# INVESTIGATIONS OF RF INDUCED BURNOUT IN MICROWAVE MIXER DIODES: A CONTINUING STUDY

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ABSTRACT

Investigations of RF induced burnout in silicon point contact and Schottky barrier mixer diodes at X-band frequencies are presented. SEM observation of diode chip condition was made through a "window" in the package prior to burnout. Comparisons of photographs before and after burnout were used to determine subtle changes in chip topography.

The susceptibility of semiconductor microwave mixer diodes to "burnout" is the most critical factor affecting the reliability of sensitive microwave receivers. RF induced burnout is caused by excessive power reaching the mixer diodes either from unwanted energy transmitted by external sources or by leakage within one's own system.

This electrical overload is usually in the form of nanosecond spikes, resulting from leakage through the receiver protection network. The spike widths can range, in this case, between 1 and 50 ns, depending on the type of receiver protector used. Examples are: ferrite, gas TR, diode limiter, or combinations of these. RF stress can also result from poor isolation in the system's duplexer.

Advances over the years in mixer performance have been principally directed towards improvements in diode noise figure, bandwidth, dynamic range, and packaging to meet improved sensitivity requirements. Only cursory attention has been given to sensitive, yet burnout-resistant diodes. As a result, the problem of mixer failure remains.

Experiments to determine the behavior of X-band diodes under RF stress conditions included levels of burnout, types of damage resulting from this stress, and causes of mixer failure. Silicon point contact and silicon Schottky barrier mixer diodes were used for this study.

Other workers have sought the cause of RF induced burnout in mixer diodes.[1-5] Their procedures have been to subject a series of mixer diodes to various conditions of pulse width and amplitude to point of failure or degradation. The package of the failed or degraded unit was then opened, and by means of an SEM (Scanning Electron Microscope), the semiconductor surface was observed for possible changes in topography. The word possible is used because a record of surface conditions surrounding the contact point was not available prior to burnout. That is, any subtle changes in the chip surface which were caused by burnout cannot be accurately determined without a record of the pre-burnout chip surface condition, regardless of how carefully the window has been cut into the package of the burned out diode. Nor could the debris found on the chip surface be determined to originate from the fabrication process or the RF burnout. Cutting the package in half, post-burnout presents problems in analysis of the chip since it becomes extremely difficult to find the original location of the whisker.

Work described here was aimed at obtaining as much information as possible about electrical and metallurgical characteristics of the diode before destructive RF testing.

To do this, a controlled set of silicon point contact (1N23E) and silicon Schottky barrier diodes was fabricated after "windows" were cut in each package; 50 Schottky barrier and 50 point contact diodes were made in windowed packages (see Fig. 1). The package opening was made large enough for SEM observation without seriously degrading mixer performance. An increase of 0.2 to 0.5 dB in noise figure at an i-f of 30 MHz was measured with the opening oriented 180° from incident RF. Before any burnout tests were performed, each device was fully characterized electrically.

Following non-destructive electrical testing, each device was photographed through the opening in the ceramic package with an SEM. SEM analysis included low magnification shots of whisker location on the chip and high magnification pictures (up to 8000 X) of the region surrounding the point.

This procedure resulted in a minimum of four pictures of each diode at various tilt angles and magnifications. No degradation in mixer properties was caused by the SEM analysis.

The diodes were then subjected to a series of RF pulse burnout tests. Pulses at 0.5 and 1.0 μs were generated by a fast rise time magnetron, and shorter pulses or "spikes" were obtained using the 1 μs magnetron pulse and a PIN diode pulse shaping network.[6] The test frequency was 9.375 GHz, and diodes were mounted in a single ended JAN standard crystal mount. The criterion for failure was 1.0 dB or greater increase in noise figure with a corresponding decrease in crystal current of 25% or more.

A sequence of SEM photographs was made on each failed device to determine changes in the region surrounding the whisker and region of the chip directly under the contacts.

Figure 2 shows the results of "long pulse" (>0.5 μs) burnout in terms of percent failure versus incident power for grouped Schottky barrier and point contact diodes at 1.0 μs pulse widths. At 0.5 μs pulse widths, the results overlap the loci of the 1.0 μs curves and are omitted for clarity. These findings indicate that long pulse stress is essentially a CW condition; i.e., burnout power for at least 0.5 μs or more is independent of pulse width.

Preliminary data gleaned from nanosecond pulse burnout tests in X-band, however, reveals a dependence of burnout power level on pulse width for these "spikes." On tests conducted with 3 ns spikes, burnout occurred at peak powers four to five times higher than that occurring at 0.5 and 1.0 μs pulse widths on diodes from the same lots.

Figures 3(a) and 3(b) are before and after views, respectively, of a silicon point contact diode subjected to 1.0 μs pulses at a repetition rate of 1000 pulses/s and a peak amplitude of 10 W. The spherical bubbles at the base of the point (arrows in Fig. 3(b)) remained on the surface after the point was lifted (Fig. 3(c)). SEM and energy dispersive X-ray analysis revealed these bubbles to be silicon, most likely pressed out from under the contact in a molten state and recrystallized.

Apparent from the results presented in this paper is the experimental evidence that the effects of RF induced burnout, even under critical SEM probing, are barely perceptible. Also a prior knowledge of the semiconductor chip topography is not only essential, but also critical to discern and analyze any physical changes or irregularities which occur post-burnout. These investigations are continuing and will be supplemented with electron-beam microprobe analysis and cross-section at the metallurgical junction of diodes subjected to programmed RF stress. The objective is a full explanation and understanding of the cause of mechanism of RF induced failure in both Schottky barrier and silicon point contact mixer diodes.

