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Three-Dimensional Characterizing Analysis of Astronomic CCDs with a deep depletion

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Buried channel JET-X CCDs (Joint European X-ray Telescope Charge Coupled Devices: EEV CCD12) with a deep depletion have been analyzed to provide an optimized condition for a charge storage and transfer. A maximum charge capacity has been found for the supplementary narrow channel by considering the potential distribution as a function of a mobile charge. Analysis for the depletion edges of JET-X CCDs have been successfully performed, showing good agreement with the depths estimated from X-ray detection efficiency measurements [1].

A time-dependent simulation for a three-phase image cell of a JET-X CCD has been performed to evaluate a full well capacity and CTE (Charge Transfer Efficiency) as a function of the fall time of a clock pulse [2]. It was observed from the investigation that the effect of the fall time on the charge transfer is very important for a very high CTE and thus a much longer fall time than a rise time is desirable. For a JET-X CCD the charge transfer efficiency was found to be approximately 99% from a simulation with a clock cycle of 4.2 ns having a full time of 0.4 ns, as shown in Fig. 1.

Note that an exact comparison of the full well conditions and thus full well capacity obtained from static and transient simulations cannot be given because the consideration of a potential barrier between two channels was neglected in the latter simulation. However, an approximate estimation for the maximum charge capacity could be obtained by comparing the surface potential barrier, φ_{sb}, and minimum potential, φ_m, of the latter with those of the former. The maximum charge capacity was calculated as 61110 electrons under a full well condition of φ_m=11.1 V and φ_{sb}=0.37 V. The potential minimum was located at 0.21 ㎛ away from the surface. This comparison demonstrates that the static maximum capacity was underestimated by approximately 1.7%. Another important effect was that the maximum capacity was also reduced when a reduced channel width is included in the simulation. For example, a simulation with a channel width of 2 ㎛ showed a very low maximum capacity of approximately 39000 electrons. It should be pointed out from this that two dimensional simulation usually underestimates a charge handling capability of a device.

As a consequence, an accurate analysis for a charge handling capability of a CCD device including a narrow channel width is only possible with a three-dimensional numerical simulation. It can be concluded from the simulated results that for a higher charge handling capability of a JET-X CCD a higher supplementary channel doping (i.e. $\geq 5.5\times10^{11}$cm ^{2}) is required to increase a potential well depth maintaining a same channel structure for a radiation hardness. Also, an optimized clocking scheme with a longer fall time (i.e. ≥0.4 ns) is strongly suggested for a higher charge transfer efficiency.

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References

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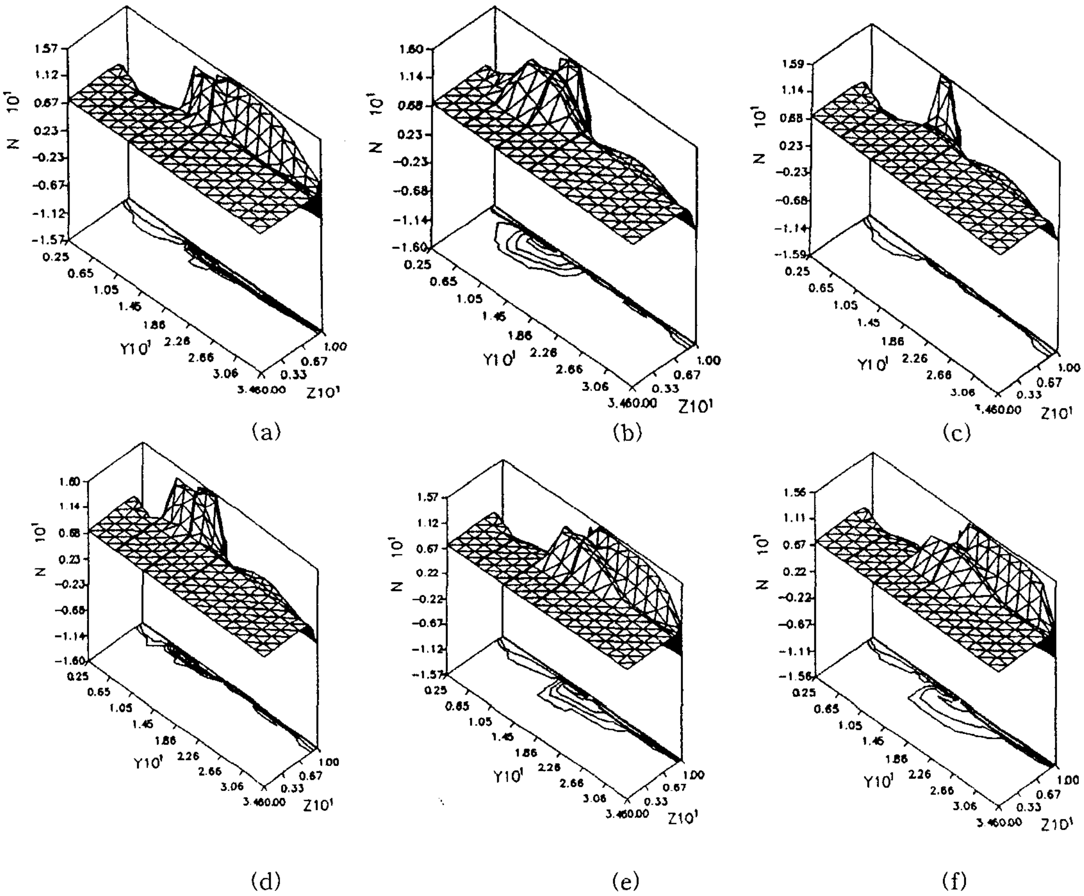

Fig. 1 A charge transfer process of a full well charge packet at different transfer times: at (a) t=1.1, (b) 1.2, (c) 1.3, (d) 2.1 (e) 2.2 and (f) 2.3 ns, respectively. The magnitude of the charge electron is shown as LOG-scale.