Development of gate length feed-forward technology for controlling variability of Vtp

Fumitoshi Kawase, [1]Hisako Kamiyanagi, Emi Kanazaki, Satoshi Shibata
Kawase.fumitoshi@jp.panasonic.com
Tonami Plant, Semiconductor Company, Panasonic Corporation
[1]Panasonic Semiconductor Engineering Corporation
271 Higashi-kaihotsu, Tonami City, Toyama, Japan
Phone: +81 -763-32-4985 Fax: +81-763-32-1322

With the scaling of the device, the stabilization of the transistor characteristic in the product line is one of the most important issues. However, it is extremely difficult that processing technique of a thin gate electrode is developed. Therefore dispersion of transistor characteristic in the device mass production is mainly caused by the gate electrode processing variability. And the dispersion band becomes equal with the width of process control limits. Feedback system (FBS) or feed forward system (FFS) as Advanced Process Control (APC) is considered in order to control these dispersions. With the scaling of the device, it becomes the extreme complicated structures by overlapping all sorts of dopant profiles (ex. Channel, Drain Extension, Source/Drain,). Figure 1 shows the concept diagram of gate length feed-forward technology. In this paper, gate length feed-forward technology was examined, which adjusts the other process influenced Lg_{eff} (effective channel length) in response to gate length. Lg_{eff} is decided by gate length, drain extension implant, source/drain implant and the later anneal process. In a integrated circuit, there are different functions such as a Pch Tr. and Nch transistors on the same wafer. As dopant of the drain extension of the Pch transistor, boron is used. On the other hand, as dopant of that of the Nch transistor, phosphorus and Arsenic are used. By difference of the diffusion speed of these dopants, a change of anneal condition influences to coefficient of fluctuation of Vt. In this paper, gate length feed-forward technology was examined under some anneal conditions to control Vt of Pch transistor whose coefficient of fluctuation of Vt is wide. With the scaling of the device, RTA technology is used as activation anneal. RTA technology is used for the shallow junction formation in a short time equal to or less than 10 seconds. In thermal process of such sort term, the processing wafer cannot achieve the thermal equilibrium state. The measurement of wafer temperature has uncertainness of actual temperature around ±2 deg. Compared to that, thermal process time control is precision and easier than the temperature control. Therefore, feed-forward technology of anneal time is extremely effective. Especially, RTA equipment such as hot wall type can control briefly the wafer temperature because the temperature of a wafer is raised rapidly by moving in desired high temperature circumstance or turned down by moving in low temperature circumstance. First of all, in the standard gate length, it becomes the correlation of *RTA time* and *Vt*. This result shows in figure2, the relation between *Vt* and the *RTA time* is approximated by Eq. ①.

$$Vt = a \times RTA_{time} + b \quad \cdot \cdot ①$$

Next, the correlation of measured length of the gate and *Vt* is shown in figure3. In the device mass production, process control of gate length is limited to maintain the transistor characteristic. It is defined that *Vt* is the maximum value in maximum value (Lg_{max}) of the gate length in the management standard when the correlation is requested. It approximates to the quadratic function the relation. The result is shown in Eq.②.

$$Vt = c \times \left(Lg_{mes} - Lg_{\max}\right)^2 + d \quad \cdot \cdot ②$$

(Lg_{mes}: measurement gate length)

Simultaneous equation of Eq①and ② was solved and Eq③ was lead.

$$RTA_{time} = A \times \left(Lg_{mes} - Lg_{\max}\right)^2 + B \quad \cdot \cdot ③$$

Figure 4 shows the controllability of Vt of using Eq.③. Diffusion area of dopant can be controlled, effective channel length (Lg_{eff}) by feed-forward technology of a gate length in RTA time. As a result, with high controllable RTA process, technology stabilized transistor characteristic is established by feed-forward technology of activated RTA time.

