Electron sources and applications for electron beams in air

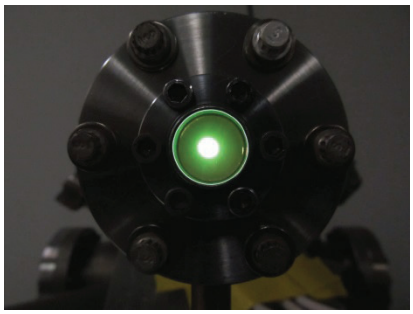
G.G. Magera and W.A. Mackie
Applied Physics Technologies, Inc., 1600 NE Miller St., McMinnville, OR 97128
bmackie@a-p-tech.com

There are many applications for electrons emitted into ambient air. These can be for direct electron injection into semiconductor laser materials, for cross-linking of polymers to facilitate curing, for sterilization, for particle detection and analysis to name a few. Beam energies needed range from a few tens of kV to perhaps a 100 kV. Beam paths bloom in air so samples are kept close to exit apertures especially where shaped beams are important. We have made and tested several sources and configurations within the application fields listed above. The sources have been in conventional pumped systems where conventional beam optics is used to shape the beam in vacuum prior to exiting via a suitable electron transparent window. Other uses have utilized smaller sealed off glass tubes where the optics is less critical and a larger spot source is desired. These tubes then would be capable of operation in a smaller system capable of easy transport.

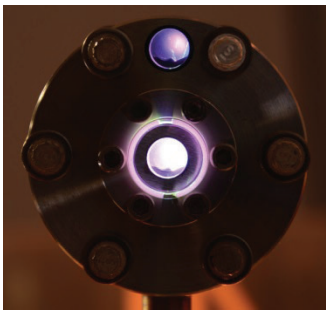
For applications requiring high beam energies (>30kV) and high beam currents the electron windows can be made of beryllium which historically has been used for vacuum isolation in X-ray tubes. An 8 micron thick Be foil has a transmission of ~80% for a 50kV electron beam voltage with the electrons having an exit energy peaked at 42keV. An electron transparent window option for applications requiring lower beam energies, small spots and shaped beams would be Si_3N_4 membranes made via semiconductor processing techniques. A 200 nm thick Si_3N_4 membrane has a transmission of >90% for a 10kV electron beam voltage.

Shown in Figure 1 are pictures taken of outputs of an external electron beam tube utilizing an 8 micron thick Be window. The external beam spot performance was tested at beam voltages ranging from 30 kV to 50 kV and external beam currents as high as 10 μA. Figure 1b illustrates the use of the external beam to produce 240 nm surface emission using AlGaN epitaxial material on a sapphire substrate. Figure 2 illustrates how Si_3N_4 membrane windows could be used with external electron beams. Figure 2b shows a picture of a 50kV external beam taken from a P47 phosphor target in 2mm of room air. The electron window is an array of 500μm × 500μm by 1.0μm thick membranes. The example shows very little scattering of the electrons while traversing 2mm air gap thus making it possible to utilize external electron beams in shape beam applications. External electron scattering can be seen in picture shown in Figure 2c where the air gap to the phosphor is 4.5mm.

We will present results using various electron transparent windows, beam voltages and emission currents.



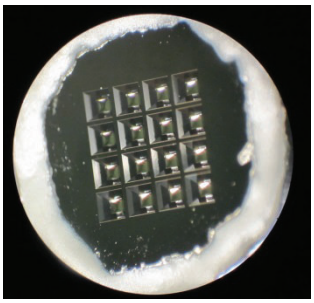
(a)



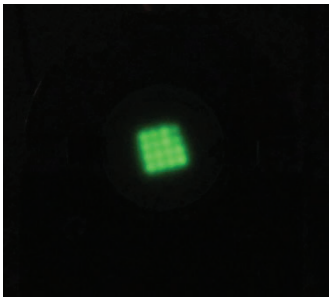
(b)

Figure 1a. A 1.0μA external electron beam with P47 phosphor external target placed in room air 2 mm in front of the electron window. The electron window is an 8 micron thick Be foil and the beam voltage is 50kV.

Figure 1b. View through its sapphire substrate of an AlGaN epi material emitting around 240 nm and pumped with a 50 kV electron beam through an 8 micron thick Be window and 2 mm of room air. The inset shows the upper central part of the full Figure at lower exposure to take the image out of optical saturation.



(a)



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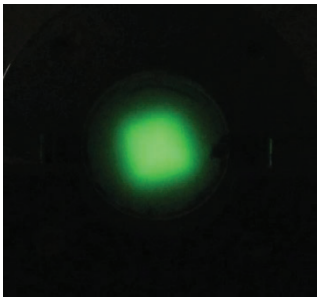

(c)

Figure 2a. A 4 × 4 array of Si_3N_4 membrane windows 500μm × 500μm and 1.0μm thick.

Figure 2b. A 1.5nA external electron beam with P47 phosphor external target placed in room air 2 mm in front of the electron window shown is Figure 2a. The beam voltage is 50kV.

Figure 2c. A 1.5nA external electron beam with P47 phosphor external target placed in room air 4.5 mm in front of the electron window shown is Figure 2a. The beam voltage is 50kV.