This Week's Citation Classic

Goodman A M. Metal-semiconductor barrier height measurement by the differential capacitance method—one carrier system. *J. Appl. Phys.* **34**:329-38, 1963. [RCA Laboratories, Princeton, NJ]

The differential-capacitance-measurement method for characterizing an ideal metal-semiconductor Schottky-barrier contact is based on assumptions which may or may not be valid. Some of these deviations from ideality were examined in order to determine their effects upon the interpretation and validity of measurements on real contacts. [The ***SCI***® indicates that this paper has been cited over 170 times since 1963.]

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"In 1960, I began research on metallic contacts to semiconductors. The purpose of the program was to be a fundamental investigation into the nature of contacts between metals and semiconductors with emphasis upon an experimental study of the charge transport properties of the contact region and the relationship of these properties to the chemical and physical nature of the contact. Since my knowledge in this area was based on the rather limited coverage in graduate courses in solid-state physics and electronics in the 1950s, I had a lot *of* learning to do.

"I started by reading Henisch's book[1] which contained the best overall review of metal-semiconductor contacts at that time. It seemed to me that the 'dynamic capacitance' (differential capacitance) measurement technique described there was so elegant and simple that I should use it as one of my investigative tools. I fabricated barrier contacts by electroplating gold on the surfaces of single crystals of cadmium sulfide and measured the barrier capacitance as a function of the applied bias voltage. To my dismay, I found that the results were rather more complicated than what I had expected. This led to the realization that the differential-capacitance-measurement method for characterizing an 'ideal' metal-semiconductor Schottky-barrier is based on a number of assumptions which, in reality, may not be valid. Some of these deviations from ideality were examined in detail in order to determine the effect of each upon the interpretation and validity of measurements on 'real' contacts. Specifically, in the paper, I considered the effects of each of the following departures from the simple model: series resistance, traps in the depletion layer, effective contact area variations with depletion layer width, an insulating interfacial layer between the metal and the semiconductor, semiconductor-surface-charge variation with bias voltage, and the reserve layer at the edge of the barrier. The results *of* this work were later used in the characterization of metallic contacts to cadmium sulfide[2,3] and strontium titanate.[4] At the time, I think I considered this work a detour from the main path of my research: in retrospect it appears to have been the more important part of it.

"In rereading the article now, the words 'one carrier system' in the title seem a bit misleading, implying, perhaps, that there should have been a sequel. Actually, those words were added to the title to sidestep the objections of a reviewer who complained that the paper did not treat the effects of minority carrier injection and extraction. These minority carrier effects have since been considered by others and are described in an excellent review by Rhoderick.[5]

"I suspect that the 1963 paper has often been cited because it addressed problems that are commonly encountered in the use of the differential capacitance method, and because it is useful in understanding and solving some of those problems."

1. **Henisch H K.** Unipolar rectification theories. (Henisch H K) *Rectifying semi-conductor contacts.* Oxford: Clarendon Press. 1957. p. 168-220.
2. **Goodman A M.** Electroplated gold and copper contacts to cadmium sulfide. *Surface Sci.* **1**:54-70, 1964.
3. ....., Evaporated metallic contacts to conducting cadmium sulfide single crystals. *J. Appl. Phys.* **35**:573-80. 1964.
4. **Carnes J E & Goodman A M.** Evaporated metallic contacts to conducting strontium titanate single crystals.*J. Appl. Phys.* **38**:3091-6, 1967.
5. **Rhoderick E H.** *Metal-semiconductor contacts.* Oxford: Clarendon Press, 1978. 201 p.