Epitaxial Electrodeposition of Cuprous Oxide onto Single Crystal Silicon(001)

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Epitaxial films of cuprous oxide, Cu_2O, are electrodeposited from aqueous solution onto single-crystalline Si(001). The epitaxial growth of Cu_2O onto Si is an unexpected result, because there is a strong driving force for the oxidation of Si to form a native amorphous SiO_2 layer. The Cu_2O films are single-crystalline in nature, with little or no fiber texture. High resolution X-ray diffraction shows that the very large lattice mismatch of –21.4% is reduced to +11.2% by the formation of a Cu_2O(001)[100]//Si(001)[110] orientation relationship, in which the film is rotated 45° around the common [001] axis. Cross-sectional transmission electron microscopy studies suggest that the growth mechanism involves an initial electroless deposition of Cu_2O epitaxial seeds in direct contact with the Si(001), with the concomitant oxidation of Si to form a layer of amorphous SiO_2 about 3 nm thick. Electrochemical deposition of Cu_2O then proceeds on the epitaxial seeds, with the deposit growing not only perpendicular to the surface but also laterally across the SiO_2 interlayer. This type of lateral overgrowth is used in the production of semiconductor-on-insulator (SOI) structures to avoid defects due to misfit strains.

The epitaxial films were deposited onto p-type Si(001) from an aqueous solution of 0.4 M Cu(II) and 3 M lactate ions at pH 9 using a bath temperature of 65°C. The wafers were supplied by Virginia Semiconductor doped with boron to a resistivity of 7.5 ohm-cm. The wafers were degreased in ethanol and acetone and then rinsed with HPLC water before etching to produce an H-terminated surface. The etch consisted of 5% HF for 1 min, hot HPLC water for 15 min, and 5% HF for 10 s, followed by a thorough washing with HPLC water. Ohmic contacts were made with GaIn eutectic.

A plan-view SEM image of a film that is approximately 2 µm thick is shown in Fig. 1. The in-plane order is evident in the SEM image. The Bragg-Bentano scan in Fig. 2a probes the out of plane orientation of the film. Only the (002) and (004) peaks of Cu_2O are observed. Fig. 2b shows a (220) pole figure for the film. The radial grid lines in the pole figure correspond to 30° increments in the tilt angle. Four sharp spots are seen at a tilt angle of 45°, corresponding to the angle between {100} and {220} planes in a cubic system. The azimuthal scans in Fig. 2c were obtained by selecting the Cu_2O(111) planes at 2θ= 36.418^{o} and the Si(111) planes at 2θ= 28.433^{o} and tilting the sample at a tilt angle of 54.7^{o}. The azimuthal scans show that the film is rotated 45° about the [001] axis relative to the Si substrate.

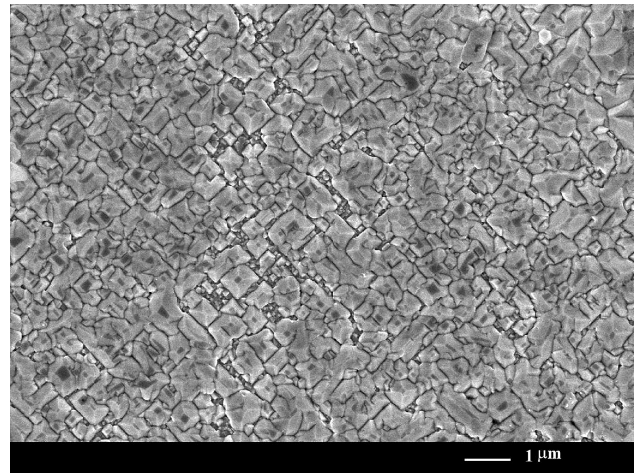

Fig. 1. SEM image of Cu_2O on Si(001)

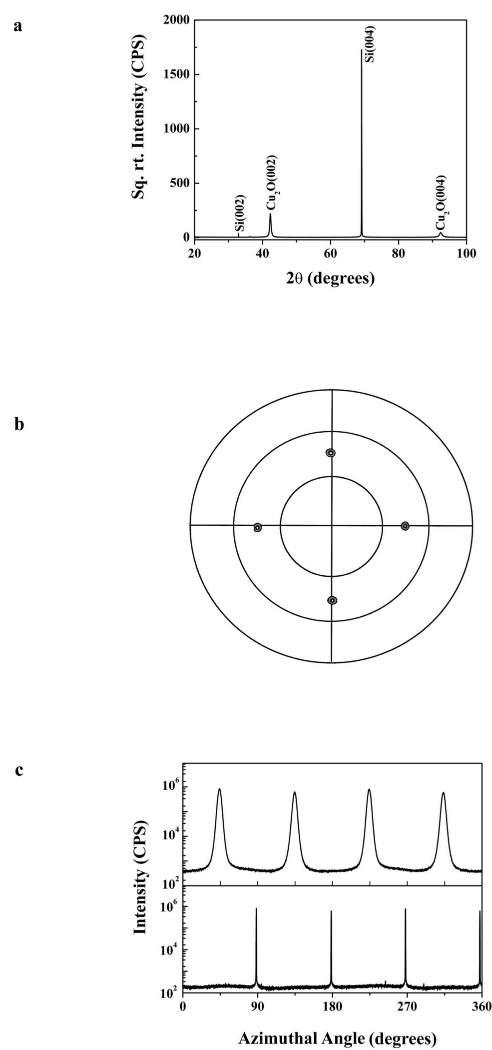

Fig. 2. X-ray diffraction results for Cu_2O on Si(001)