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Optical Excitation Response Times for Field Emission from an Individual p-type Si Nanowire

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There has been extensive research on optically modulated and optically pulsed tip electron sources for new high field physics in the ultrafast laser community [1], electron microscopy [2] and ultrafast electron diffraction [3]. This is mostly the excitation of metallic tips or surfaces for which the quantum efficiency is extremely low eg. 10-3-10-4. This means that the high current emission will be limited by temperature effects. Another route is to exploit the photo-excitation of p-type semiconductor tips for which very high photon-electron conversion rates can be obtained (>10%), though at the expense of much slower time responses.

In contrast to the exponentially increasing current as a function of applied voltage common for metal emitters, semiconducting emitters can reveal strong current saturation related to a field-induced depletion zone originating at the emitter apex. The saturation current is highly sensitive to light and temperature. The basic behavior [4] and rough theory [5] were worked out many years ago followed by many experimental results with cursory analysis. However there is a dearth of in-depth measurements and concomitant understanding of the phenomenon in terms of semiconductor physics. We have shown that SiNWs can serve as an excellent platform for exploring FE from semiconductors with the added advantage for future applications that they can be mass produced. Our principal present goal is to understand the optical time response and eventually apply this knowledge to higher current, faster, cone-like Si emitters.

Our optical response to square wave laser pulses reach the μsec time scales which are among the fastest for semiconducting nanowires in the literature and are postulated to be controlled by the reservoir of defect states in the gap. Note that the literature is almost exclusively made on double-clamped nanowires without field emission. In contrast, the response time to electrical pulses reach the highest we can apply currently (100 MHz) which means that the two transport stimulations do not access defect reservoir populations in the same way.

The rather original measurement techniques will be explained.

[1] P. Hommelhoff and coworkers - PRL 97, 247402 (2006), Nature 475,78 (2011), C. Ropers and coworkers - PRL 98,043907 (2007), PRL 105, 147601 (2010), Nature 483, 190 (2012), Yanagisawa and coworkers - PRL 103, 257603 (2009), PRL 107, 087601 (2011), etc.

[2] A.H. Zewail, Science 328, 187 (2010), C. Ropers and coworkers, Nature 52, 200 (2015).

[3] C. Ropers and coworkers Science 345, 200 (2014).

[4] J.R. Arthur, Applied Physics 36, 3221 (1965).

[5] L.M. Baskin, O.E. Lvov and G.N. Fursey Phys. Stat. Solid. B 47, 49 (1971).

Topic

Field Emission

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