A bakeable, ultrahigh vacuum, time-of-flight mass spectrometer has been constructed in order to investigate, for the first time, the nature of the ion species formed prior to the flashover of a parallel plate diode. During operation, the field in the gap of the diode is maintained approximately 5% below that required for visible flashover. The anode is biased at some positive potential, $V_B$. When a high voltage pulse, $-V_P$, is applied to the cathode, the ions formed at the anode surface or in the gap of the diode are accelerated and pass through apertures in the cathode, striking an electron multiplier detector one meter away. The time interval between the resulting signal amplified and displayed on an oscilloscope, and the beginning of its sweep triggered by the pulse applied to the cathode is a direct measure of the ion's travel time, $T$. If the duration of the cathode pulse is long compared to the travel time of the slowest species in the gap of the diode, and if an ion's initial kinetic energy is zero, its identity can be determined from the expression:

$$m/n \, (\text{amu}) = \frac{0.193}{L^2} V_B \left[ 1 - \frac{d}{D} \left( 1 + \frac{V_P}{V_B} \right) \right] T^2,$$

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where \( L \) is the cathode to detector distance, \( d \) the distance from the species formation position in the gap to the anode, and \( D \) the gap spacing. Here all distances are expressed in meters, all voltages in kilovolts, and the travel time in microseconds. Since ions will only be detected for

\[
0 \leq \frac{d}{D} \left( 1 + \frac{V_F}{V_B} \right) \leq 1,
\]

the extent of ion production in the gap can be probed by varying the ratio of the pulse-to-bias voltage.

Preliminary observations at 300°K indicate the presence of multiply charged metal anode ions as well as ions of adsorbed residual gas. Field induced dissociation of \( \text{CO}^+ \) and \( \text{H}_2^+ \) near or at the anode surface is seen. The type of species observed suggests that energetic electrons, originating at cathode microprotrusions and desorbing species at the anode surface upon impact, are the primary preflashover production mechanism.

To investigate the importance of cathode microprotrusions, actual cathodes were incorporated into a dc field emission microscope utilizing a transparent fluorescent screen as the anode.\(^2\) At applied fields greater than \( 10^4 \) V/cm, cathode emission areas were observed, indicating local field enhancements of at least one hundred. As the cathode-to-screen potential was raised, increased emission from established sites occurred while new emitting areas often appeared even if the voltage was held constant, supporting the view of whisker "growth" as a result of the applied field.\(^3\) Breakdown, however, often occurred at areas of negligible emission, indicating that strong electron emission is not a sufficient condition to induce visible flashover. If the highly polished anode element of the diode was examined in a similar fashion, localized emitting areas were
also observed, suggesting that field enhancement at anode microprotrusions might be responsible for the formation of the highly charged metal anode ions observed prior to flashover. It is interesting, if not instructive, to note the striking similarity in charge state between the anode metal ions observed in this experiment and those reported for other metals in the classic atom probe studies of Müller and co-workers.⁴,⁵

No detected species were formed in the gap of the diode, at fields of $5 \times 10^5$ V/cm, approximately 5% below that required for visible flashover. Preliminary results suggest that the number of ions produced in the gap may be a strong function of the applied field since a noticeable change in the type and abundance of species occurs at flashover.

By inserting a 0.5 mm thick disk of aluminum oxide, pierced by a 0.5 mm diameter axial hole, preflashover spectra of this insulator can be obtained. Using gold electrodes, residual gas species were obtained from the anode and insulator hole surface, as well as the dominant anode species Au $2^+$. Al $^+$ and O $+$ are observed in small abundance from the insulator while two characteristic, but as yet unidentified species were observed late in time. Related observations suggest that these may represent Al $0_3^+$ release at two different times during the preflashover process.
REFERENCES


