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Synchrotron Radiation Excited Chemical Vapor Deposition of a-Si:H and $Si_xN_yH_z$ Film

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INTRODUCTION Synchrotron Radiation(SR) has been used as a powerful light source in structural and spectroscopic analyses such as X-ray diffraction, EXAFS and photoelectron spectroscopy(1). Spiller et al. were the first to show that SR can also be a powerful light source in X-ray lithography because of its brightness and good collimation properties(2). In this report, another SR application, SR excited chemical vapor deposition(CVD) is introduced and demonstrated.

SR, as a light source of photo CVD, possesses several advantageous features: (a)a continuous spectrum covering soft X-ray to vuv regions, (b)large dissociation and ionization cross sections for most gas molecules, (c)clean plasma formation in a localized space, isolated from electrodes and walls of a reaction chamber. On the other hand, several disadvantages cause a low deposition rate: (d)lower photon density by about three orders of magnitude than that of an ArF excimer laser, and (e)unfeasibility of high source gas pressure due to lack of appropriate window materials in the vuv range.

EXPERIMENTS The experimental setup for SR excited CVD, utilizing vuv photon fluxes from 2.5 GeV storage ring at the KEK Photon Factory is shown in Fig. 1. The high vacuum of the beam line is maintained by the differential vacuum pumping system. As a result, pressure as high as 2×10^{-2} Torr in the reaction chamber can be realized, while keeping the pressure of the mirror chamber lower than 3×10^{-9} Torr. Source gas(100% SiH_4 or 100% SiH_4+N_2) was fed into a small cell in the reaction chamber. DC bias voltage was applied between the electrode and the substrate holder. Partial pressure of SiH_4 gas was typically 3×10^{-3} Torr.

RESULTS Thicknesses of the deposited films were determined from Talystep measurements. Deposition rate was almost constant in the experimental substrate temperature Ts range(Fig. 2). Bias application (200 V in this case) greatly increased the deposition rate (Fig. 2). This suggests that the reaction gases are efficiently ionized by SR and that the ionized species are collected onto the substrate by electric field application.

An IR absorption spectrum for deposited a-Si:H film is shown in Fig. 3. The peak around 2000 cm^{-1} is assigned to the Si-H stretching vibration and only a weak peak is observed for the $Si-H_2$ bending vibration. Therefore, it is concluded that Si-H bonds are dominant in the deposited a-Si:H film.

An Auger in-depth profile of deposited $Si_xN_yH_z$ film is shown in Fig. 4. Although the partial pressure ratio(P_{N_2}/P_{SiH_4}= 1) is much lower than that in the glow discharge method(3), nitrogen atoms are efficiently incorporated(N/Si≒0.8). It was confirmed from the IR spectrum that these nitrogens are bonded to Si and H. The radical and ion generation rates for N_2 in glow discharge plasma are very low, since the binding energy

for N_2(9.8 eV) and the first ionization potential for N_2(15.6 eV) are substantially larger than the average electron energy in the glow discharge plasma. On the contrary, SR has sufficient photon energy to dissociate or ionize N_2 gas. Furthermore, the photoabsorption cross section of N_2(~20 Mb) above the ionization threshold has the same order of magnitude as that of SiH_4(~40-50 Mb). Therefore, SR produces an amount of nitrogen ions(N^+, N^{2+}, N_2^+) comparable to SiH_m^+ ions. This causes high concentration of nitrogen atoms in the film. The authors believe that production of these active ions is one of the interesting features of SR excited CVD which potentially opens the way to the formation of new materials.

In summary, a new SR application, SR excited CVD has been introduced and several interesting properties of the deposited film have been demonstrated.

REFERENCES

(1) E. E. Koch et al., Handbook on Synchrotron Radiation, ed. by E. E. Koch (North-Holland, Amsterdam, 1983) p.3.
(2) E. Spiller et al., J. Appl. Phys., 47(1976)5450.
(3) D. Haiping et al., J. Electrochem. Soc., 128(1981)1555.

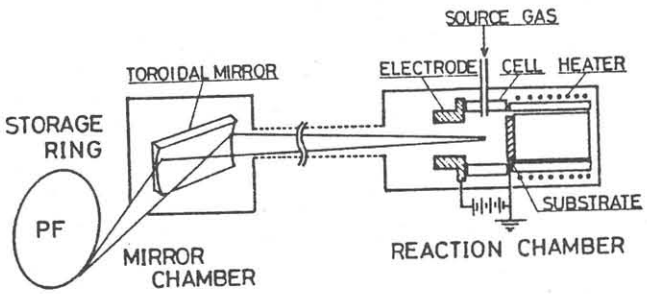

Fig. 1 Schematic diagram of SR excited CVD apparatus.

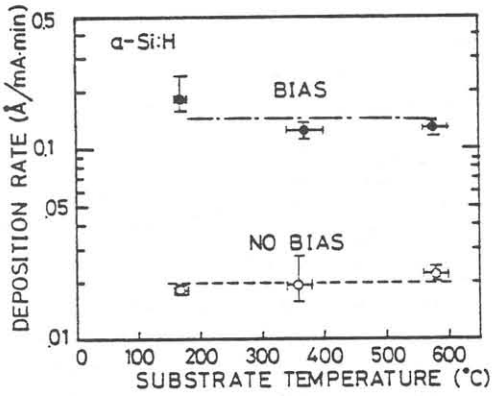

Fig. 2 Dependence of deposition rate on substrate temperature.

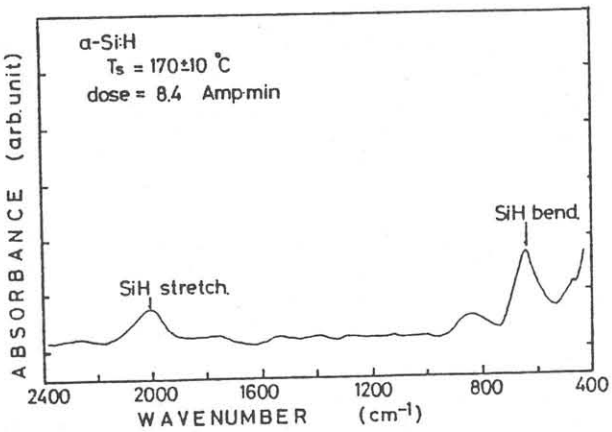

Fig. 3 IR absorption spectrum for deposited a-Si:H film.

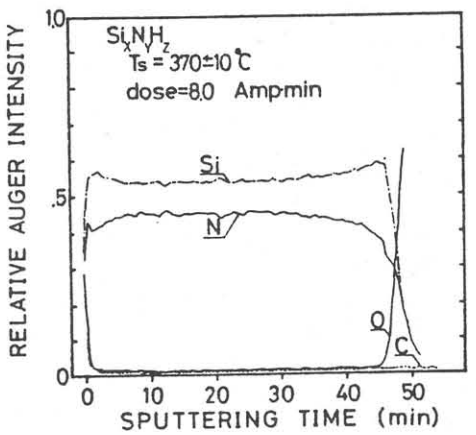

Fig. 4 Auger in-depth profile for deposited a-SiN:H film.