FORMATION OF ATOMICALLY SHARP SILICON NEEDLES
(ABSTRACT)

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Electron emitters in vacuum microelectronic devices need to have sharp tips in order to permit electron emission at moderate voltages. This is due to the proportionality of the electric field to V/r, where r is the tip radius and V the applied voltage. For the case where vacuum microelectronic devices are made on silicon it is also desirable to have the tips made of a material compatible with silicon processing. Electron emitters made of silicon cones 5-10μm height are often used in these experiments; tip radii are reported top be in the range 200-400A°.

The purpose of this work was to try to exploit a known oxidation inhibition of silicon at regions of high curvature (1) in order to develop emitter tips significantly sharper than those obtained previously. While this idea has already been proposed and used (2,3), the present study is the first to examine the system (oxidation of conical silicon tips) in some detail at high resolution.

The results of this study is the development of a method for preparing uniform silicon tips with tip radii less than 1.0nm, and the clear demonstration of oxidation inhibition at a region of high and complex curvature. TEM images of two tips are shown at different magnifications in Fig 1. Fringes of the Si {111} planes with spacing 3.13 A° are seen at the tip. Contrast disappears where the tip diameter becomes less than 1.0 nm due to the limited number of atoms left to perform electron scattering. These structures are the sharpest silicon needles ever reported, and are possibly the sharpest needles of any material ever made.

A range of initial (before dry oxidation) tip morphologies converges to the same final tip configuration after dry oxidation sharpening, and the same final configuration is also reached for oxidation times differing by a factor of two. Thus, in addition to atomic sharpness, tip geometries are uniform: variations are too small to measure.

Besides application as efficient electron emitters, these tips also have potential application in scanning tunneling microscopy, biological probe studies, and in other novel microelectronic device structures.

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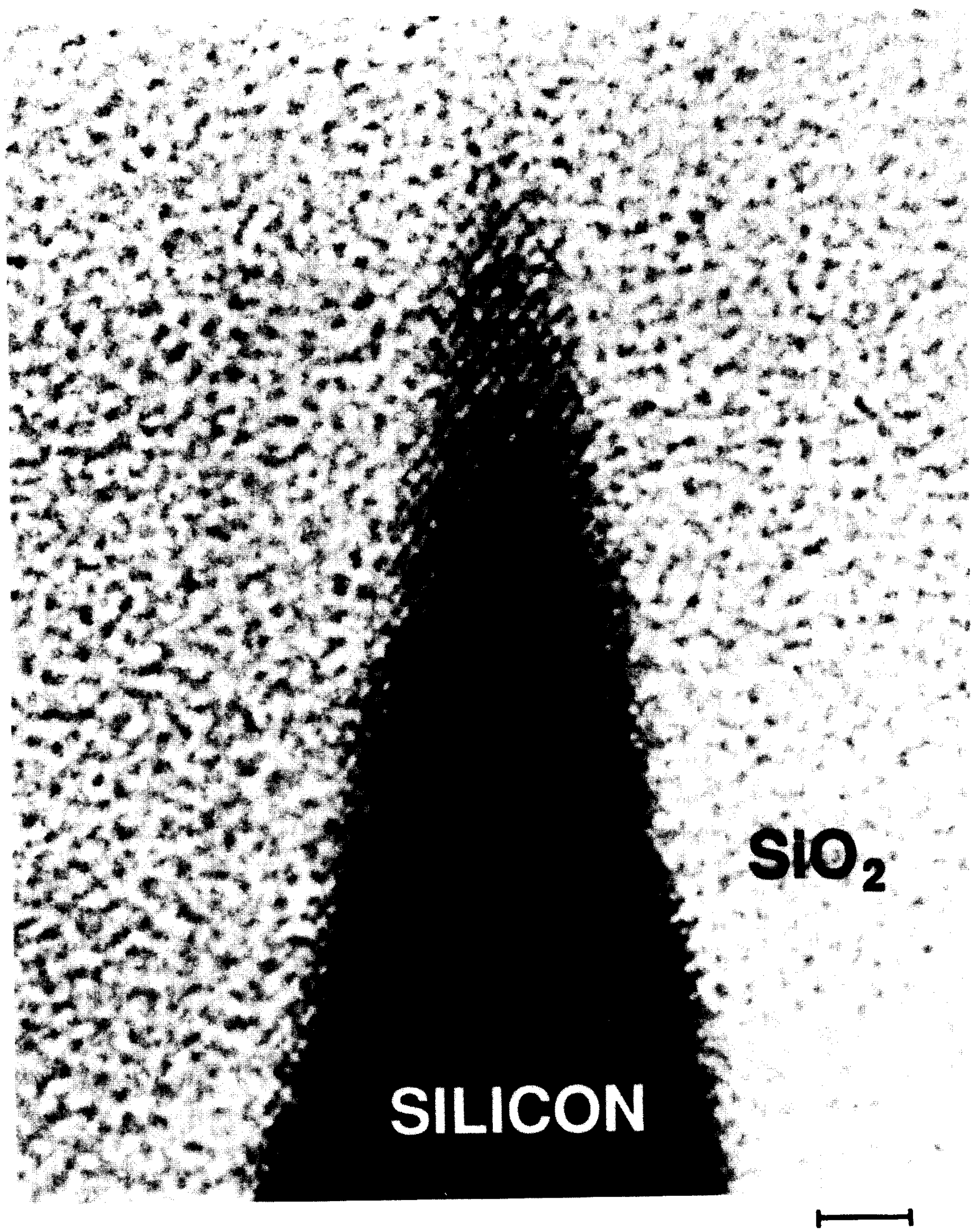

Fig 1. High magnification TEM image of sharpened silicon tip showing lattice fringes corresponding to Si{111} planes with a spacing of 3.13A°. Tip radius of curvature is less than 1.0 nm.

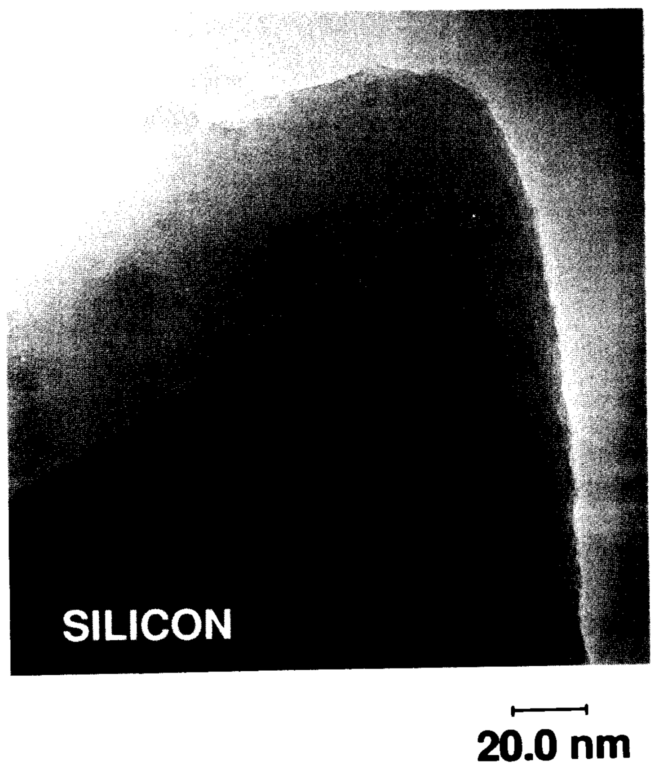

FIG 1A. TEM image of silicon tip after oxidation sharpening.