Improvement of dopant concentration control with Acoustic Control System for B-SiGe epitaxy deposition

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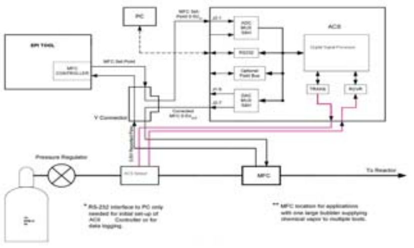
Introduction - Currently, SiGe-B epitaxy is a leading technology to induce strain in PMOS channel and improve the hole mobility to achieve better device performance [1-2]. In practice, we observe that the device performance strongly depends on the dopant concentration, especially boron concentration. It is shown that the Acoustic Control System [ACS] is able to actively respond to instantaneous variations of incoming gas and achieve better dopant control [3]. In this paper, we report reduction of boron concentration variation using ACS technology for SiGe-B epitaxy.

Experiment - The study is conducted on a single-wafer processing tool. The process is RPCVD SiGe-B epitaxy. B_2H_6 and GeH_4 are used as boron and germanium source. H_2 is the carrier gas. ACS is used to reduce the variation of GeH_4 and B_2H_6.

The ACS measures concentration of a gas mixture using acoustic waves - by measuring the time delay between two received spread acoustic spectrum signals. Sensitivity of the measurement is principally a function of the difference in molecular weight between two constituent gases [3] .

Fig. 1 shows the set up for this experiment. Incoming gas passes the ACS sensor first. Concentration of the gas is sent to the controller. Controller sends signal to the MFC downstream to compensate for any variation in the incoming stream.

Fig. 1: ACS configuration for Tool ID #9



Result -Fig. 2 is the normalized Ge and B concentration vs. time before and after ACS is installed. Concentration is measured by LEXES on patterned wafer used to monitor the epitaxial process. Data is normalized to the respective target of the manufacturing process. It shows that the variation of GeH4 and B2H6 is significantly suppressed.

Fig. 3 shows the frequency of flow adjustment for the production tools involved in the experiment. Tool #9 has ACS installed. Other tools use standard analog MFC control. Flow adjustment is used to control concentration as determined by statistical process control rules. When concentration of in-film B and Ge is out of control, incoming gas flow is adjusted to bring it in control. It is shown that frequency of adjustment is reduced more than 50% with the ACS.

Discussion - In this experiment, we show that adding a ACS control system to the gas supply system reduces variation of the in-film Ge and B concentration. It demonstrates that the ACS can be used in direct gas injection system in addition to its traditional use in bubbler systems. The benefit of lower frequency of flow adjustment provides direct benefit of higher tool availability for mass production.

Fig. 2 - Reduction of in-film [B] and [Ge] variation; System implemented at the vertical line. There are flow adjustments without the ACS, but none after ACS installation.

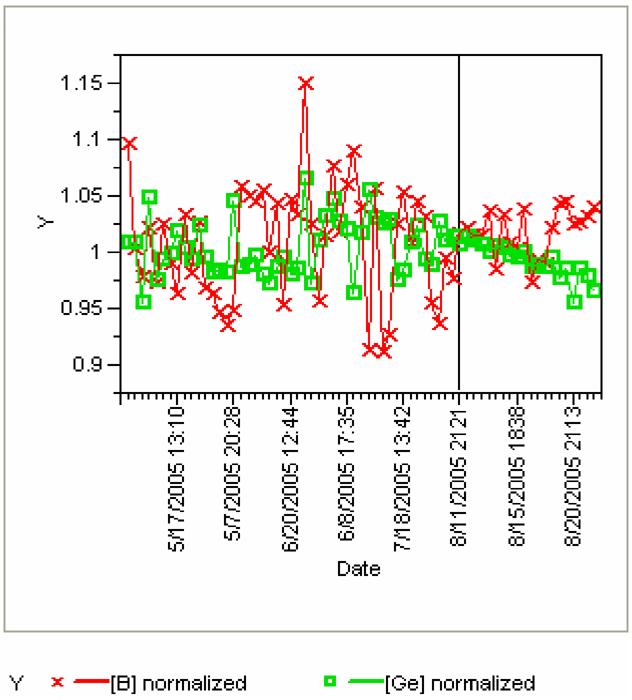
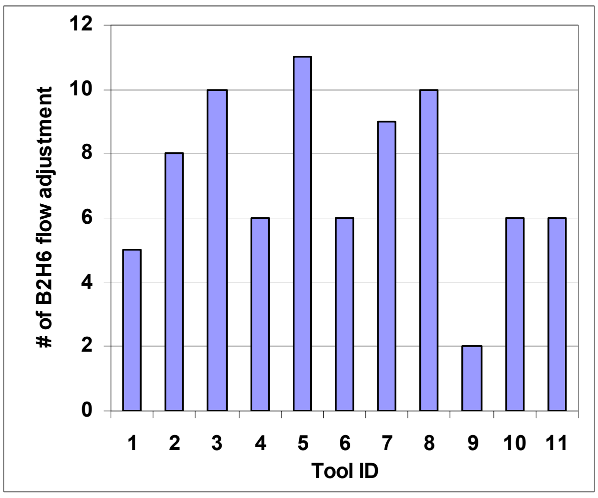


Fig. 3 - Reduction of frequency of flow adjustment for B2H6



Reference

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