Nano-probe TEM analyses for thin films and quantum devices

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Abstract

Materials characterization is a continuous quest that parallels the search of improved materials and devices, with particularly stiff challenges being raised by the recent development of nano-structures and related technologies.

The recent field-emission transmission electron microscopy (FE-TEM) has improved significantly analytical resolution due to a extremely fine (~0.5 nm) and brightest electron source available from Shottky field-emitter. The FE-TEM is now believed as a unique nanometer scale analytical tool in the course of materials science research and developments.

In the present study, various examples of analytical techniques and the related nano-structural data obtained from FE-TEM will be presented. Interfacial reactions of nano-thin films, compositional variation of quantum devices, and atomic structures of nano-tubes, nano-wires and nano-particles will be presented in the recent research activities of nano-structure analysis.

The analysis on compositional variation becomes more important for interfaces and other thin regions of multi-layer thin films and quantum devices. To acquire more accurate EDS and EELS spectrum in nano-scale, the reaction volume must be defined precisely in terms of sample thickness. Measurement of sample thickness can be obtained either by general CBED technique or by EELS [Fig. 1]. From sample thickness and beam broadening, we could define the reaction volume. For Si specimen, in order to collect the spectrum data within sub-nanometer region, we must perform the EDS and EELS analyses in the specimen with less than 100nm thickness. To reduce the error rate of spectrum data, the k-factors of the specimens in EDS should be determined from standard samples.

Through the Fast Fourier Transformation (FFT) image processing, the resolution of crystal phases and defects of various specimens could be improved. For epitaxial SrRuO3

thin films, Burgers vector of misfit dislocation could be easily analyzed from FFT image. The removal of background noise could reveal clear HREM image of misfit dislocations and the Burgers vector could be determined from Burgers circuit drawn in the FFT image [Fig 2]. In addition, various dislocation types were analyzed by Bragg filtering, FFT with interesting diffraction spots. For Ni80Fe20/Cu multi-layer thin films, crystallinity of thin films colud be obtained in about 10 nm interface region and the effects of Buffer layer on coherency of crystallinity could be analyzed. In order to distinguish between Ni80Fe20 and Cu layer, line profile from FFT and inverse FFT with (200) spots was used to identify the layer distance of each layer precisely.

Through these analytical methods, nano-wires, nano-tubes, and nano-particles could be observed and the microstructure and compositional variation of quantum devices such as quantum wall and quantum dots infra-red photo-detector could be determined.

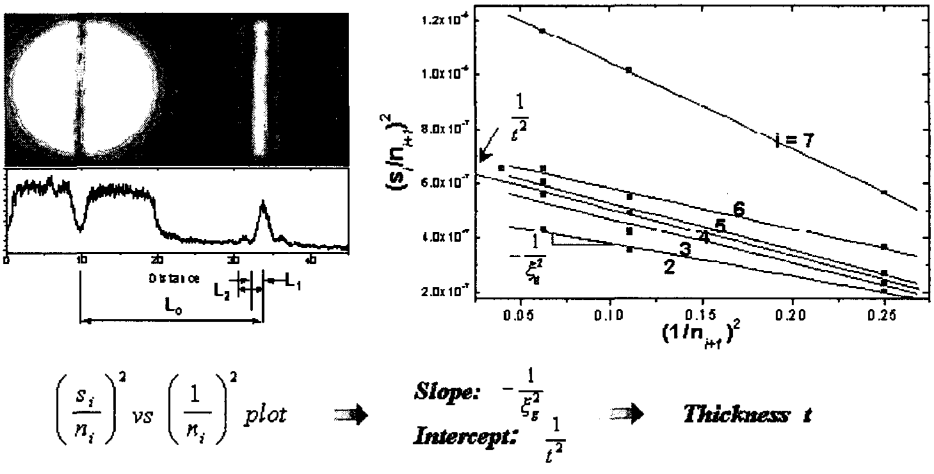

Fig. 1. Thickness determination using conventional CBED technique.

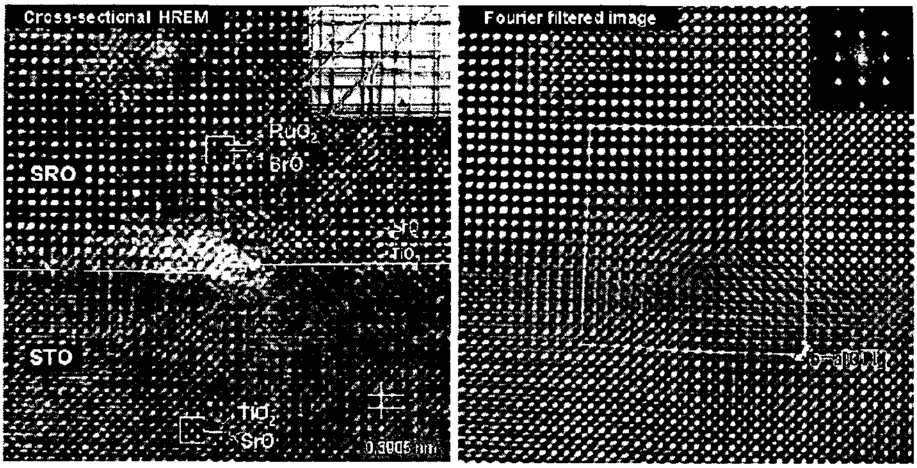

Fig. 2. HREM image and Fourier filtered image of SrRuO3 film grown on SrTiO3 substrate from interface region containing a misfit dislocation.