The temperature dependence of steady-state electronic conduction in SiO$_2$ films was investigated using metal-oxide-silicon capacitors. To remove anomalies due to space charge polarization, a special experimental procedure was employed whereby the steady state current measurement was made at decreasing applied voltage or temperature. Experimental data will be presented to show that Schottky thermionic emission and Schottky-like field emission have been, for the first time to the author's knowledge, observed in SiO$_2$ at temperatures above 300°C. The self-consistency of the data will be discussed.

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According to the unified theory of contact-limited conduction in solid insulators, Schottky thermionic emission and Fowler-Nordheim (FN) field emission are two limiting cases of a generalized formulation (1): The former prevails at low fields and high temperatures whereas the latter dominates at high fields. The well-known mathematical expressions of current flow for these two mechanisms (i.e., the Schottky-Richardson equation and the FN tunneling equation) can be readily obtained from the generalized equation, using approximations appropriate for the respective temperature and field conditions. In the intermediate range where no simplifying approximation can be made, the generalized equation cannot be solved in a closed form, and numerical analysis has shown that Schottky-like field emission may be observed in this transition region. Although the theory appears to be well founded its experimental verification, particularly in the moderate and high field range, has been difficult primarily due to the lack of metal-insulator systems having appropriate material parameters.

Since the advent of insulated-gate field-effect transistor technology, the quality of the SiO₂ films thermally grown on silicon has improved to such an extent that with the oxide's low impurity content, low trap density, high dielectric strength and wide bandgap, the metal-oxide-silicon (MOS) structures have become an excellent investigative vehicle for contact-limited conduction studies. So far, however, the reports on steady-state electronic conduction in SiO₂ films have been scarce and varied, and fail to fit into a coherent picture. For example, electronic conduction in high purity SiO₂ films was earlier reported to be space-charge limited or bulk limited at low fields and high temperatures (2), but has been recently shown to be limited by FN emission (or contact-limited) at high fields (3,4). To resolve the apparent discrepancy, which is attributable to conduction transients (3) and anomalies arising from mobile charge polarization (5), high field space-charge buildup (6) or interface states effect (1,4), we have conducted a careful study of the temperature dependence of the d.c. conduction in thermal oxide over a wide range of applied fields.

The present note reports the results of this investigation and presents what is believed to be the first, self-consistent evidence showing that Schottky thermionic emission, Schottky-like field emission, and FN tunneling all occur in the SiO₂ system in the appropriate temperature and field regions predicted by the unified theory.

The experimental study was conducted using floating guard-ringed MOS capacitors which were fabricated on 2 Ω-cm, p-type, (100)-oriented silicon substrates, thermally oxidized at 1000°C in dry oxygen to various oxide thicknesses ranging from 500Å to 3000Å. Metal electrodes, 0.041 cm² in area, were deposited on the oxide films from an E-gun heated source. After metallization, capacitor specimens were annealed in N₂ atmosphere 5 minutes at 500°C for Al electrodes (7), and 10 minutes at 800-1000°C for more inert metals such as Cu, Au and Pt. The annealing treatment was found to remove the radiation damage as well as the interface states in the completed MOS structures. Capacitance-voltage measurements indicated that the interface states and fixed oxide charge in these capacitors have been reduced to less than 10¹¹ cm⁻². The mobile charge concentration in the oxide films was

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