SESSION IX: Optical Display and Storage Techniques

THAM 9.6: Charge Transfer in Charge-Coupled Devices

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PREVIOUS THEORETICAL work [1-4] on the operation of charge-coupled devices has been rather qualitative. These studies emphasize one of a number of factors which can influence the charge-transfer process, for example, nonlinear diffusion [1-3] and fringing fields [4]. However, none of these studies take account of all the factors in a realistic way.

Results of Study Assessed

This paper will present the results of a study of the charge-transfer process in a realistic model of a high density CCD. This model includes a realistic relation between the surface charge and surface potential, fringing fields and all relevant electrodes. The nonlinear diffusion equation describing the charge transfer has been solved using a new and efficient numerical scheme, the box scheme [5].

Charge Transfer Features

It has been found that the charge transfer process divides quite naturally into three distinct stages. The first stage consists of the initial spreading of the charge confined under the storage gate until charge is present under the transfer gate. This process takes only a few nanoseconds. During the second stage, the charge transfer occurs in a manner analogous to the operation of a conventional MOS transistor. The storage electrodes act as the source and the drain and the transfer electrode acts as the control gate. In this stage, the charge distribution under the transfer gate is rather constant, while that under the storage gate is decaying with almost a nonchanging shape. This process takes a few tens of nanoseconds. During the final stage, the charge transfer is limited by thermal diffusion of charge from under the storage electrode. For certain gate configurations and clocking schemes, fringing fields may also assist the transfer of charge during this stage. This process requires hundreds of nanoseconds.

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1 Kim, C. K., and Lenzlbinger, M., *Journal of Applied Physics;* to be published.

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3 Engler, W. E., Treman, J. J., and Baertsch, R. D., *Applied Physics Letters,* 17, p. 469; 1970.

4 Kosonocky, W. F., and Carnes, J. E., *IEEE Journal of Solid State Circuits, SC-6,* p. 314; 1971.

5 Keller, H. B., "Numerical Solution of Partial Differential Equations," *Academic Press,* p. 327; 1971.

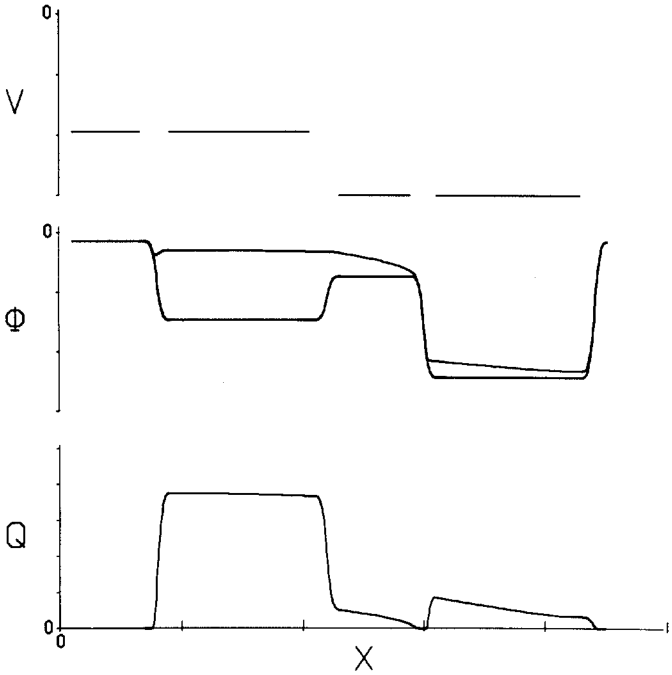

FIGURE 1—Computer solutions of surface-charge density and surface potential during charge transfer in a two-phase charge-coupled device.