Low Energy Electron Beam Excitation of Rare Gases

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The interaction of heavy ion beams with dense gas targets leads to light emission. Target atoms are partly excited via direct collisions of the high energy projectiles and partly via secondary electrons produced in such primary ionizing collisions. The electron energy spectrum of these electrons extends from low energies to typically a few keV [1].

A method for low energy electron beam excitation of dense rare gases has been developed for studying the electron induced excitation process separately. The technical concept shown in Fig.1 is straight forward and well known from early electron ray tubes using so called Lenard windows made from aluminum. Here, however, a novel and very thin, strong and completely vacuum tight ceramic foil is used for separating the vacuum in which the electron beam is formed from the dense gas used as a target [2,3]. The foils consist of silicon nitride and have a thickness of 300nm. They are non stoichiometric and have a reduced internal stress of 250MPa (tensile). They are manufactored using chemical vapor deposition (CVD) of silicon nitride on a silicon wafer and special etching techniques for removing the silicon in pre-defined areas of the wafer. This results in thin membranes which can be manufactored in various shapes and sizes and already mounted on frames consisting of that part of the silicon wafer which is not etched away. The foils were provided for us by Bell Laboratories Lucent Technologies, Murray Hill, NJ and Fraunhofer Institut für Festkörpertechnologie München.

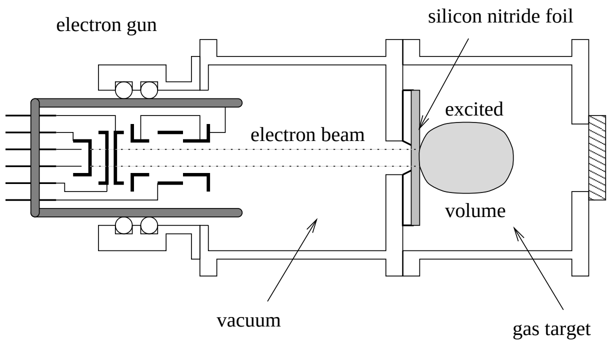

Fig. 1: Schematic drawing of the experimental setup

A 1x1mm^2 aperture and a 0.7x40mm^2 slit geometry have been used, so far. The square shaped film withstands a pressure differential up to 2 bar and 1 bar has already been successfully tested for the slit which has been delivered very recently and will now be subject to further testing. Electron beams of 18 keV particle energy are normally used in the experiments. The beam looses only 5% of its power in the 300nm silicon nitride foil. Titanium foils - for comparison - can be manufactored with a thickness of 2000nm without pinholes leading to leakage. A similarily low loss of beam power in such a Ti-foil would require 100 keV electrons, a voltage very difficult to work with. The typically 20 keV electron beam needed for the silicon nitride foils, however, can be provided by a simple and inexpensive electron gun maunfactored in large quantities for monochrome TV and computer screens. Electron beams up to 50μA are routinely used with the 1mm^2 entrance foils and can be as high as 150μA with 1 bar Helium gas where the beam power is deposited further away from the foil leading to less heating than e.g. with Argon or Xenon gas where the range of the electrons in the gas is on the order of 1mm.

The setup has first been developed by one of the authors (J. Wieser) in 1995 working at Rutgers University on an A. v. Humboldt fellowship and has now been reproduced in an improved version at the Munich Tandem laboratory. Up to now it has been used for studying the excimer continua of the pure rare gases in comparison with heavy ion beam excitation [4,5]. The second excimer continua with maxima at 125, 150, and 172nm and about 10nm spectral width are emitted with a high efficiency on the order of 40% and can be used as a broadband VUV light source. Very good gas purification is needed for that purpose which has been developed using a hot Ti-wire as a getter material. Gas kinetic processes such as energy transfer from excimer molecules to narrow-band line radiation, a concept which is widely used in electron beam, heavy ion beam and nuclear pumped lasers, can be studied using the setup described here.

Another application of the e-beam excited gas targets may be the development of a system for producing spin-polarized ^{3}He at atmosperic pressure. The scheme would be similar to those using optical pumping of low pressure discharge plasmas and subsequent compression of the polarized gas [6]. Exciting He-atoms into the metastable 2^3S state which is used for optical pumping in dense gas directly, would avoid the compression stage. Very pure Helium is needed to prevent quenching of metastables by nitrogen impurities. Other gas kinetic processes such as metastable quenching by excimer formation are presently studied.

References

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