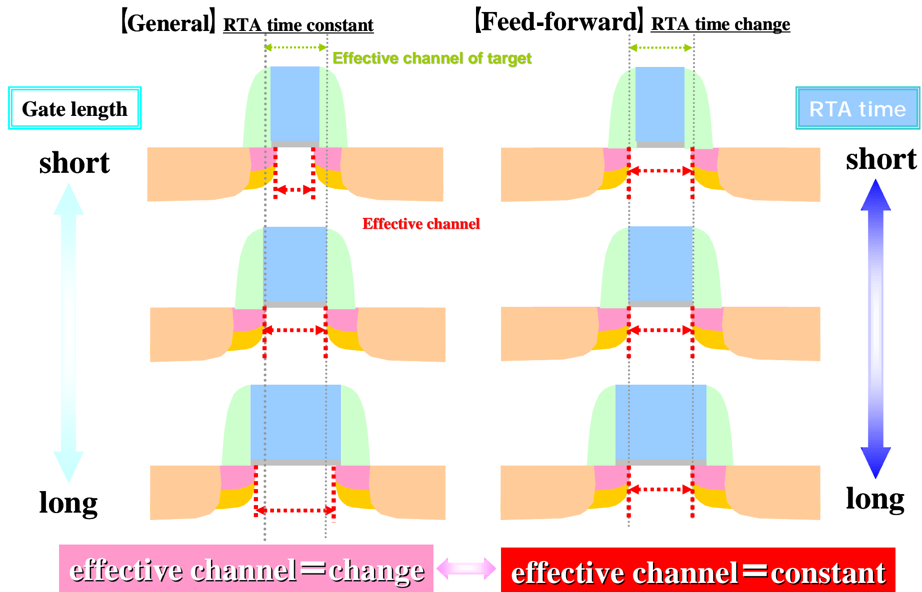

Fig1. Gate length feed-forward technology

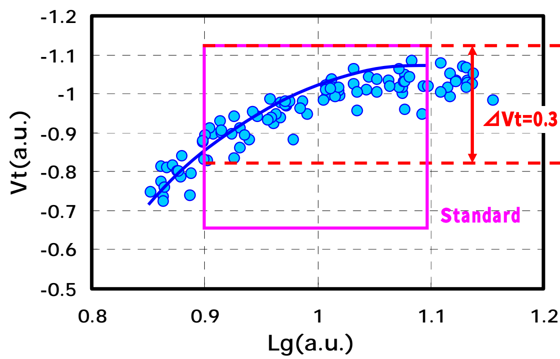

Fig2.Correlation between gate length and Vt

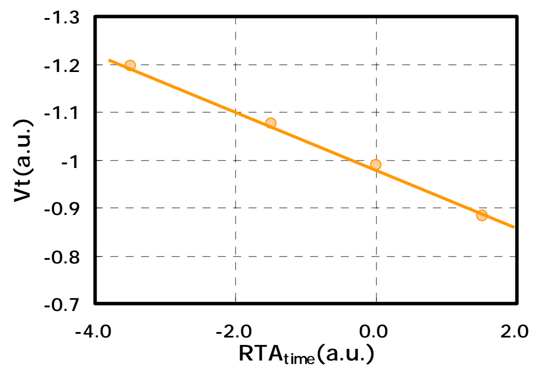

Fig3. Correlation between RTA time and Vt

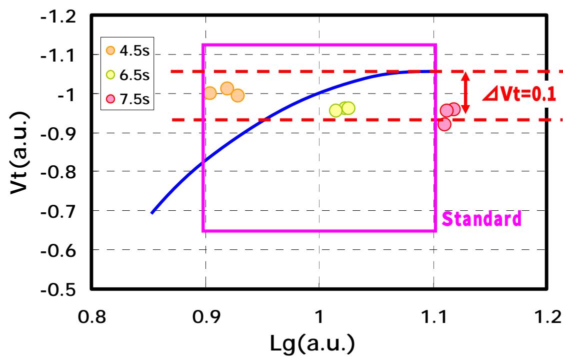

Fig4. Result of controlling variability of Vt