A FIELD EMISSION SILICON DETECTOR

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A bulk semiconductor used as a particle detector contains a very high information density, 80 electron-hole pairs are produced per micron. This information density is not normally exploited due to the noise and readout density problems inherent in normal charge-sensitive amplifier readout. If, however, these electrons are extracted into the vacuum a number of strategies can be used to amplify and image them. Extraction of the electrons into the vacuum is normally inhibited by the potential barrier between the conduction band and the vacuum level. I will discuss one device which will be able to extract electrons into the vacuum for amplification with a microchannel plate and imaging on a phosphor screen.

Some work has been done at Westinghouse[1-3] on imaging infra-red light using a semiconductor photocathode. Extraction of the electrons is accomplished using field emission on one surface of p type silicon. The field emission centers are typically 10 μm high with 25 μm spacing with tip radii of ∿100-500 Å. The fabrication of the device is based on the fact that silicon etches about 100 times faster than SiO_2. With an appropriate matrix of SiO_2 deposited on a silicon substrate one can etch under the SiO_2 pads until tall thin emitters are formed. The technique is diagrammed in figure 1.

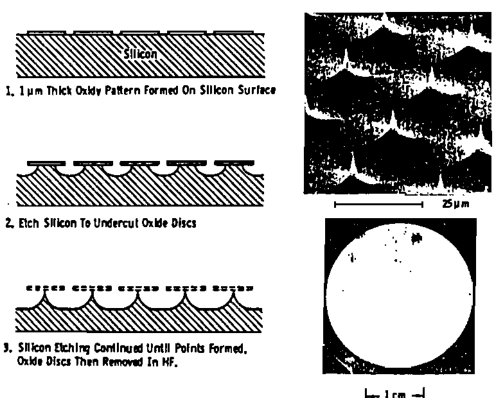

Fig. 1 - Fabrication method of forming uniform array of silicon point emitters by selective etching, such an array and emission picture (From Ref. 3)

The analysis of the emission is somewhat more difficult than that of a metallic field emitter due to field penetration into the semiconductor. The equipotentials for the device are shown in figure 2.

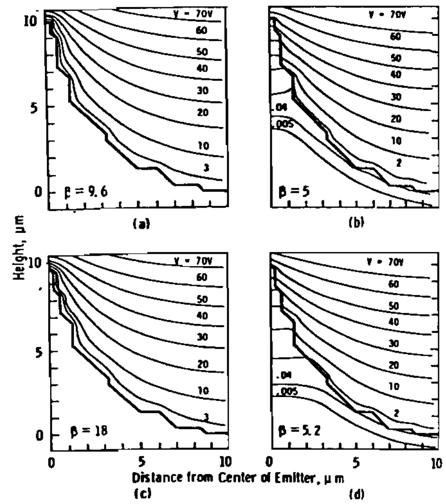

Fig. 2 - Computer calculated equipotential lines for metallic (a), (c) and p-silicon (b), (d) field emitter structures. The field intensification factor is given for each case. (From Ref. 3)

In order to operate as a particle detector the depletion depth, d, must be substantial (several mm). This is not the case for operation as a photocathode. A large depletion depth corresponds to substantial field penetration into the semiconductor. This in turn lowers the effective field amplification, β, at the emitter tip. One needs values of β of 10 - 500 to achieve field emission with reasonable fields. Other potential problems are the uniformity of the emission, which requires careful etching technique. In principal, however, the etching and masking problems are simple, well within the state of the art. Such a device, used at a target in a hadron beam can achieve bubble chamber resolutions at drift chamber rates.

References

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