Deal B E, Sklar M, Grove A S & Snow E H. Characteristics of the surface-state charge (Q_{ss}) of thermally oxidized silicon. *J. Electrochem. Soc.* **114**:266-74, 1967.
[Research and Development Labs., Fairchild Semiconductor, Palo Alto, CA]

The fixed oxide charge associated with thermally oxidized silicon has been studied as a function of processing conditions. Its density can be reproducibly controlled over two orders of magnitude. Its origin is proposed to be partially ionized silicon, resulting from the oxidation process. [The *SCI*® indicates that this paper has been cited over 260 times since 1967.]

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"This paper is the second by this group of authors to be designated as a *Citation Classic*. The first deals with the capacitance-voltage method used to investigate metal-oxide-semiconductor (MOS) structures.[1] Two other publications have also proved very popular—one discusses the effect of alkali ions, i.e., Na^+, on MOS instability,[2] and the other presents the general relationship for the thermal oxidation of silicon.[3]

"The cited paper describes effects of high temperature processing steps on the surface-state charge, Q_{ss} (now designated fixed oxide charge, Q_f). This charge is one of four general types of electrical charges associated with thermally oxidized silicon. Up to the time of the publication (1967), the various types of instabilities and charges in oxidized silicon structures were not properly characterized or understood, and it was difficult if not impossible to manufacture stable MOS devices with the proper threshold (turn-on) voltages. The results of this investigation helped to characterize the four types of charges and to control fixed charge densities (and therefore device parameters) by employing the proper process conditions. The evaluations were made possible by the very careful processing techniques of the second author (M. Sklar).

"Over the past 15 years considerable controversy and disagreements have occurred among workers in this field due to lack of consistency in designation of the names and symbols used to denote the four types of charges. Recently, a committee sponsored by groups in the IEEE and Electrochemical Society attempted to resolve the problem and have presented recommended terminology for silicon oxide charges.[4]

"This publication and the others mentioned have been cited many times in the literature because the results presented have helped lay the groundwork for today's current MOS technology, which in 1982 is expected to represent more than five billion dollars in total sales worldwide."

1. **Grove A S, Deal B E, Snow E H & Sah C T.** Investigation of thermally oxidized silicon surfaces using metal-oxide-semiconductor structures. *Solid-State Electron.* **8**:145-63, 1965.
[Citation Classic. *Current Contents/Engineering, Technology & Applied Sciences* **10**(24):20, 11 June 1979.]
2. **Snow E H, Grove A S, Deal B E & Sah C T.** Ion transport phenomena in insulating films. *J. Appl. Phys.* **36**:1664-73, 1965.
3. **Deal B E & Grove A S.** General relationship for the thermal oxidation of silicon. *J. Appl. Phys.* **36**:3770-8, 1965.
4. **Deal B E.** Standardized terminology for oxide charges associated with thermally oxidized silicon. *IEEE Trans. Electron Devices* **ED-27**:606-8, 1980.