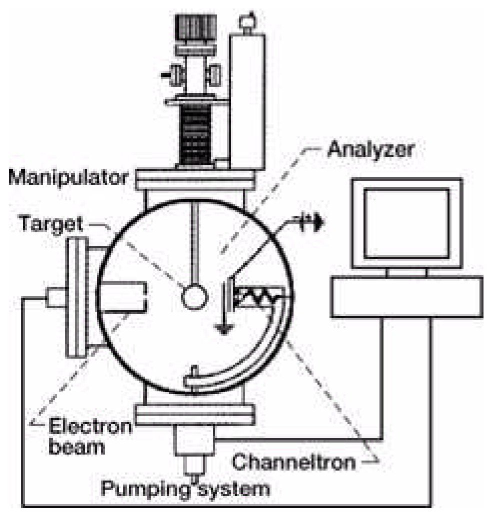
Angular Distribution of Elastically Scattered Electrons Determined and Its Effect on Collector Performance Computed

It has been demonstrated that the suppression of secondary electron emission significantly improves the performance of electron beam collectors (ref. 1). However, a complete analysis of the effects of secondary electron emission with respect to collector performance has not been possible because of the lack of quantitative data on angular distributions of secondary electrons. Secondary electrons are emitted with energies ranging from near zero to the energy of the incident primary. For our purposes, we define elastically scattered electrons as secondary electrons within 20 percent of the incident energy. Elastically scattered electrons are of great concern because their energy allows them to follow trajectories that can carry them almost anywhere within the vacuum envelope. If these secondaries leave the collector and reenter the slow wave circuit, they can produce undesired signal distortion and oscillation.

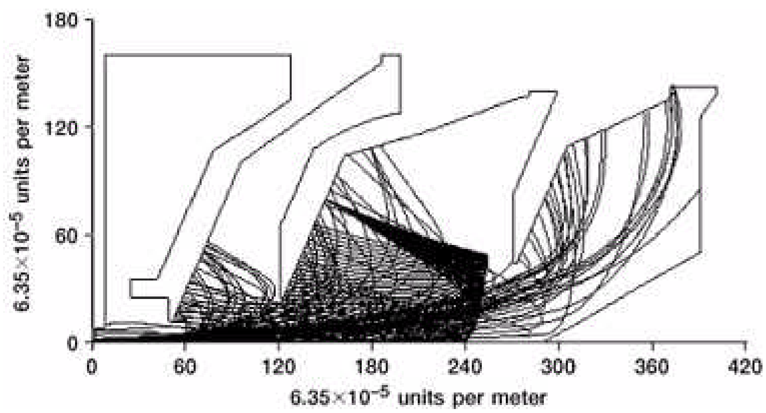


Apparatus for determining the angular distribution of secondary electrons.

This apparatus, which was built by Krainsky (ref. 2), was used at the NASA Lewis Research Center to obtain detailed measurements of the angular distributions of elastically scattered secondaries. Data were obtained for three surfaces of significant interest to collector applications: highly polished copper, copper roughened by ion sputtering, and isotropic graphite. Lewis researchers discovered that elastically scattered electrons have a complex angular distribution that is strongly dependent on the atomic number and surface morphology of the target material, as well as the energy and angle of incidence of the primary beam. At low energies, secondary emission from polished copper in the chosen energy range is primarily directed back to the source of primary electrons (backscattering).

Forward scattering increases with primary energy until, at high energies, forward scattering dominates the angular distribution. Although back-scattered secondaries dominate the distributions of the textured copper surface, the yield is substantially lower. From the standpoint of secondary emission, isotropic graphite is the most attractive material because it exhibits low yield and little back scattering.

The measured data were curve-fitted into linear combinations of Gaussian and Lorentzian functions, which were used in an interpolation routine to calculate the approximate distributions at any arbitrary primary energy and angle of incidence. The complexity of the data did not provide easy incorporation into the computational model. Furthermore, the volume of the data exceeded computational resources and software limits. However, improvements in computational power and software enhancements now allow the inclusion of the newly available data into previous models of electron beam collectors. Simulations on a collector designed for a 32-GHz traveling-wave tube (TWT) showed that forward-scattered electrons had little effect on collector performance. The angular distributions for ion-textured copper dominated by back-scattered secondaries were of more concern because those electrons are likely to reenter the slow wave circuit. However, our model of these distributions showed that approximately 1 percent of the primary beam current returned to the slow wave circuit, which is in agreement with experimental observations. The following figure shows a sample of such a model. These additions have brought even more accuracy and insight to previous modeling attempts.



Computer model of back-scattered electrons from one impact site in the collector design for the Hughes 32-GHz traveling-wave tube proof-of-concept design for the Cassini Mission.

References

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