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Formation of Fe nanowires along dislocations in Si.

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Nanowires are attracting much attention because of the potential applications in various fields. For example, some peculiar structures such as magnetic vortexes and uniaxial structures could be generated in nanoscopic magnetic materials [1]. In the applications to quantum spintronics devices, it is very important to find out the properties of the spin and charge transport phenomena in nanoscopic magnetic materials.

When dislocations are introduced in a crystal the areas around the dislocations are distorted and elastic fields are generated. As a result, the solute atoms in a crystal tend to migrate and segregate to the dislocation lines, forming so-called Cottrell atmosphere. In addition, dislocation lines are known to induce pipe-diffusion. Using these mechanisms Nakamura and co-workers succeeded in fabricating Ti-nanowire bundles in sapphire[2]. In this work we have attempted to fabricate Fe-nanowires in Si.

The starting material used in our experiments was an undoped dislocation-free CZ-Si wafer grown to the $[100]$ direction. A specimen was cut into a rectangular shape whose longitudinal axis is parallel to the $[0\bar{1}1]$ direction. To introduce dislocations in the specimen, it was scratched on the (100) surface and stressed in four-point bending in vacuum at 900℃. Following an annealing process, metallic iron was evaporated onto the (100) surface in vacuum. Then, the specimen was further annealed at 800℃ for 2 hours to promote the diffusion of the iron. Then the specimen was cut into a wedge-shape as shown in FIG.1. Here, because the $(2\bar{1}1)$ surface is at an angle of about 35° with the iron deposited (100) surface, we can obtain the distribution of iron precipitation particles as a function of the distance from the iron deposited surface and the density of dislocation. The local conductivities on the $(2\bar{1}1)$ surfaces were investigated by the conductive atomic-force microscopy (c-AFM) to examine whether the nanowires were fabricated.

FIG.2 shows a topographical image and a c-AFM image at the depth of about 110μm from the iron deposited surface. In this topographical image some protrusions are observed. In the current image, on the other hand, spots of high electrical current are observed at the same positions as the protrusions. In the case of the iron-free specimen (FIG.3), there are no spots of high current on the $(2\bar{1}1)$ surface, indicating that the spots in FIG.2 are related to iron. FIG.4 schematically illustrates the distribution of the high current spots on the $(2\bar{1}1)$ surface. We couldn't observe any spots near the iron

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deposited surface, because interstitial iron atoms diffused into Si substrate uniformly in this area. In the deeper area, the spots density is higher in the area close to the scratch, where the dislocation density is high. This indicate that iron atoms are segregated around the dislocations.

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References

[1] S.P.D. Li et al., Phys. Rev. Lett. 86 (2001) 1102.
[2] A. Nakamura et al., Nat. Mater. 2 (2003) 453.

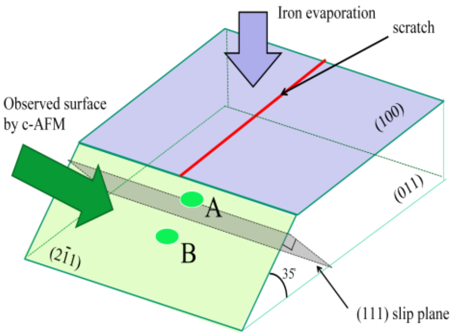

FIG.1. A schematic illustration of the specimen cut for AFM observations. Iron atoms were deposited onto the (100) surface and the $(2\bar{1}1)$ surface was observed in AFM.

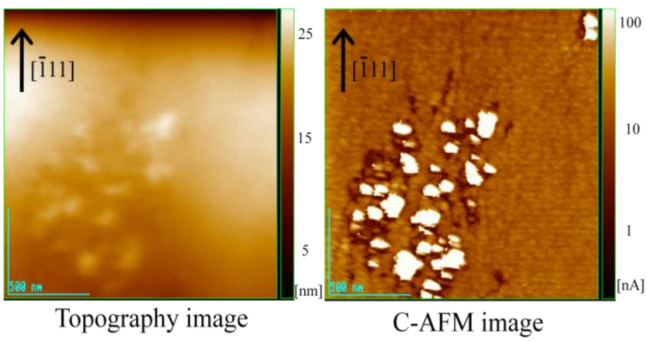

FIG.2. The topographic image and c-AFM image of the $(2\bar{1}1)$ surface at the depth of about 110 μm from the iron deposited surface.

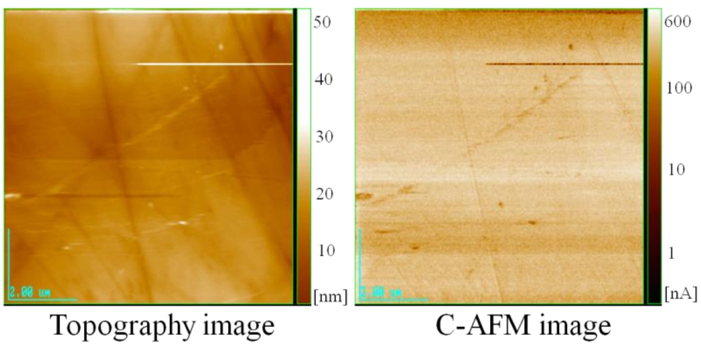

FIG.3. The topographic image and c-AFM image of the $(2\bar{1}1)$ surface of an iron-free specimen.

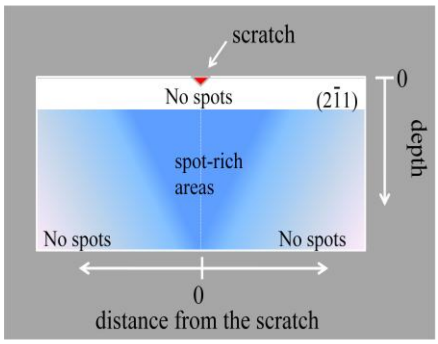

FIG.4. The distribution of the spots on $(2\bar{1}1)$surface in FIG.1. The spot density is high in dark blue region.