Alemnis Nanoindenter Integration in Hitachi TM3030Plus SEM Microscope

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In material science mechanical properties are defined by different tests performed on a sample. Since materials often behave differently in micro and macro scales performing and observing the results of such tests requires specialized equipment. The Alemnis nanoindenter allows such tests while specialized microscopes allow to observe the results. The goal of this thesis is to design a platform that allows real time observation of the nanoindenter in a Hitachi TM3030Plus SEM.

Introduction

Most of the industry relies on the use of metals, semiconductors, ceramics, glasses, polymers or a combination of either. Knowing and predicting the properties of a material is therefore crucial for research and development in industry as well as experimentation in scientific research. One of such mechanical properties is hardness. Often, materials behave differently on macro and micro scales which is why it is interesting to perform mechanical property tests on a micro or nano scale. Nanoindentation is composed by a variety of indentation hardness tests applied to small volumes such as for example thin films and is characterized by the use of small loads of small tip sizes which implies a residual area in the order of micrometres or even nanometres. This creates the problem of measuring the residual area which is solved by observing it with an atomic force or a scanning electron microscope (AFM and SEM respectively). It is therefore an interesting possibility to be able to perform tests on such scales but alas, the problematics involving SEM's render said tests hard to carry out. The chambers are often too small while the measuring tools too big to allow any implementation. This is made worse by the required high or even ultrahigh vacuum environment of the SEM.

Goals and initial situation

The goal of this thesis work is in fact to create and validate a system that efficiently allows to perform live nanoindentation tests and observe them. To do so a positioning system which fits the narrow chamber of the Hitachi TM3030Plus SEM that carries an Alemnis Indenter has been designed. Its function is to bring the indentation tip exactly under the electron beam so that an in-situ indentation is possible (indentation is done while image is recorded). In addition, the stage allows to tilt the indenter to get the best view possible. The original function of the microscope was simple observation of samples, for this purpose the system contained an XY stage which allowed to navigate along the sample stub while the height or working distance had to be set manually outside the chamber.
Realized work

The new system uses a different principle based on the precise positioning of the indenter relative to the electron beam source. Given that the indenter has its own local XY stage and that the indentation point is always the same (for a given sample height), the new SEM positioning system modifies the working distance and the observation angle of said indentation. This system has been labelled ZC stage where Z stands for working distance or height of the indenter relative to the source and C is the tilt axis respectively. This is interesting because based on the type of sample and the desired observation precision the working distance can be adjusted, within boundaries, to obtain optimal resolution and observation conditions. The Z axis is guided by small linear stages and is actuated by a fine threaded screw which lifts the entire platform. This platform houses the rotational mechanism which is independent from the Z positioning yet uses the same gear-screw principle but with a shaft that is axially free but radially constrained. This allows for a dynamic, irreversible movement. With the new ZC stage it is possible to tilt the indenter between 7.5 and 35.5 degrees while remaining in a work distance between 10 and 17 millimetres. Finally, a NewPort Picomotor nano actuator allows to regulate a sample height up to 12.5 millimetres which allows a vast range of samples to be used. This solution does not require any modifications on the original SEM structure or on the indenter, it is composed of simple mechanical parts most of which are standardized to avoid machining afterwork.

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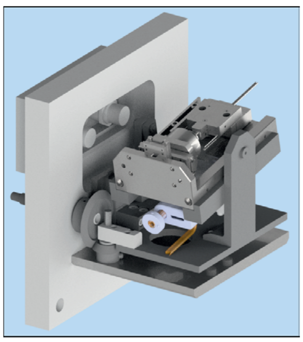

Full CAD model of design housed on the Hitachi door frame