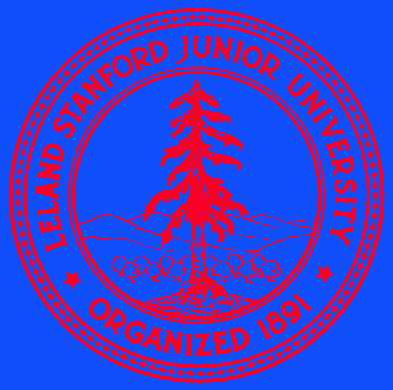
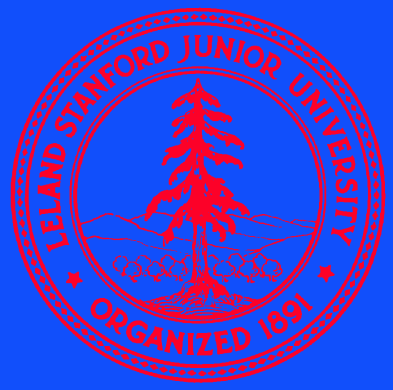
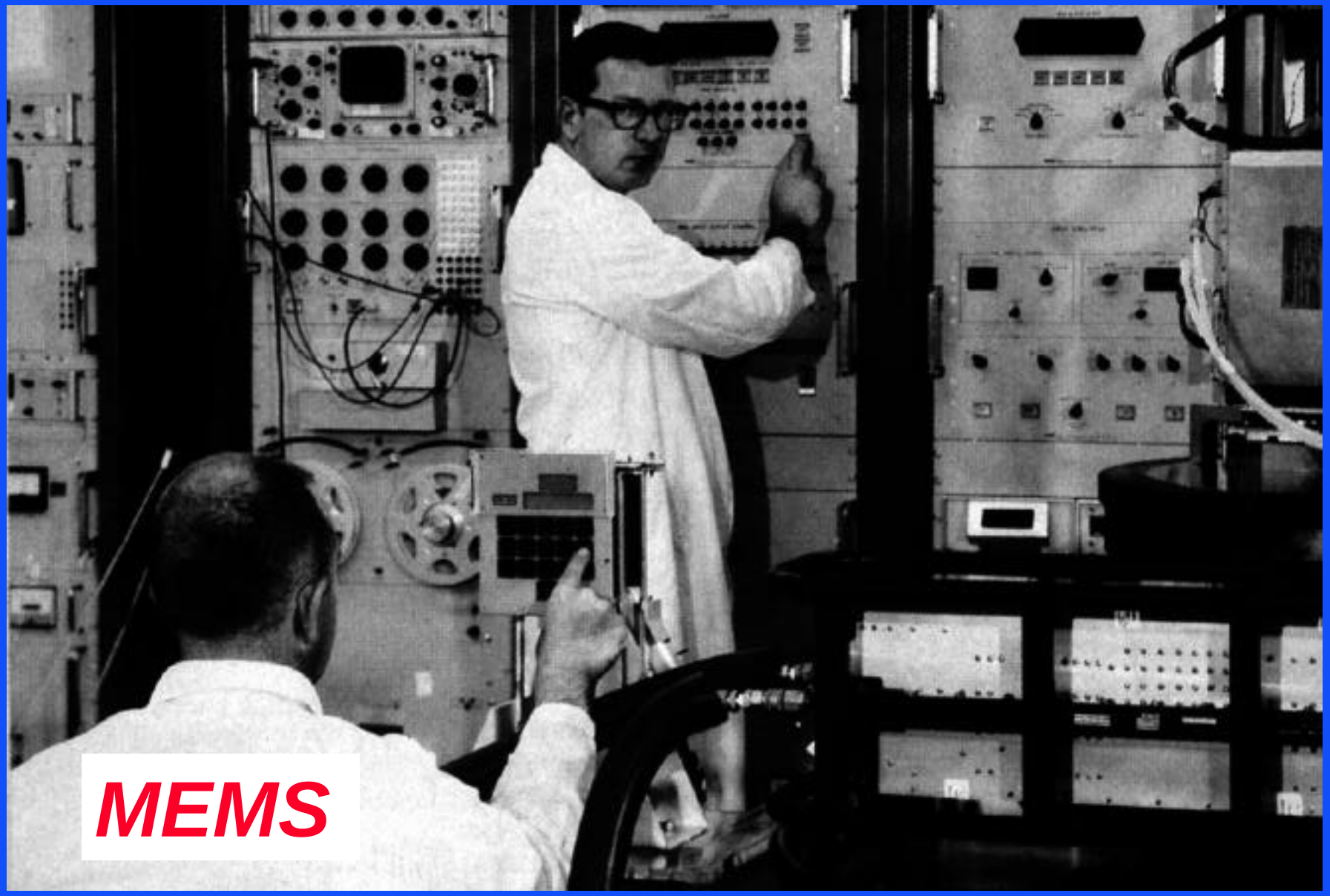
HISTORY OF MICROMACHINING

