Surface and thin-film characterization at the Materials Science (MS) beamline

X-ray reflectometry of high-tech surfaces

Introduction

Many technologies require the design and manufacture of specific surface coatings and layers. Quality control can be absolutely essential, especially with regard to coatings for X-ray optics, where thickness control and flatness need to be controlled at the atomic level.

Synchrotron radiation, as available at the PSI Swiss Light Source (SLS) offers the possibility to characterize exhaustively those surfaces with the most stringent specifications, with the aim of optimizing the fabrication process.

Beamline

The MS-X04SA Materials Science beamline (Fig. 1) will be equipped with a short-period, in-vacuum undulator, providing radiation between 5 and 40 keV, which is equivalent to a wavelength range of 2.5 to 0.3 Å.

The high parallelism, intense flux and brilliance of this photon beam, coupled with its ultra-high resolution and a five-circle diffractometer, make this facility ideally suited for application to the characterization of thin films.

The minimum focus in a 1:1 configuration will be approximately 130 µm x 15 µm.

A picture of a thin-film growth chamber mounted on the surface diffractometer is shown in Fig. 2.

Principle

Surface reflectometry exploits the phenomenon of interference between X-rays reflected from the interface(s) of layers of dissimilar materials.

From the width, modulation depth and decay characteristics of the reflective interference fringes, precise values can be determined for layer or multi-layer thicknesses, the number of multi-layer repeti-

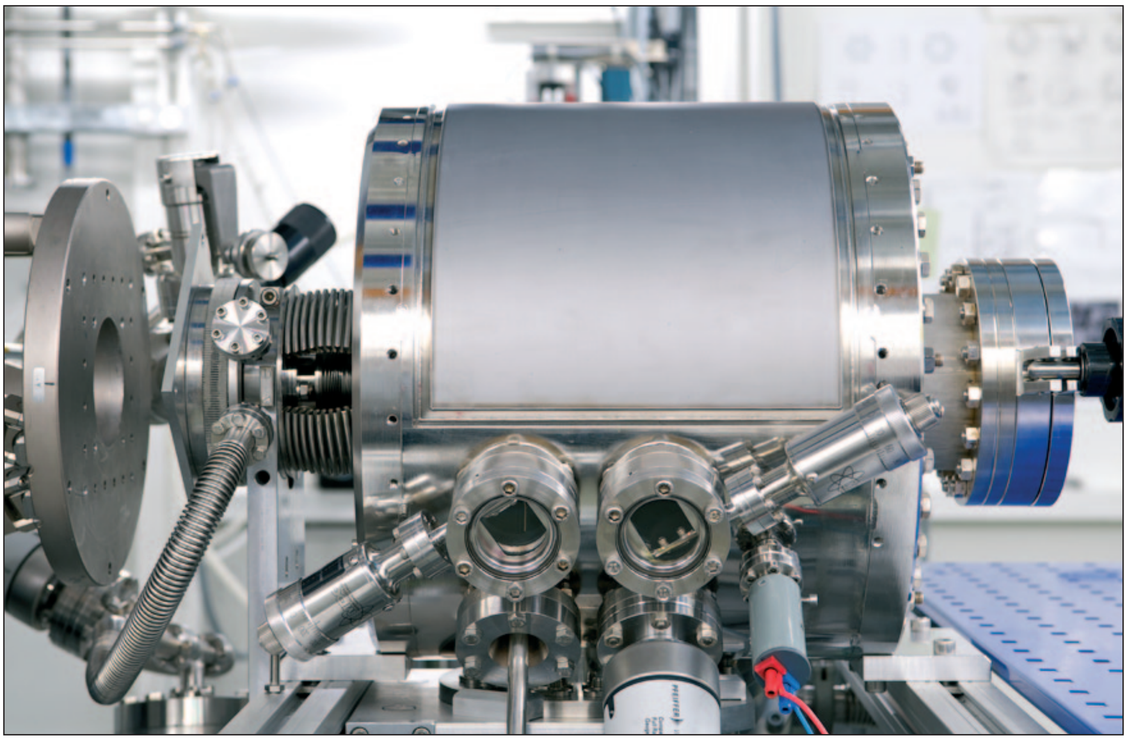

Figure 1: **MS surface beamline, detail.**

tions, substrate layer or inter-layer interface roughness, and the roughness of the surface, all with picometre accuracy.

Applications

The precise densities of component layers can be determined on a nanometre (nm) scale, which is an important parameter in X-ray optics, especially for the design of X-ray mirrors.

Surface reflectometry is the method of choice for surfaces where perfection of thin layers at the atomic scale is required.

Other typical examples for the application of this investigational method are nanoscale coatings, and multilayer structures in the semiconductor industry, for instance.

