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60 MHz VHF-PECVD for SN-2-SiNx and Microcrystalline Si Film

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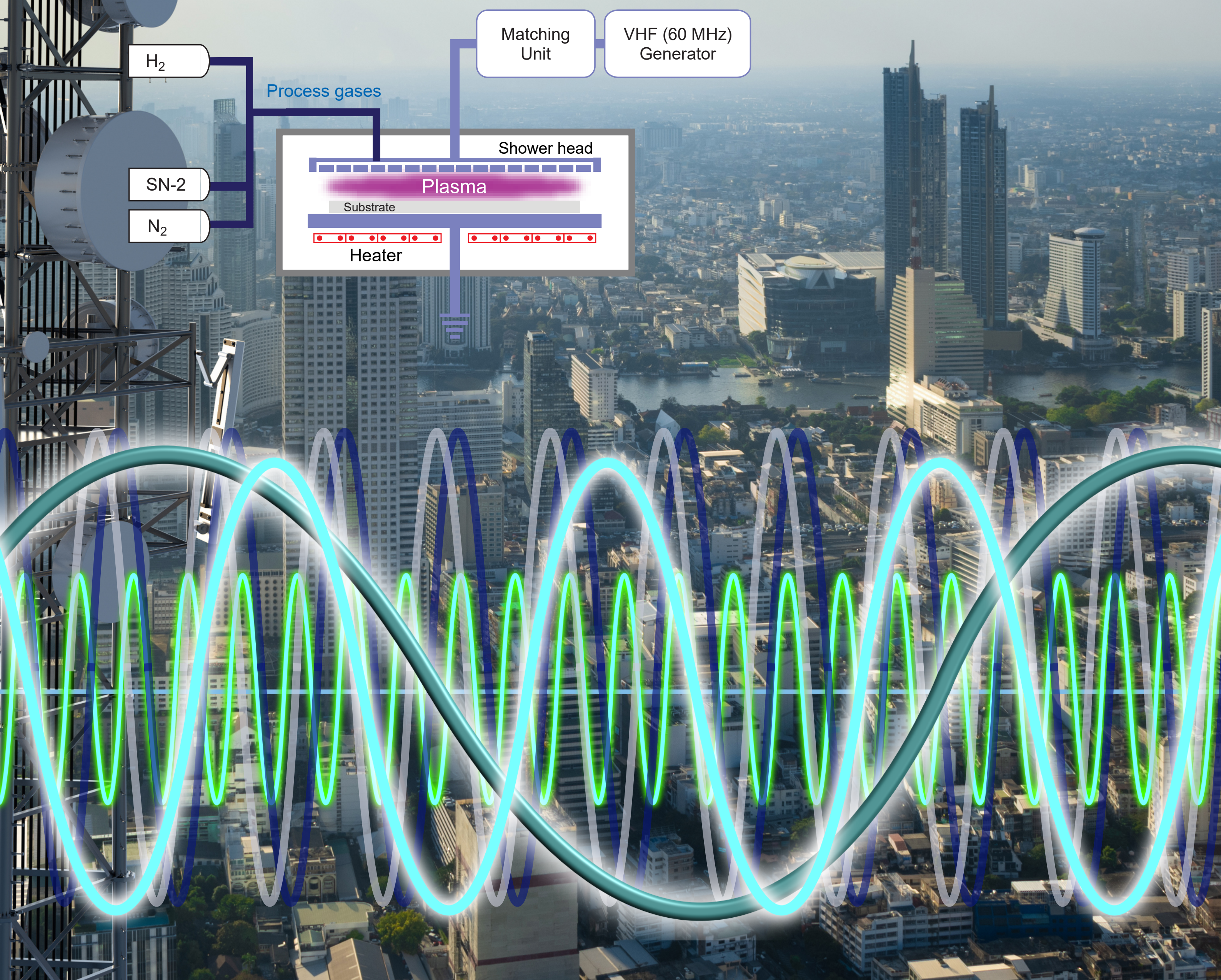


Introduction

Samco has been developing plasma enhanced chemical vapor deposition (PECVD) technology using liquid precursors along with conventional PECVD technology for silicon oxide and silicon nitride films using SiH_4 as the source gas. Furthermore, we provide superior stress control PECVD technology using dual-frequency - the combination of 13.56 MHz and 400 kHz. In order to meet our customers' demands, we now introduce VHF-PECVD technology using 60 MHz. The study outlined below shows the results of SiNx deposition and a Si crystallinity evaluation using Samco's unique liquid precursor, SN-2.

