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Structural Analysis of Buried Nanowire by X-ray Standing Wave Method

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Introduction

Atomically perfect nanowire with bismuth atoms has attracted much interest in recent years [1]. STM analyses revealed that the Bi wire is qualitatively different from other atomic wires that are formed by many group-III and -V elements at the initial stage of growth on Si (001): the Bi wire is free of kinks or defects, a narrow width of 1nm is kept for more than 400 nm, and the wires appear to be embedded in the surface, not as adsorbates.

Since the wire formation is a self-assembling process, it might play a role of template for the nanodevice fabrication. Its mechanism also is great interest in surface science, because a precursor Bi monolayer (ML) surface is well known with specific structures [2]. Although X-ray photoelectron diffraction and the theoretical analysis were applied to reveal the Bi wire structure in UHV condition [1,3], the wire in the buried interface can be hardly estimated because of the methodological difficulty, despite its importance in application. Only transmission electron microscope suggested a weak interaction of the amorphous Si (a-Si) layer to the Bi nanowire [4]. X-ray standing wave (XSW) method is suitable for this perfect, dilute, and buried system. The three-dimensional site of Bi atoms has been estimated relative to the Si bulk crystal.

Experiments

A vicinal Si(001) wafer was used to produce a single domain of Bi lines. After STM observation of the Bi lines, the surface was capped with the a-Si of 20 MLs thick by electron beam deposition at room temperature. The experiments were carried out at the BL14B. The incident photon energy was kept at 16.5 KeV for Bi L-excitation. The Bi Lα fluorescence yield was obtained using a solid state detector. The XSW profile was taken by scanning angle of the Si crystal in the vicinity of 115 Bragg reflection.

Results and Discussions

Fig.1 illustrates the measured XSW profile with the reflectivity. The solid lines are the best fits calculated using dynamical diffraction theory. The XSW results are represented by two independent fitting parameters: the average atomic position d_{hkl} and coherent fraction Fc. According to our previous results on the 004 reflection, the Bi height from the Si(004) bulklike atomic plane is 0.26±0.04 Å with 60% of coherence of the position. Considering that the Bi atoms are in a fixed height, the measured d_{115} value was transformed to d_{110} within the horizontal plane by use of geometrical projection: d_{110}=0.0±0.5 Å, F_{110}=0.5±0.1. The χ^2 fitting results denoted that the Bi atoms exist closed to the first Si(004) layer (i.e. Si-dimers layer), not in the second layer.

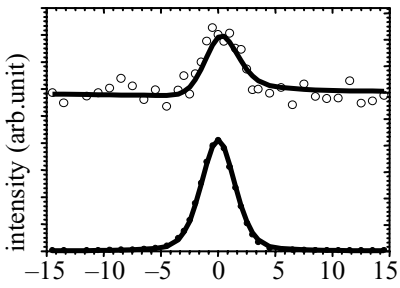

Fig. 1
Upper: normalized Bi Lα fluorescence yield (open circles).

Lower: measured 115 reflectivity.

A proposed model of the wire structure is shown in Fig.2 with the Bi position that is allowed by the XSW results. The hutched area (top view) and the solid lines (side view) correspond to the allowed Bi atomic position. Detailed discussion is referred to other report [5]. The authors gratefully acknowledge Doctors K.Hirano and X.W. Zhang of Photon Factory.

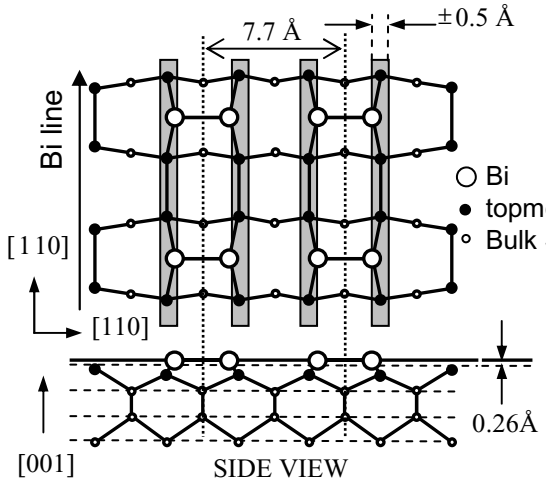

Fig.2 Derived Bi wire model and the Bi position that is allowed by the XSW analysis. The marked values (±0.5 Å and 0.26 Å) on atomic coordinates are results of the XSW analysis.

References

[1] J.H.G.Owen, et al., Phys.Rev.Lett. **88** (2002) 226104.
[2] Y.Qian et al., Phys.Rev.B **54**(7), (1996) 4424.
[3] M.Shimomura et al., Surf.Sci.**447**, (2000) L169.
[4] K. Miki et al., Microscopy of Semiconducitng Materials, Inst. Phys. Conf. Ser. **164**, 167 (1999).
[5] A.Saito et al., Jpn.J.Appl.Phys., **42** (2003)4B, 2408.

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