EE312, Prof. Greg Kovacs

Stanford University

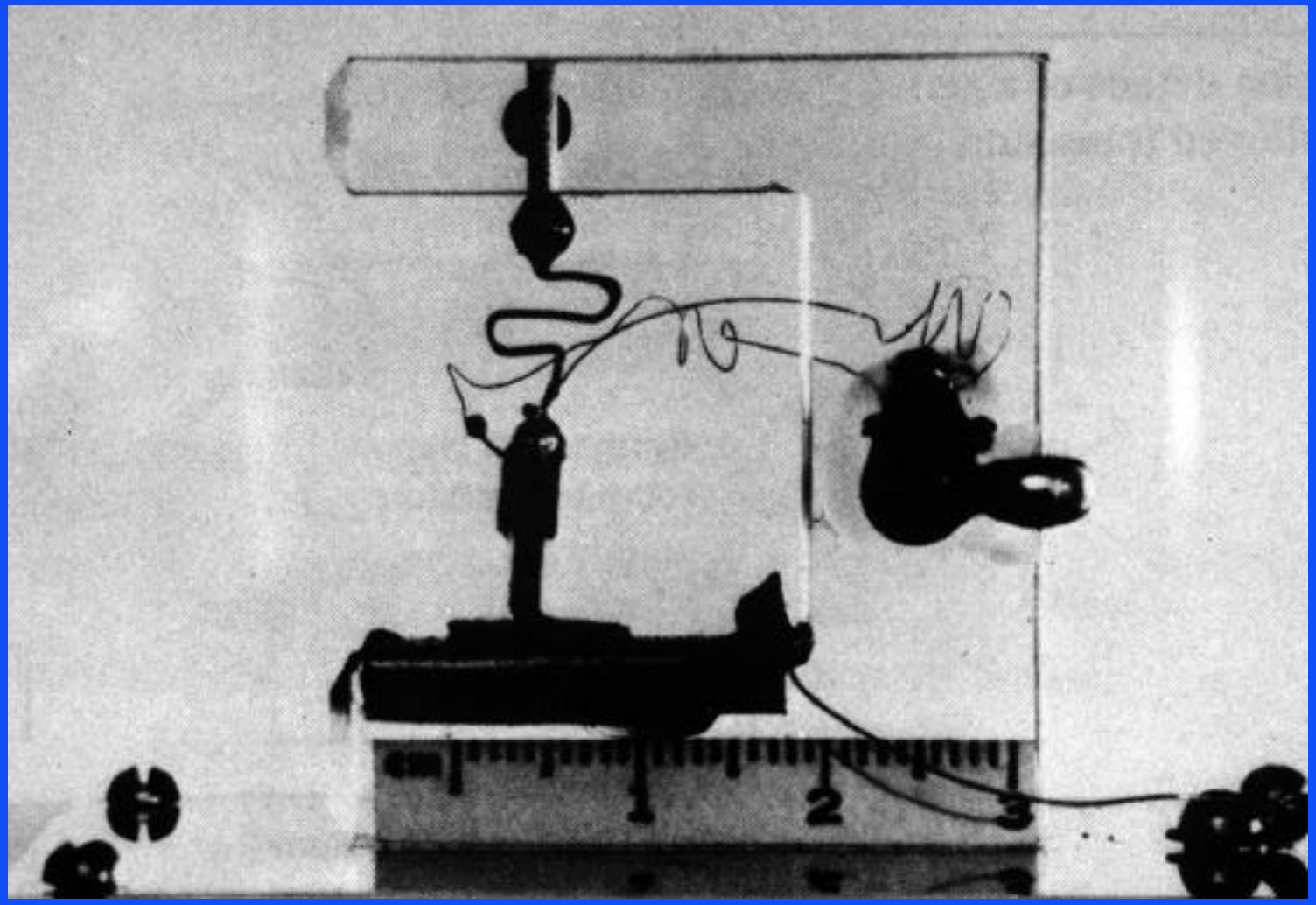




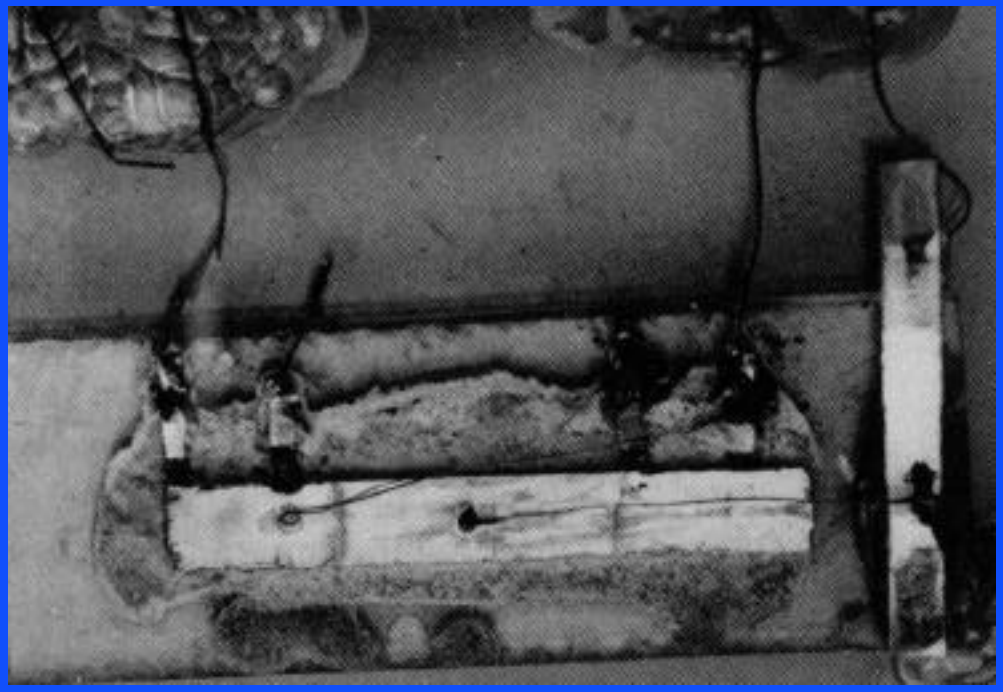


Original Image: TRW Archives.

First Transistor - Bell Labs c. 1947



First Integrated Circuits



First prototype integrated circuit, fabricated by Jack Kilby, summer 1958, Texas Instruments.

AVAILABLE NOW FROM TI

100:1 miniaturization with SOLID CIRCUIT* semiconductor networks

Now—3 years ahead of industry's expectations—*Solid Circuit* semiconductor networks from Texas Instruments for many of your high-reliability miniaturized systems!

Solid Circuit networks are a major departure from conventional components because they integrate resistor, capacitor, diode, and transistor functions into a single high-purity semiconductor wafer. Protection and packaging of discrete elements is eliminated, and contacts between dissimilar materials are minimized, reducing element interconnections as much as 90%. Fabrication steps have been reduced to one-tenth those required for the same circuit function using conventional components.

Only a few process steps and time-proved TI mass production techniques permit a high degree of process control in *Solid Circuit* network fabrication. The result of these facts: *reliability is built into each Solid Circuit network.*

If you need to reduce equipment size and weight—or to design a more complex system in the same size—investigate *Solid Circuit* networks for your missile, satellite, space vehicle, and other microelectronic programs. TI engineers are ready to custom design this concept to your requirements. Contact your nearest TI Sales Engineer today. The TI Type 502 *Solid Circuit* network is immediately available for your evaluation.

