Field Emitter Array Performance Enhancement By Self Heating

P. R. Schwoebel, C. A. Spindt, and C. E. Holland
Applied Physical Sciences Laboratory
SRI International, Menlo Park, CA 94025 USA

The adsorption of common contaminants on the emitting surface of microfabricated field emitter tips typically increases the average work function and the emission current noise. As a result, the following operational issues have been identified in some field emitter array based device development efforts: (1) a roughly monotonic decrease with time of the mean emission current at constant applied voltage and (2) fluctuations of the emission current about this decreasing mean. The consequences are poor time correlation between the applied voltage and emitted current and the need to gradually increase the applied voltage to maintain a given current.

It has been known for many years that the current-voltage characteristics vary between tips in microfabricated field emitter tip arrays. Besides the ensuing spatial non-uniformity, a large variation in the current-voltage characteristics between tips in an array decreases the average current per tip that can be extracted without precipitating voltage breakdown events.

Early field emission investigators realized that cathode surface cleaning and annealing stabilized the emission current as a result of contaminant desorption and tip surface smoothing. The etched wire tungsten emitter tips commonly used at that time were ideally suited for field emission investigations due to their high yield strength and ease of cleaning by heating in vacuum. When it was necessary to employ arrays of etched wire tungsten tips for high current device applications, Dyke and coworkers realized that emission uniformity between tips in an array could be significantly improved by high temperature annealing.

We recently investigated using the extracted field emission current to controllably heat microfabricated field emission tips. Smoothing and recrystallization of the tip surface by surface self-diffusion and, at least, partial surface cleaning by thermal desorption is the result. Self-heating not only allows for the achievement and maintenance of stable emission characteristics, but can be used to make the current-voltage characteristics of microfabricated field emitter tips nearly identical to one another. The improvement in emission uniformity will allow for more reliable array operation at increased electron emission current densities. In this paper we review and summarize the results of these studies.