Gas Discharge Processes at Micrometer Scales

Paul Rumbach[1], Yingjie Li[1], Santiago Martinez[1], Thibault Twahirwa[2], David B. Go[3]
[1]Deptartment of Aerospace and Mechanical Engineering
University of Notre Dame, USA
phone: (1) 574-631-8394
e-mail: prumbach@nd.edu and dgo@nd.edu

[2]Department of Chemistry
Morehouse College
Atlanta, GA 30314, USA

***Abstract*—Modern microfabrication techniques have allowed for the miniaturization of nearly all electrical systems. In particular, we have seen the development of microelectromechanical systems (MEMS) leading to microplasma devices with length scales less than 10 µm. At these extreme scales, electric fields become sufficient to initiate field emission, where electrons tunnel out of a negatively biased surface (cathode) into the surrounding gas creating a microdischarge. In this work, we have developed simple scaling laws for these field emission-driven discharges. To confirm this scaling, we measure the current as a function of pressure for field emission-driven discharges in atmospheric air with electrode gaps, d, ranging from 4.8 – 14.0 µm and reduced electric fields, E/p, ranging from 330 – 14,000 V/(cm torr). As shown in Fig. 1, we find that current scales log-linear with pressure as predicted by the avalanche equation i = iFEeαd where iFE is native field emission current and α is Townsend's ionization coefficient. With this data, we are able to extrapolate Townsend's ionization coefficient as well as average collision cross sections as a function of E. These results compare favorably values predicted by kinetic (particle-in-cell/Monte Carlo collision) simulations of the collision dynamics under these conditions, as shown in Fig. 2.**

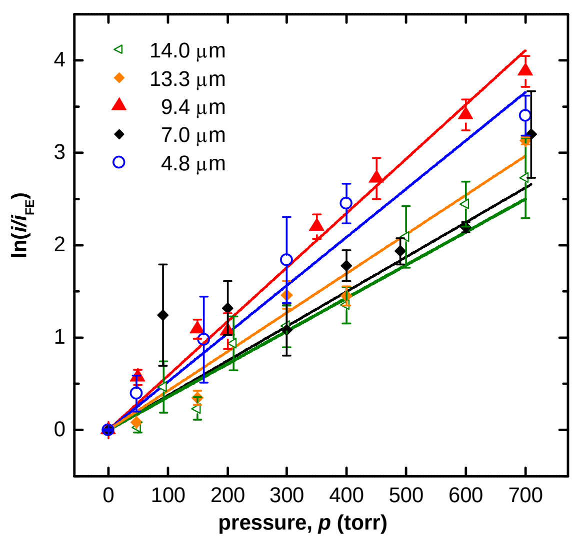

Fig. 1 Logarithmic plot of normalized current as a function of pressure *p* for electrode gaps of 14.0, 13.3, 9.4, 7.0 and 4.8 µm operating at 350 V and using laboratory air.

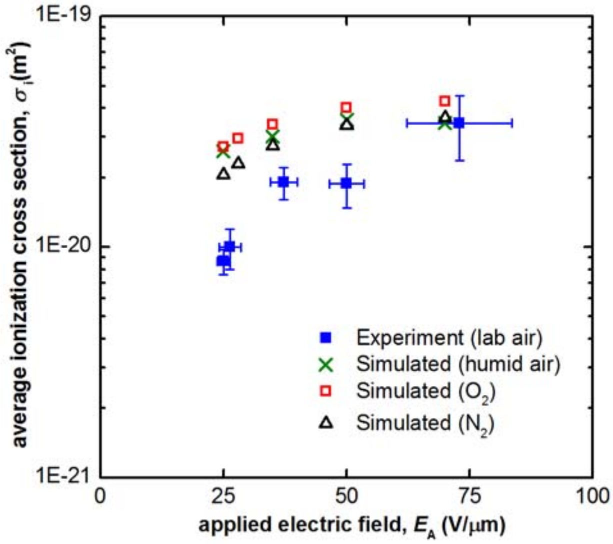

Fig. 2 Plot of average ionization cross section σ_i as a function of applied electric field E_A for both simulated and measured data.