Electronic structures analysis of the CVD-ZrN films using high resolution angle-resolved photo-electron spectroscopy

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Copper interconnect technology has been widely developed and applied to the high-speed ULSI devices. In the fabrication of Cu interconnects, it is necessary to cover Cu surfaces of interconnects to prevent diffusion and oxidation due to the high diffusivity of Cu atoms. While dielectric films such as SiN of SiC have been generally used as a capping layer, the high dielectric constant (k=7.0 for SiN, and k=4.5 for SiC) causes the increase of signal delay in Cu interconnects

We have developed a new self-aligned cap technology using ZrN deposited by chemical vapor deposition (CVD) method [1]. From the resistance measurements, it has been estimated that a few nm thick ZrN film grown by CVD behaves as a metal when deposited on Cu, but as an insulator on a dielectric layer. These novel properties of CVD-ZrN enable us to fabricate a self-aligned cap layer without an etching process and to achieve high reliable interconnects. However, the mechanism in which this material shows such character still remains unclear. In this work, electrical and chemical structures of ZrN films were studied by high-resolution photoelectron spectroscopy method.

The measurements were carried out at BL27SU using a soft X-ray spectrometer with high energy resolution system. The sample structures used in the present experiments were ZrN(5 nm)/SiO_2(100 nm)/Si-substrate, and ZrN(3 nm)/Cu(250 nm)/Si-substrate. Valence band and core level spectra were measured with the excitation energy of 1.085keV, and the energy resolution of about 220meV.

Figure 1 shows the valence band spectra of ZrN/SiO_2 and ZrN/Cu films. The valence band edge of the ZrN film deposited on Cu is found to be much closer to Fermi level than that on SiO_2, and that the energy difference of band edge between two samples is more than 2eV. This result indicates that electric structures of thin CVD-ZrN films greatly depend on the underlying material, and that the peculiar characteristics of thin ZrN films are attributed to the change of their electric structures.

[1] H. Kondo, Y. Nakao, T. Suzuki, H. Sakai and N. Shimizu, Proc. of IEEE International Interconnects Technology Conference, P.292 (2002).

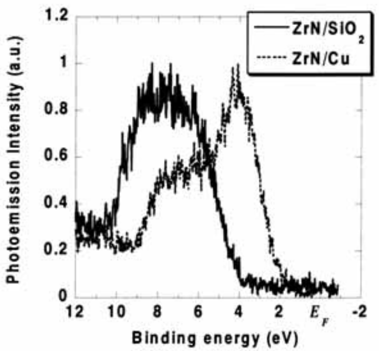

Fig.1. Valence-band spectra of ZrN/SiO_2 and ZrN/Cu.

Evaluation of Bendable Optical Elements for Soft X-ray

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A large number of "Arm Method" mirror benders have been supplied to SPring-8 and KEK/PF, where the mirror bender is a device to give bending moment to a plane mirror by pulling arm shafts situated parallel to the mirror surface. We have already reported the performance of the bender*(1)* by measuring the curvatures and slope errors of the bent mirror using LTP II (Long Trace Profiler) belonging to SPring-8.

In the present work, we installed the bender into SPring-8 BL27SU, to evaluate the focusing capability of a bent Si mirror with a size of 50(w)x540(l)x25(t)mm^3. The reproducibility, the stability, and the effect of water-cooling were also investigated, in which cooling water to the bender was supplied by so called "double pipes" that was constructed by a plastic tube inside a bellow pipe. The bender used is designed to perform the smallest curvature of the mirror to 400m. Because of large off-axis optical configuration of the beam line, the shape of the mirror must be an off-axis ellipsoid. Since the bender has two shafts to which different stepping motors are equipped, the shape of the mirror could be controlled to arbitral pseudo elliptic-cylinder, which focuses the beam to an one-dimensional (horizontal) μ-spot.

The beam profile on the focusing point was measured by a profile monitor, which consists of a photodiode detector with a 10 μm diameter pinhole slit and moves along horizontal and vertical directions by stepping motors with 0.04 μm per step. The focal point along the beam axis was determined as the position having the smallest beam size.

Experimental and calculated beam profiles are shown in Fig.1, where the calculated one is obtained by convolution of the Gaussian distribution function and the instrument function of the pinhole slit. The size of the front-end slit of the beam line is 3.0x0.3mm^2 and the undulator gap is 58mm.

Twice of the standard deviation of the Gaussian pattern is 42.3 μm, which is larger than the image size of 33.0 μm estimated from the source size (758 μm) and the demagnification ratio of the optics (1/23).

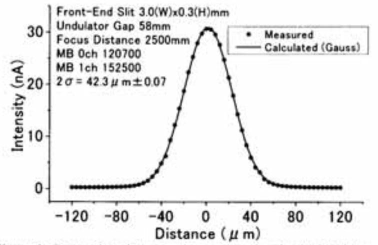

Figure 1. Comparison between the measured and calculated beam profiles

The result of the reproducibility is shown in Table 1. In this measurement, after changing the pulse counts of the stepping motors to a certain extent, they were returned to the original positions. The RMS deviation of the five measurements is 0.22 μm, which is about 0.5% of the beam width.

Table 1. Reproducibility

	1st	2nd	3rd	4th	5th	Ave.
2σ (μm)	42.2 ±0.12	42.1 ±0.11	42.0 ±0.12	41.6 ±0.13	41.8 ±0.13	41.93 ±0.22

The result of the stability during 4-hours operation is shown in Fig.2 as the variation of beam widths along with that of synchrotron ring beam current. Little effect of the beam current on the spot size was observed.

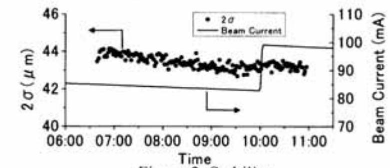

Figure 2. Stability

The water-cooling mechanics works well judged from the beam sizes with different front-end slit sizes. The stability of the temperature of cooling water is better than that of the room temperature.

(1) Kamachi et al., 8-th int.conf. SRI (2003).