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Summary of the Workshop on the Applications of X-Ray Standing Waves in Studies of Surfaces, FiIms, and BuIk MateriaIs

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Summary of the workshop on the applications of x-ray standing waves in studies of surfaces, films, and bulk materials

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Highlights of the satellite workshop on the technique of x-ray standing waves which preceded the 5th International Conference on Synchrotron Radiation Instrumentation held at the State University of New York at Stony Brook, USA are presented. At the workshop, many applications of the x-ray standing-wave technique were described in both invited and contributed talks. While the predominant use of the XSW technique was to analyze the structure of adsorbates on surfaces, applications in the characterization of thin films, interfaces, clean surfaces, and bulk materials were also presented. Most of the talks concentrated on experimental results, but some theory was also featured. © *1995 American Institute of Physics.*

A one-day workshop on the x-ray standing-wave technique was held on July 17, 1994 at the State University of New York at Stony Brook. This workshop was one of several which preceded the 5th International Synchrotron Radiation Instrumentation meeting held there the following week. The XSW workshop was attended by 47 registrants, and most of the currently active x-ray standing-wave research groups worldwide were represented. This was the first such standing-wave workshop held as a satellite meeting in conjunction with an International SRI Conference, and the first session devoted to standing waves as part of any global international meeting since the 15th Congress of the International Union of Crystallography held in Bordeaux, France in 1990, which is reflective of the maturing of the method worldwide.

After opening remarks by David Heskett (Univ. of RI) and Lonny Berman (NSLS), the workshop began with introductory talks presented by Bob Batterman (Cornell and CHESS) and Mike Bedzyk (Northwestern and ANL). Professor Batterman used a rope to model wave propagation and developed his ideas simultaneously on transparencies as his talk progressed. He presented the basic theory of and provided some insights into dynamical diffraction and phase shifts in x-ray scattering. Professor Bedzyk described some of his results of x-ray standing waves at a reflecting mirror surface. In these investigations, which were carried out primarily at CHESS, he worked in the total external reflection geometry to generate the standing-wave field. This enabled him to adjust the x-ray standing-wave period to the longer periods appropriate for investigating the geometry of multilayer and Langmuir–Blodgett films.

In the late morning session, Hiroshi Kawata (Photon Factory) presented magnetic XANES and Compton scattering measurements of a single crystal of $Y_3Fe_2(FeO_4)_3$ (known as YIG) under a standing-wave field which was generated by circularly polarized radiation from an ellipitcal wiggler at the KEK Laboratory in Japan. By adjusting the standing wave field within his (bulk) sample, he was able to examine the magnetic response at specific atomic sites to the incident circularly polarized radiation. Michail Kovalchuk (Institute of Crystallography, Moscow) summarized the activities of his group using the XSW technique to study the amorphization of semiconductor surfaces, impurities in semiconductors, and long period multilayers. The last talk of the morning session, which was held jointly with the XAFS workshop, was a description by Fabio Comin (ESRF) of his beamline for XSW and SEXAFS which is currently under construction at the ESRF in Grenoble, France.

To start the afternoon session, Jorg Zegenhagen (Max-Planck-Institute-Stuttgart) presented some more theory of x-ray standing waves from his recent review article,[1] then continued with a description of a combined XSW/STM investigation of different coverages of Ga on Ge(111). In the examples he presented, the two techniques produced complementary information which was important in deriving the structure of these overlayers. Jim Patel (AT&T) followed with a talk on his studies of the vibrational amplitudes as a function of temperature of overlayers of Ga, As, and Ge on Si(111) and Si(100) obtained by using the XSW technique. Temperature-dependent changes in the coherent fractions, which provided a measure of the adsorbate vibrational amplitudes, were observed in all of the systems he investigated. To conclude the early afternoon session, Joe Woicik (NIST) presented his results on the structure of clean InP(110), Sb overlayers on III–V(110) semiconductors surfaces, and In on Si(111), the latter involving a combined XSW/SEXAFS study. His work was distinct from the previous talks in that he made use of the back-reflection geometry in his XSW studies. In addition, his study of InP(110) is one of the only reported applications of the XSW technique to derive the structure of a clean surface.

In the final session of the workshop, seven shorter contributed talks were presented: "The possibilities of the x-ray standing-wave method for investigations of the structure of real crystals: Theory and applications," by Ivan Vartanyants (Institute of Crystallography, Moscow); "The dangers of using low-energy Auger emission to gain surface sensitivity with normal-incidence x-ray standing waves," by Bruce

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Cowie (SERC Daresbury); "Si–alkali metal interface studies with x-ray standing waves," by Stefano Lagomarsino (Istituto di Elettronica della Stato Solido, Rome); "Lattice location of trace elements within minerals and at their surfaces with x-ray standing waves," by Yonglin Qian (Northwestern Univ.); "Adsorbate structure and substrate relaxation for the Sb/Si(001)–(2×1) surface: What we can learn from Fundamental and multiple-order reflections," by Paul Lyman (Northwestern Univ.); "X-ray standing-wave investigation of the structure of Rb/Cu(111)," by Xiaorong Shi (Univ. of Tennessee); and "X-ray standing-wave study of the $SrTiO_3$(100) surface," by Lonny Berman.

The workshop was concluded by closing remarks from Lonny Berman who observed that, with the advent of synchrotron radiation, the number of standing-wave groups worldwide has doubled in the past several years, but is still a relatively small number (between 10 and 15). He noted that synchrotron radiation made possible the relatively recently introduced backscattering geometry in XSW investigations, which greatly broadens the spectrum of samples that can be studied, to include imperfect crystals. However, the use of this geometry is still rather limited, in large part because the soft-x-ray wavelengths that are needed to study most crystals in this configuration require specialized vacuum beamline and experimental chamber environments. Finally, he remarked that while the variety of XSW applications is large and growing, the most common use of x-ray standing waves is as a tool to investigate the structure of surfaces.

Copies of the speaker's viewgraphs were collected and assembled into an informal proceedings, which was distributed to all the registrants. Anyone else who wishes to obtain a copy can make a request to one of the authors of this article.

[1] J. Zegenhagen, Surf. Sci. Rep. **18**, 199 (1993).