Benefits of VHF

Compared with 13.56 MHz, VHF has superior characteristics such as a higher plasma density and low ion bombardment. It enables high-speed deposition, reduction of the surface damage on the film interface and substrate, and formation of micro-crystalline Si for deposition of a-Si. VHF-PECVD is expected to be a good candidate for insulation and passivation films on electronics and high-frequency devices, which require a significantly lower plasma damage.

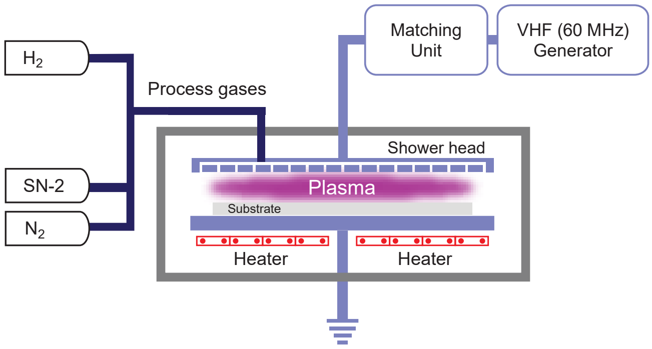
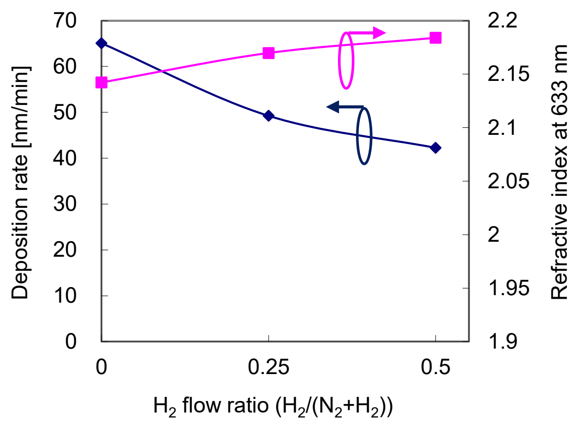


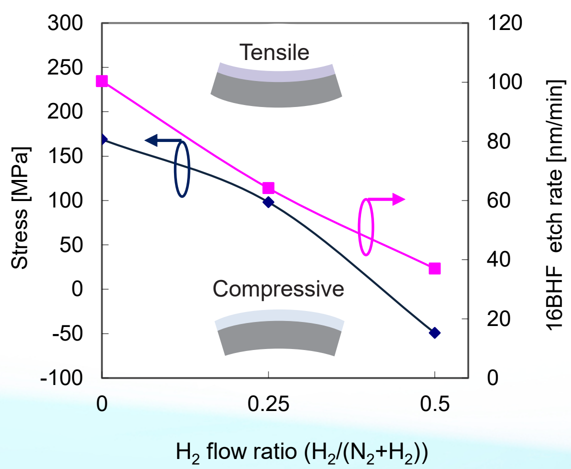
Figure 1. Schematic of VHF-PECVD reaction chamber.

SN-2-SiN_x Deposition

Figure 1 shows the system configuration used in this study. The combination of SN-2 and N_2 can form the SiN_x film, but the hydrogen from the SN-2 precursor remaining in the film causes deterioration of its quality. We introduced H_2 as an additional process gas, and evaluated film quality by changing the H_2/N_2 ratio while keeping a constant total flow rate of H_2 + N_2. The film's quality was evaluated by the deposition rate, refractive index, film stress, and 16BHF wet etch rate. Process conditions were a VHF power of 100 W and a stage temperature of 350 °C. Figure 2 shows that increasing the H_2 flow ratio leads to the compressive stress of the SiN_x film, shifting from tensile to a more compressively stressed film, and a lower wet etch rate.



(a) Deposition rate and refractive index



(b) Stress and 16BHF etch rate

Figure 2. (a) Deposition rate, refractive index, (b) stress, and 16BHF etch rate vs H_2 flow ratio to the total of N_2 and H_2 flow.

Figure 3 shows the FTIR spectroscopic evaluation of SiN_x films deposited with the H_2 flow ratio of 40% and 0%, respectively. The difference between the H_2 flow ratio of 40% and 0% is found in the intensity of the Si-N and Si-H bonds. The film at 40% shows a decrease in the Si-H bond. This indicates that H_2 flow reduces the hydrogen in the film, and the film composition is getting closer to Si_3N_4. A similar trend was observed for 13.56 MHz PECVD technology, suggesting that our extensive process expertise on SiNx deposition at 13.56 MHz is also applicable to 60 MHz VHF-PECVD. In addition, while the refractive index of the SiN_x film was as high as 2.15, we could control index down to 2.00 by adjusting the process parameters.

