1. Introduction

Scanning Probe Microscopes (SPMs), such as AFM (Atomic Force Microscope), SNOM (Scanning Nearfield Optical Microscope) or KPM (Kelvin Probe Microscope), are instruments commonly implemented in characterization of surface topography and other properties (optical, electrical, tribological, etc.) [1]. SPMs can provide measurements in a range of a few tens of micrometers, with sub-nanometre lateral and vertical resolutions [2,3]. Different fields of research and, to some extent, of industrial production benefit from implementation of SPMs, such as micro-electro mechanical and bio-medical systems, data storage and micro-optics devices. The working principle is based on the interaction between a sharp tip (with a tip radius normally smaller than 10–15 nm) and a sample. The surface is scanned in a raster fashion and the topography is reconstructed sequentially, as a collection of consecutive profiles. Such imaging process is inherently slow, and is commonly affected by drift distortions. Drift is an uncontrolled time dependent movement of the tip relatively to the sample surface, which limits the accurate correspondence between acquired points and real surface. Proper modelling and quantification of drift is important in precision positioning and measuring systems: finding strategies to avoid, control or partially compensate it, allows improvement of the actuation quality and eventually reduction of measurement uncertainty [4–10].

## 2. Scanning systems and drift distortions

The scanner is a fundamental component of an SPM: it is responsible for controlling and changing the position of the probe relatively to the sample in order to measure surface properties and topography. With only few exceptions [11,12], SPMs rely on raster scanning: this is a sampling procedure for generating a surface map, based on a line-by-line sweep of parallel profiles.

In order to obtain high lateral resolution, raster scanning is performed with actuators whose motion can be incremented and controlled in nanometric steps. Such actuators are normally made by taking advantage of piezoelectric technology (PZT). PZT materials can be shaped into the form of hollow tubes [13], or coupled to mechanical flexures [14], or a hybrid of the two [15,16]. Voice coil actuators are also implemented, allowing the movement of the probe with good accuracy [14]: such electromagnetic actuators usually have a larger scan range and are cheaper than piezoelectric scanners.

Both piezoelectric and electromagnetic actuations provide very good performance in terms of resolution (down to 0.1 nm), range (up to 500 μm) and speed (larger than 500 μm/s, and more than 50 Hz); on the other hand, some limitations are present and distortions can reduce the positioning accuracy of such systems. In particular, nonlinearities of the actuation are introduced, due to hysteresis, creep, drift or aging effects, causing spatial and temporal distortions of the measuring volume [17]. For this reason, the so called closed-loop SPMs incorporate sensors that can perform a partial linearization and compensation of the displacement. Linear variable differential transformer (LVDT) or capacitive sensors, are

* Corresponding author.
*E-mail address:* francesco.marinello@unipd.it (F. Marinello).

0957-4158/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mechatronics.2011.07.002