SEMICONDUCTOR NETWORK CONCEPT

The concept of a semiconductor network is the relation of conductance paths in a semiconductor to the classical circuit elements, establishing an orderly design approach based on circuit knowledge. In this manner, semiconductor networks may be designed to perform the functions of a wide variety of existing circuits. Through the proper selection and shaping of semiconductor conductance paths, it is possible to realize such electronic functions as amplification, pulse formation, switching, attenuation, and rectification.

An assembly of 13 *Solid Circuit* networks, actual size, performs a full serial adder function, replacing 15 conventional components with a 100:1 size reduction. Weight: 1.5 gm. Volume: 0.02 cubic inch.

*Trademark of TEXAS INSTRUMENTS INCORPORATED

OUTPUT 2 OUTPUT 1 BASE 2 BASE 1 INPUT GND

4 EQUAL SPACES EACH 0.047

0.030 0.090 0.120 TI 0.230

(ACTUAL SIZE)

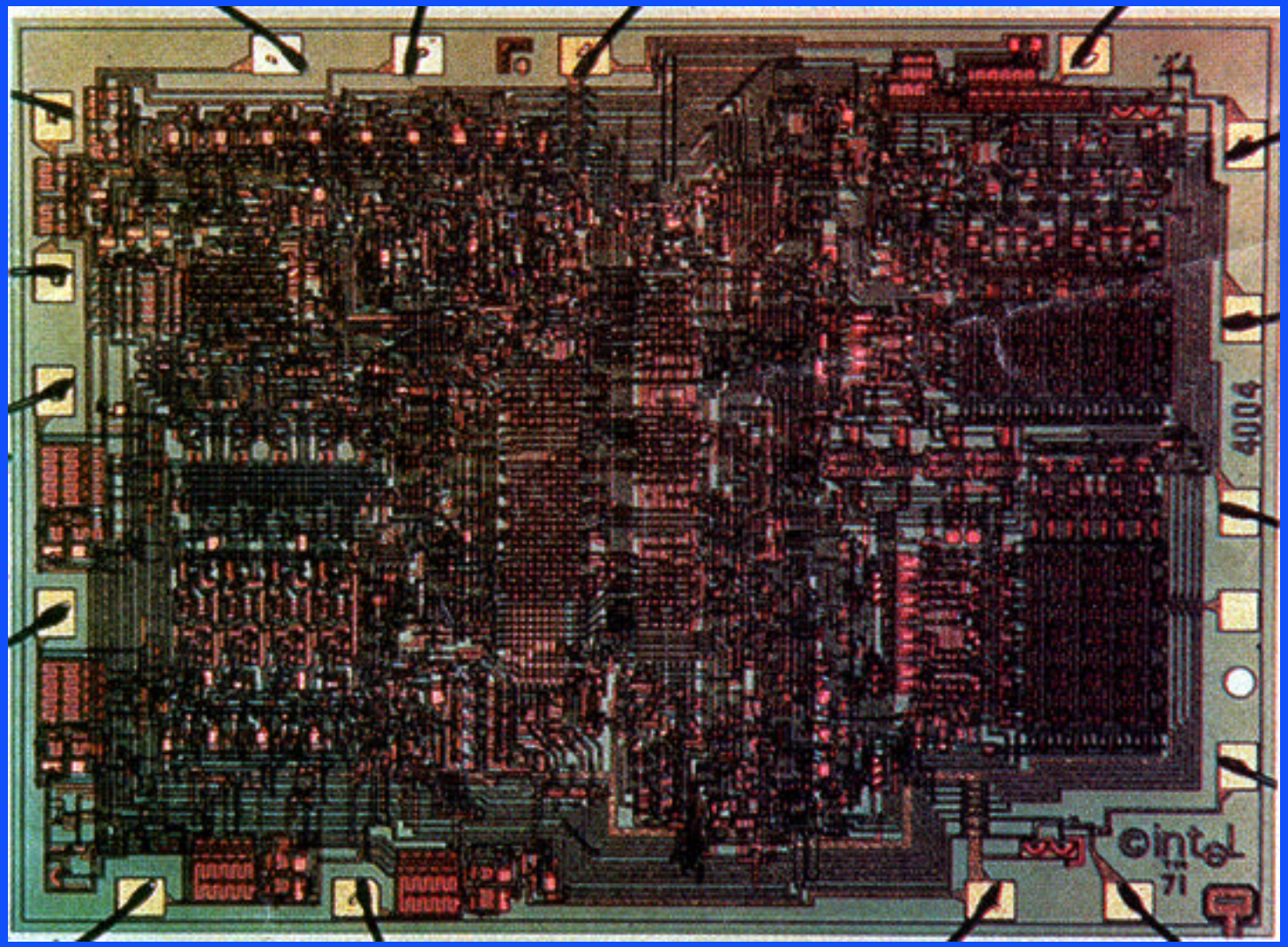
ALL DIMENSIONS IN INCHES

TEXAS INSTRUMENTS INCORPORATED

SEMICONDUCTOR-COMPONENTS DIVISION · POST OFFICE BOX 312 · DALLAS, TEXAS

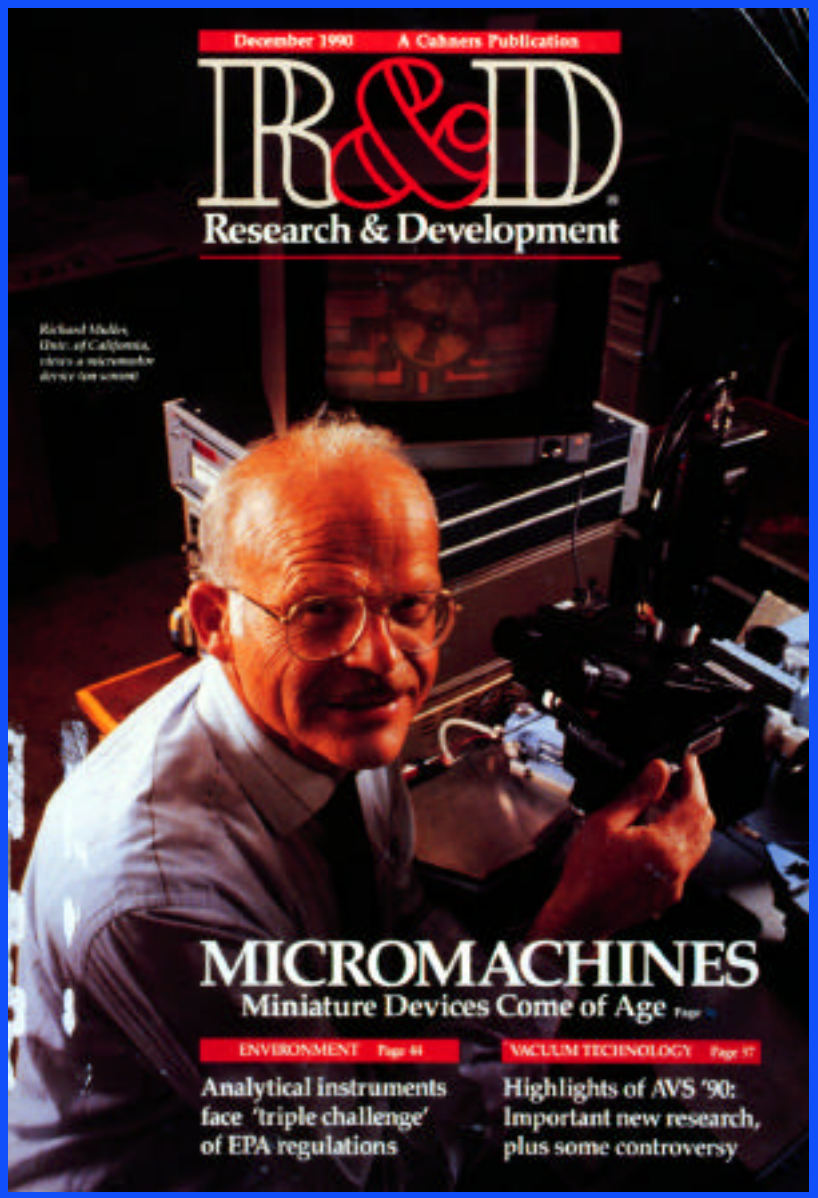
First advertisement for integrated circuits, Business Week, 3/26/60.