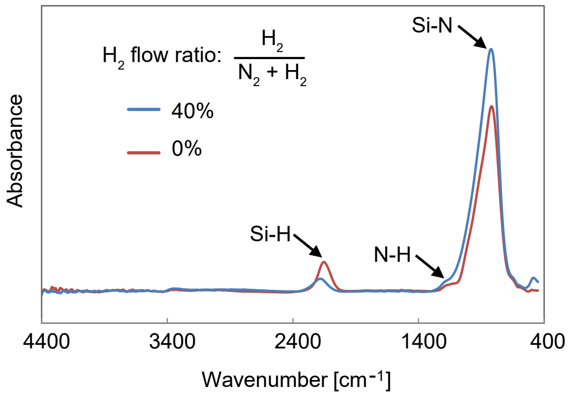


Figure 3. FTIR spectroscopic evaluation of H_2 flow ratio of 40% vs 0%.

Evaluation of SN-2-Si Film Crystallinity

Figure 4 shows the X-ray diffraction results of comparing the SN-2-Si with SiH_4-Si film deposition on c-plane sapphire using VHF-PECVD. The VHF power was 100 W, and the stage temperature was 250 °C. The pattern (1) shows intense peaks at preferential orientation Si (111): 2θ = 28.6°, Si (220): 2θ = 47.5°, and Si (311): 2θ = 56.3 °. Pattern (1) and pattern (2) show intense peaks at the same position, suggesting that we could deposit the microcrystalline Si film using SN-2 as well as SiH_4.

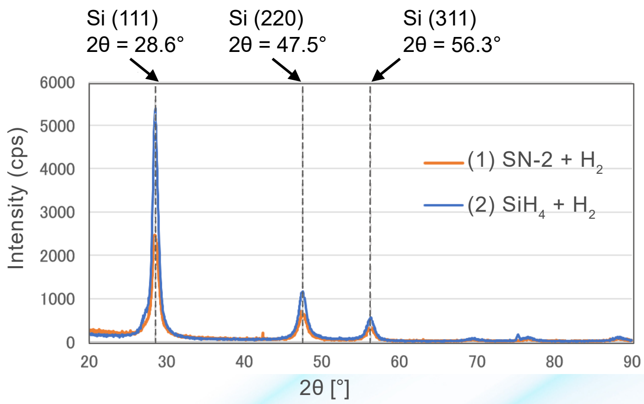


Figure 4. Comparison of Si film crystallinity of SN-2 and SiH_4 by X-ray diffraction.

Conclusion

This report demonstrates that we could tune the SN-2-SiN_x film quality deposited using VHF-PECVD by adjusting the H_2 flow rate. The SN-2-SiN_x film deposited by VHF-PECVD shows the same tendencies as that of desposited using 13.56 MHz PECVD. We also evaluated the SN-2-Si crystallinity by X-ray diffraction, and the result suggests that Si deposited in VHF-PECVD can be microcrystallized, in a manner similar to deposition using SiH_4 PECVD. We are developing a process to apply SN-2-SiN_x VHF-PECVD deposition to radio-frequency (RF) devices such as GaN/GaAs/InP HEMTs and plasma discharge damage-sensitive devices such as photodiodes, thin-film transistors, and solar cell applications. Samco keeps providing new and innovative solutions to meet our customers' demands.

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Samco Inc.

For more information please email: info@samco.co.jp

URL: https://www.samco.co.jp/en/

Japan (Kyoto)
Phone: +81-75-621-7841

South Korea (Suwon)
Phone: +82-70-8252-7841

Taiwan
Hsinchu Office
Phone: +886-3-516-5100
Tainan Service Office
Phone: +886-927-607-351

PR China
Beijing Office
Phone: +86-10-8219-4215
Shanghai Office
Phone: +86-21-6249-4662

Singapore
Phone: +65-6465-4220

Malaysia
Phone: +603-7629-7560

US, Canada & Latin America
West Coast Office, California
Phone: +1-408-734-0459
East Coast Office, New Jersey
Phone: +1-631-464-0664

samco-ucp ltd. Liechtenstein
Phone: +423-377-5959
Email: info@samco-ucp.com