**Lampert M A. Simplified theory of space-charge-limited currents in an insulator with traps. *Phys. Rev.* 103:1648-56, 1956.
[RCA Laboratories, Radio Corporation of America, Princeton, NJ]**

Passage of the electron quasi-Fermi level through a discrete trap level in the forbidden energy gap of an insulator, due to injection of excess electrons, marks the onset of a nearly vertical rise of current with further increase of voltage. The corresponding TFL (trap-filled-limit) voltage enables simple measurement of the number of traps. [The *SCI*® indicates that this paper has been cited over 335 times since 1961.]

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"In the late-1940s and early-1950s, A. Rose and collaborators at RCA Laboratories in Princeton showed that the phenomenon of space-charge-limited injection currents provided a powerful tool for the measurement of electron, or hole, trap concentrations in insulators.[1] Appropriate to the amorphous films he had been studying, Rose modeled the trap energies as a continuous distribution extending over the forbidden gap until merging with a band edge.

"Having joined RCA Labs in 1952, I had not yet gotten accustomed to Rose's highly personal style—exceptionally intuitive, with mathematics hardly anywhere in sight. And so I set about to re-derive some of his results in more traditional, mathematical fashion. The simplest candidate for analysis was a trap distribution uniform in energy. Further, just to add a little novelty to the situation, I imposed an energy ceiling on the distribution, cutting it off before it reached a band edge. Something quite bizarre emerged from the calculations. So long as the quasi-Fermi level was moving within the distribution, I confirmed Rose's result, namely, current rising exponentially with voltage. However, once the quasi-Fermi level passed through the energy distribution ceiling into a region of no traps, the current rose even more steeply with voltage! On the one hand this made no sense; on the other, I just couldn't find any errors in the calculation. Worried that the bizarre result might be an artifact of some indispensable approximations that I'd made, I thought to settle the issue by finding a significant set of traps for which the injection problem was completely solvable analytically, with no approximations at all. A set of traps at a single, discrete energy level fitted the bill quite nicely, and the complete solution to that problem became the basis for my 1956 paper. The 'bizarre' result I had initially found with a bounded, uniform distribution reappeared in all its glory in the discrete-trap solution. I had stumbled upon what I called the trap-filled-limit (TFL) phenomenon—a nomenclature which has been widely accepted. A very simple physical explanation of this phenomenon was a few more years in coming.[2] The 1956 paper is widely cited presumably because the TFL phenomenon is such a powerful tool for getting at dominant trap numbers in insulators, and perhaps also because of the presence of just enough mathematics to lend it an aura of authority. A more comprehensive survey of both space-charge and neutral injection currents in insulators and semiconductors can be found in a 1970 book.[3]

"I should like to underline the role of sheer good luck in the TFL discovery. Rose's oversight, deriving from his preoccupation with trap energy distributions as compared to a discrete trap energy, became my good fortune. So it goes! An old Yakutsk proverb reads, 'He who eschews good luck will only chip a tooth!' Twenty-five years later, Lady Luck, normally attentive only to youth, once again smiled in my direction as, thanks to a long-persisting oversight by the founders of modern electrolyte theory, I stumbled upon a well-hidden and remarkable property of the familiar nonlinear Poisson-Boltzmann equation, namely, a Coulomb condensation."[4]

1. **Rose A.** Space-charge-limited currents in solids. *Phys. Rev.* **97**:1538-44, 1955.
2. **Lampert M A.** Injection currents in insulators. *Proc. IRE* **50**:1781-96, 1962.
3. **Lampert M A & Mark P.** *Current injection in solids.* New York: Academic Press, 1970. 351 p.
4. **Lampert M A.** The Coulomb condensate of the nonlinear Poisson-Boltzmann equation: a unified theory. *Chem. Phys.* In press, 1982.