

Welmer P K. The TFT—a new thin-film transistor. *Proc. IRE* 50:1462-9, 1962.
[RCA Laboratories, Princeton, NJ]

Operable thin-film transistors (TFTs) of the insulated-gate field-effect type were produced by vacuum deposition of polycrystalline semiconductor films onto an insulating substrate. Completely integrated thin-film circuits incorporating passive elements and TFTs operating in the enhancement mode were described. [The SCI® indicates that this paper has been cited in over 135 publications since 1962.]

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"The thin-film transistor (TFT) described in this paper attracted considerable attention when first presented at the IRE-AIEE Device Research Conference¹ in 1961. It was an early form of the insulated-gate field-effect transistor,² similar in operation to the now-familiar silicon MOS transistors used in integrated circuits. As the first functional device of its type, it permitted completely integrated thin-film circuits to be deposited on a glass substrate by automated processes at a time when modern silicon circuits were still in their infancy. Although the TFT approach to integrated circuits was soon displaced by single-crystal silicon for most applications, the advantage of the TFT for large-area circuits was apparent, and it is still being actively investigated for panel displays.³ Our early demonstrations of thin-film circuits employing hundreds of TFTs

undoubtedly contributed to the number of citations to this paper.

"The TFT project at RCA Laboratories offered us an excellent opportunity to apply some of the evaporation techniques developed during our earlier work on television camera tubes. The first semiconductor films used for the TFT were of CdS for which considerable experience had been gained in work on the vidicon. Although fine pattern lithography using photoresist masking was well known in 1961, I preferred to use mechanical masks which could be moved within the vacuum system thereby permitting fabrication of a complete circuit in one pump-down of the system. The same stretched-wire masking jig which had been built for producing color filter patterns in the early tricolor vidicon⁴ served to define the source, drain, and gate in the TFTs. This technique was still in use several years later for fabricating self-scanned thin-film image sensors containing tens of thousands of components. Our early experience with n- and p-type TFTs led to my invention of the low-power complementary inverter and flip-flop circuit⁵ now widely used for C-MOS silicon memories.

"For me personally, the TFT development with its integrated circuit aftermath provided a most enjoyable phase of my working career. It was rather fun to challenge the silicon establishment with an alternative approach which we felt offered some unique advantages. The TFT resulted in my being awarded the 1966 IEEE Morris Liebmann Prize and, with coauthors, 'best paper' awards at the 1963 and 1965 International Solid State Circuits Conferences.

"Among the many people at RCA Laboratories who made early contributions to the TFT program were Frank Shallicross, G. Sadasiv, Lorand Meray, Verne Frantz, Herbert Lambert, and W.S. Homa. I am also grateful to A. Rose for many helpful discussions on wide band gap semiconductors."

1. **Welmer P K.** *An evaporated thin film triode.* Unpublished paper presented at the IRE-AIEE Device Research Conference, Stanford University, Stanford, CA, June 1961.
2. **Shockley W & Pearson G L.** Letter to editor. (Modulation of conductance of thin films of semi-conductors by surface charges.) *Phys. Rev.* 74:232-3, 1948.
3. **Brody T P, Asars J A & Dixon G D.** A 6 × 6 inch 20 lines-per-inch liquid-crystal display panel. *IEEE Trans. Electron Devices* ED-20:995-1001, 1973.
4. **Welmer P K, Gray S, Beadle C W, Borkan H, Ochs S A & Thompson H C.** A developmental tricolor vidicon having a multiple-electrode target. *IRE Trans. Electron Devices* ED-7:147-53, 1960.
5. **Welmer P K.** *Insulated-gate field-effect devices and electrical circuits employing such devices.* US patent 3,191,061. Filed May 31, 1962, issued June 22, 1965.