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Extreme and ultra high vacuum technologies for field emission electron guns on electron microscopes

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Here we presents recent vacuum technologies for generating and measuring extreme high vacuum (XHV) and ultra high vacuum (UHV) in field emission electron guns on electron microscopes. An XHV cold-field electron emission (CFE) gun operating at pressures ranging from ~10^{-8} Pa to ~10^{-10} Pa was constructed. Only the CFE current emitting from W(310) surfaces revealed the existence of a "stable region" with high current angular density just after tip flash heating. In the "stable region," the CFE current was damped very slowly. The presence of non-hydrogen gas eliminated this region from the plot. Improvement of the vacuum prolonged the 90% damping time of the CFE current from ~10 min to 800 min. The current angular density I_ of CFE current was 60 and 250 μA/sr in the "stable region" for total CFE currents of 10 and 50 μA, respectively. These results were about three times larger than I_ when measured after the complete damping of the CFE current. The CFE gun generated bright scanning transmission electron microscopy images of a carbon nanotube at 30 kV.

Outgassing rates of low-carbon steels were measured using rate-of-rise and throughput methods. Outgassing rates of water vapor during pump-down were higher than those of stainless steels, probably due to the nature of native surface oxide layer. However, hydrogen outgassing rates without a high temperature pretreatment were as low as (1-4)×10^{-10} Pam^3/sm, which is much lower than that of untreated stainless steels. No dramatic reduction was observed in H_2 outgassing after vacuum annealing at 850 °C for 12 h, suggesting that the low-carbon steels had been fully degassed during the steelmaking processes. This may be due to the use of the Ruhrstahl-Hausen vacuum process during steel refining instead of an older process, such as argon-oxygen decarburization. The extremely low H_2 outgassing rate from low-carbon steels makes them applicable for use in ultrahigh vacuum or even extreme high vacuum applications, particularly where magnetic field shielding is needed.

A UHV field emission (FE) electron guns made of low-carbon steels was recently constructed. The soft magnetic property of low-carbon steels enable the UHV chamber wall to shield the electron gun from stray magnetic fields For axis adjustment of the gun, a double O-ring seal was employed for moving a FE electron source. Field emission currents of > 100 μA were routinely obtained while maintaining the pressure of the gun in the range of 10^{-8} Pa. A scanning electron microscope equipped with the gun has presented clear nano-scale images.