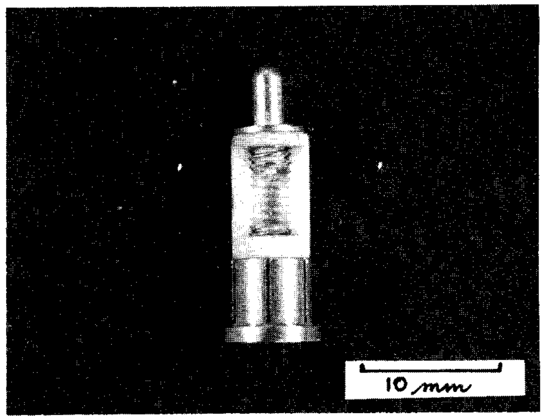


FIG. 1. X-band mixer diode in ceramic package with 250 mil height window.

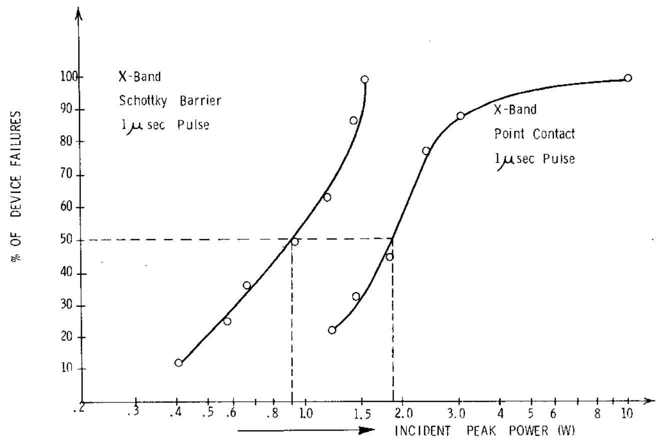


FIG. 2. Percent device failure versus peak incident power for X-band silicon point contact and Schottky barrier diodes for 1 μs pulse width.

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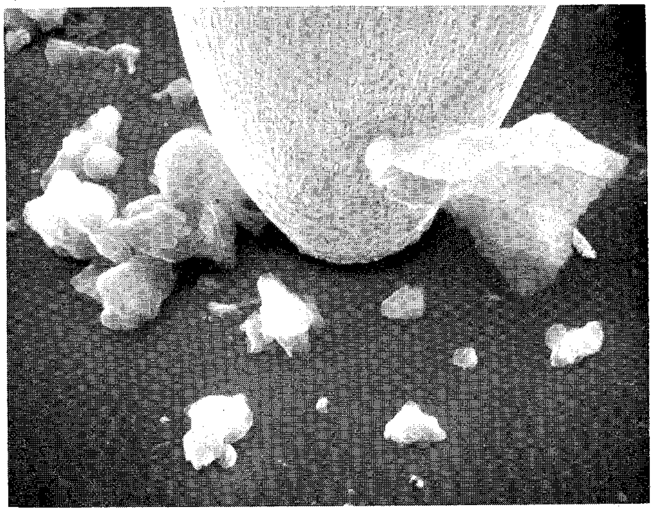

FIG. 3(a). SEM photograph of topographical features of the area surrounding the whisker point of 1N23 point contact diode before burnout (tilt angle: 30°; magnification: 2100 X).

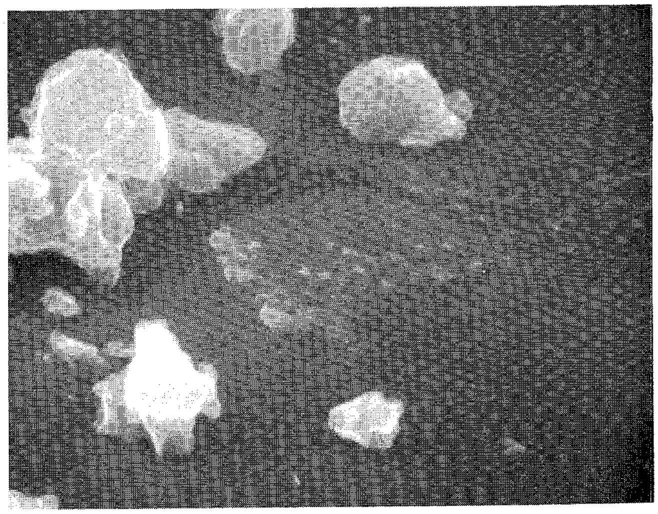

FIG. 3(c). As in Fig. 3(a), same diode after burnout with whisker point lifted (tilt angle: 30°; magnification: 4000 X).

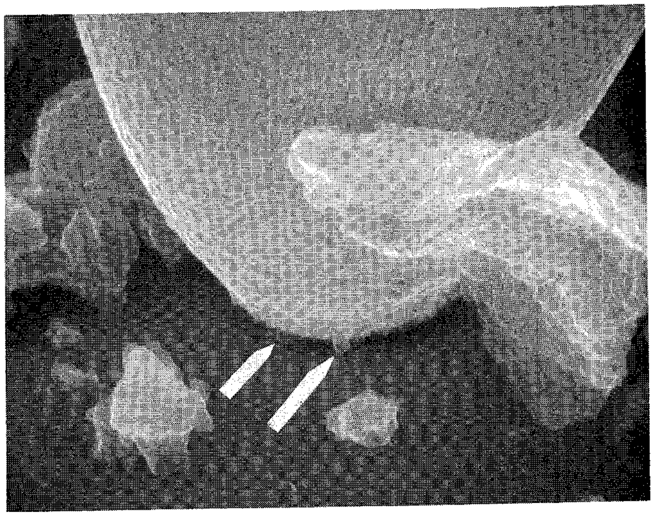

FIG. 3(b). As in Fig. 3(a), same diode after 1.0 μs, 10 W peak burnout (tilt angle: 31°; magnification: 4000 X).