IEEE EDS Webinar: November 13, 2019

Transport Theory for 21st Century Device Technologists

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In 1950, van Roosbroeck [1] formulated the so-called semiconductor equations that have guided the development of semiconductor technology. In their first course on semiconductors, every device engineer learns these equations and how to solve them. Is this sufficient for the next 50 years? The speaker will argue that it is not.

As devices have gotten smaller and more sophisticated, research on carrier transport has proceeded hand in hand with advanced device research. The frontiers of knowledge have been extended, and we now have a deep understanding of how transport plays out in devices. Experts continue to dive deeper, but Carver Mead has pointed out that more is needed [2]. Periodically, we need to pull back from frontier research the new understanding that should become the working knowledge of all device engineers. To do so, we must decide what is essential, simplify appropriately, and unify seemingly disconnected topics. Doing this is not easy, but Mead argues that it is absolutely essential.

This talk is my attempt to follow Carver Mead's advice. Modern transport theory should proceed from the bottom up by first understanding transport at the smallest scales and then working up to micro- and macro scales approaches for larger devices. Doing so presents quantized conduction, ballistic transport, and diffusive transport in a simple, connected way. The connection to thermal transport from the nanoscale to the macroscale is then straightforward too. All of this can be taught to beginning graduate students in about the time we now take to teach them the drift-diffusion equation. The speaker will argue that is time to re-write our textbooks to prepare a new generation of students to advance electronics in the 21st century.

[1] W van Roosbroeck, "Theory of the flow of electrons and holes in Germanium and other semiconductors," *Bell System Technical Journal*, vol. 29, pp. 560-607, October, 1950.
[2] Carver Mead, *Collective Electrodynamics*, MIT Press, 1999.