Multilayer X-Ray Optics, Past and Future

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Thin films with thicknesses in the nanometer range have been produced since thousands of years. B. Franklin (l757) described how a film of water could quiet the waves and it was trivial to calculate the film thickness. Langmuir and Blodgett used similar films to produce multilayers by dipping a slide multiple times into the fluids with a known film on top. They produced multilayers with periods Λ from 3-8 nm, and these were used as x-ray reflectors (Nobel 1932). Natural crystals served as the first x-ray reflectors or deflectors for x-rays (Laue, Ewald, Bragg, Darwin, 1912...) and a full 3-D theoretical treatment was developed. Enhanced transmission of x-rays was observed by Borrmann 1941 for the case that atoms in a crystal were located in the nodes of the standing wave field in the crystal. The theoretical description of that effect was probably known to Ewald around 1917.

Thin films for visible optics (Enhanced reflection or AR coatings) were only developed after 1930 and the Quarter Wave Stack was the standard design for good reflectors. Several papers stated that nothing could be achieved in the UV due to absorption. Utilizing the standing wave pattern in a structure to enhance or reduce the interaction with light was rediscovered by the author in 1970 and allowed to design useful coatings for the UV and x-ray region. These coatings are now used in astronomy, lithography, microscopy, spectroscopy covering the energy range from 20eV to 100keV and have been discussed at many conferences.

Dreams for the future: Enhance other desired properties of solids. Electron, phonons and other excitations have wave properties that might be modified by an optimized standing wave field. Even without a theoretical prediction we might discover the effect by monitoring the desired property during the growth of a film looking for oscillations. Some such oscillation have been observed for superconductors.

Expand our 2-D thin films to 3-D. The size of the atoms is the most severe limitations for further developments of ML films. If we could learn to control the position of each atom in a structure we could open up many new applications and create new materials. Transfer surface effects in a 3-D structure! Enhance performance of capacitors, batteries, memories.

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