Study of VTCMOS characteristics and its optimum conditions with a compact analytical model

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Variable Threshold Voltage MOSFET (VTCMOS) has promised to be amongst the next generation of ultra-low power devices operating at low supply voltage [i]. The performance of a VTCMOS is mainly determined by the body effect factor (γ) and *S-factor* at a given $|V_{bs}|$. In this study, a very compact analytical model of VTCMOS is proposed to study the *active on-current* ($I_{on}(a)$), linking it with the *stand-by off-current* ($I_{off}(s)$) characteristics.

Fig 1 shows the modeled $I_{on}(a)$ and its contour map projected onto the $\gamma - V_{bs}$ plane, at a fixed $I_{off}(s)$ of 10^{-13} A/μm. When $|V_{bs}| = 0$ (a normal MOSFET), as γ increases V_{th} increases due to increased S and thus $I_{on}(a)$ decreases. However, when V_{bs} is sufficiently large (for example, $|V_{bs}| = 1.2$V), as γ increases V_{th} decreases and $I_{on}(a)$ increases. Therefore, there are two completing factors that degrade and enhance $I_{on}(a)$. When the two factors are balanced at a certain $|V_{bs}|$, $I_{on}(a)$ does not depend on γ, as shown in Fig 1. We denote the characteristic value of $|V_{bs}|$ as $|V_0|$. V_0 is very important because its value would give a rough idea for the optimum conditions of a VTCMOS performance. Importantly, when $|V_{bs}| > |V_0|$, as γ increases $I_{on}(a)$ increases, whilst when $|V_{bs}| < |V_0|$ as γ increases $I_{on}(a)$ decreases. Recent numerical simulations are consistent with these modeling results [ii]. The physical origin of $|V_0|$ can be understood by differentiating $I_{on}(a)$ with respect to γ and given by: $|V_{bs}| \equiv |V_0| = [\log_{10}(I_{off}(s)^{-1}) - \Omega'] \cdot dS/d\gamma$. We found that the value of $dS/d\gamma$ is closely related to the SCE. When the SCE appears, $dS/d\gamma$ tends to decreases and $|V_0|$ decreases. This is because when the SCE appears S-factor is degraded at a smaller γ and the γ-dependence of I_{on}(a) is weakened even when $|V_{bs}|$=0V. However, it is found that worse SCE causing S and γ to degrade quickly makes $I_{on}(a)$ smaller at a given $|V_{bs}|$. Thus, in order to enhance $I_{on}(a)$ it is essential to reduce the SCE.

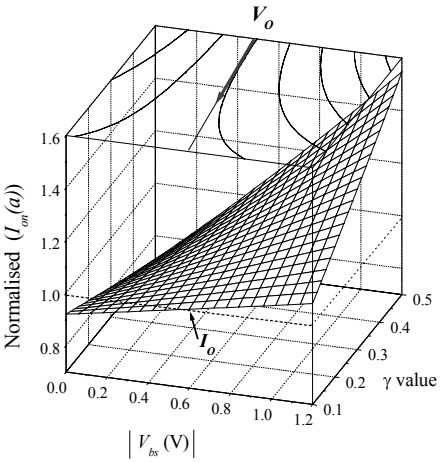

Fig 1. Calculated $I_{on}(a)/I_o$ and its contour map onto the $\gamma - V_{bs}$ plane.

[i] T. Kuroda *et al*, IEEE J. Solid-State Circuits, vol. 31, pp. 1770-1779, 1996 [ii] H. Koura *et al*, Jpn. J. Appl. Phys., vol 39, pp. 2312-2317, 2000