MODEL PREDICTION OF STOCHASTIC EFFECTS OF PLASMA-INDUCED DAMAGE IN ADVANCED ELECTRONIC DEVICES

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Three-dimensional device technologies such as finFETs[1] have attracted much attention recently, where plasma processing plays an important role in realizing such structures. Ion bombardment damage—denoted here as "plasma-induced physical damage (PPD)"—has been intensively studied, because the mechanism is naturally governed by basic plasma parameters[2] and the stochastic mechanisms. Lateral straggling and sputtering of incident ions were found to be responsible for defect creation in the fin (sidewall) during finFET etching[3]. The created defects degrade device performance[4] and enhance the parameter variability[5] in ULSICs when the plasma fluctuates. Figure 1 illustrates the PPD mechanisms with a classical molecular dynamics (MD) simulation result. In this MD simulation[6] (Fig. 1(b)), one thousand Br atoms—regarded as ions—were impinged only on the bottom surface at normal incidence. As seen, in addition to the damaged layer formation under the bottom surface, one can see the species permeating the fin bulk due to straggling and sputtering (Figs. 1(a) and 1(b)). Figure 1(c) shows the number of atoms counted in the fin from the MD snapshots. These species become the latent damage because they are hardly removed by the conventional wet-etch process.
The PPD mechanisms are described by the modified PPD range theory[7] and the damaged layer thickness (d_{dam}) which includes the created defects (n_{dam}) is expressed by

$$d_{\mathrm{dam}} = A_{\mathrm{PPD}} \times E_{\mathrm{ion}}^{k}, \qquad (1)$$

where E_{ion} is the average energy of incident ions. A_{PPD} and k are the process and material dependent constants. In conventional manufacturing processes, the damaged layer is stripped off by the subsequent wet-etch after the plasma process. The etched depth (d_{R}) results in the Si loss (Si recess[8]). The remaining defects (N_{dam}) after the wet-etch is related to both n_{dam} and d_{R} with the trade-off relationship[5]. The latent defects degrade drain current of the damaged MOSFET (I_{dam}), which is analytically written as

$$I_{\mathrm{dam}} = I_0 \times [1 - B_{\mathrm{PPD}}\, N_{\mathrm{dam}}], \qquad (2)$$

where I_0 is the initial drain current[4]. B_{PPD} is the process and material dependent constant. The variation of E_{ion} in response to the fluctuation of plasma enhances that of I_{dam} in an ULSIC. Model predictions[3] verify that the variability enhancement by PPD induces serious performance degradation of an ULSIC. Therefore, one should pay careful attention to the stochastic PPD mechanisms discussed in this article for designing future three-dimensional devices and the ULSIC variability / reliability.

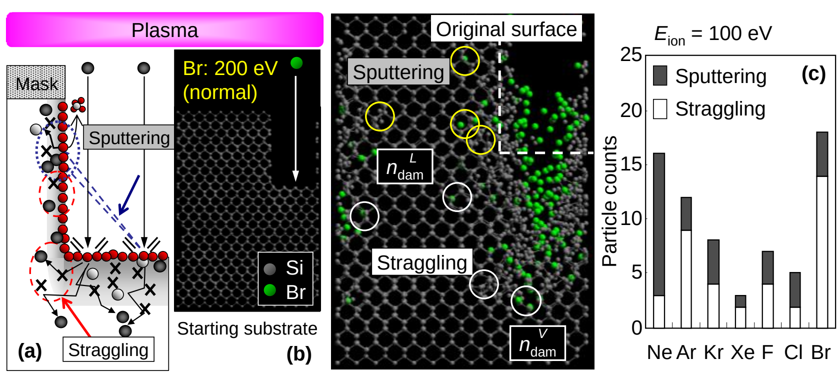

Figure 1 – *Stochastic effects of ion bombardment damage during fin-structure etching*

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