Using this technique, for meaningful results the layers should not exceed approximately 200 nm in total thickness or exhibit roughnesses in excess of one or two nanometres.

An example of a silicon mirror coated with Rh is shown in Fig. 3.

Other potential applications include, among others, the following:

1) The characterization of multilayer structures used for X ray monochromators in the mid-energy X-ray region and for monochromators with large bandwidths, where total photon flux is at a premium and brilliance is of secondary importance;
2) The characterization of chemical diffusion rates into materials from the surface for chemical processes such as oxidation and carbidation;
3) The characterization of wetting layers in thin-film coatings over a broad range of applications, such as catalysis and tribology, in order to establish the degree of coverage and the wetting angles;
4) The study of the long-term degradation and wear properties of tribological surfaces and coatings, such as the transition-metal nitrides;
5) The characterization of two-dimensional layers required as pre-structures for further technological processes in the formation of inorganic and organic electronic devices.

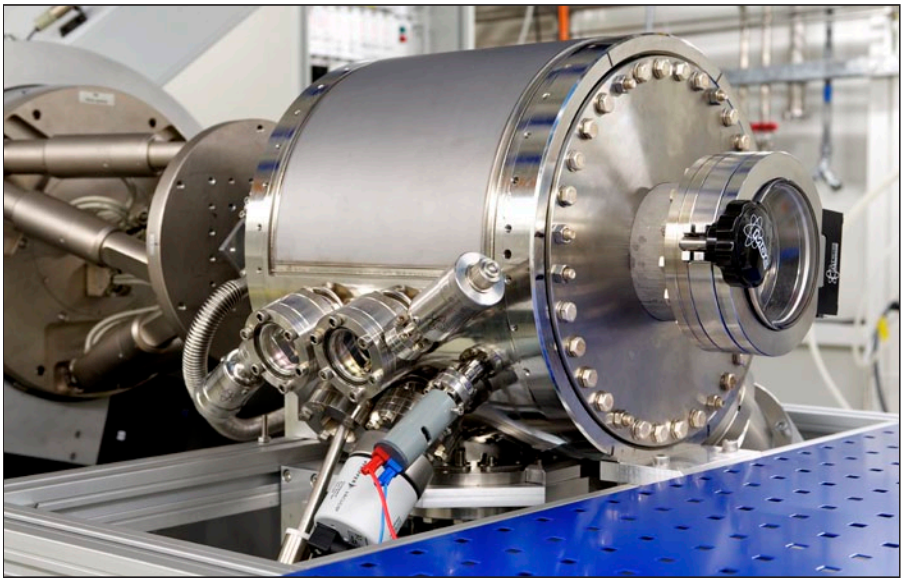

Figure 2: **In-situ growth chamber mounted on the surface diffractometer of the Materials Science beamline.**

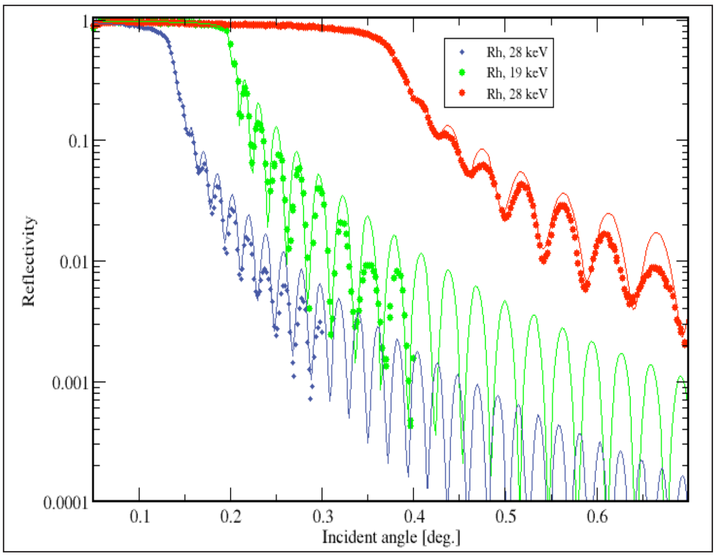

Figure 3: **Example of a 50 nm Rh coating on a 2" diameter silicon mirror, investigated using X-ray reflectometry and recorded at three different X-ray energies.**

Contact
Philipp Willmott
Beamline scientist
WLGA/233
Tel. +41 (0)56 310 51 26
philip.willmott@psi.ch

Paul Scherrer Institut
5232 Villigen PSI, Switzerland
Tel. +41 (0)56 310 21 11
www.psi.ch

Please direct any commercial enquiries to
SLS Technotrans Ltd.
Dr. Philipp Dietrich
Tel. +41 (0) 56 310 4573
philipp.dietrich@psi.ch

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