First Microprocessor - Intel 4004 - 1971



Micromachined sensors and actuators, or "MEMS" were made possible by the existence of cleanrooms for making conventional integrated circuits.

What's In a Name?



Micromachined devices are certainly not new. In fact, the origins of some of the major "families" of devices can be traced back to the 1960's and 1970's.

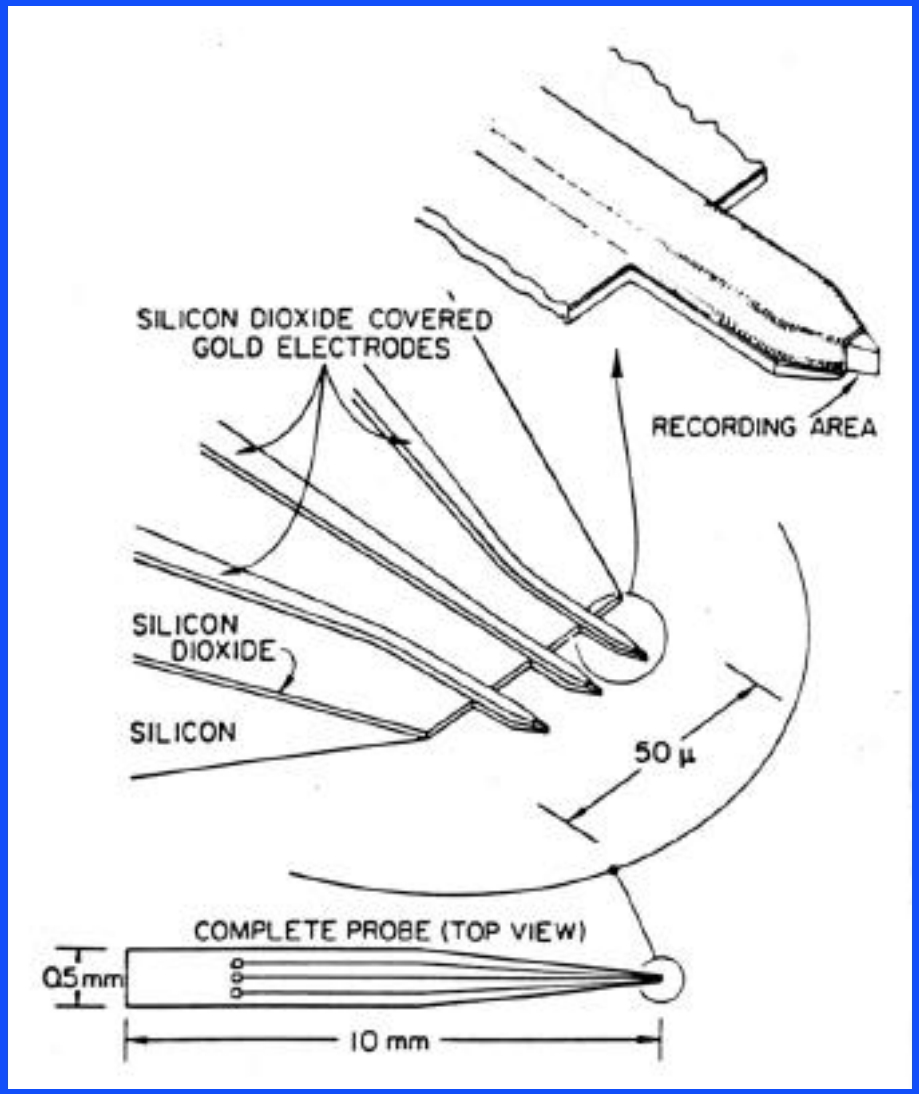
Early MEMS Work at Stanford

- **Early "MEMS" work funded by NASA and NIH - before NSF and DARPA came on the scene.**

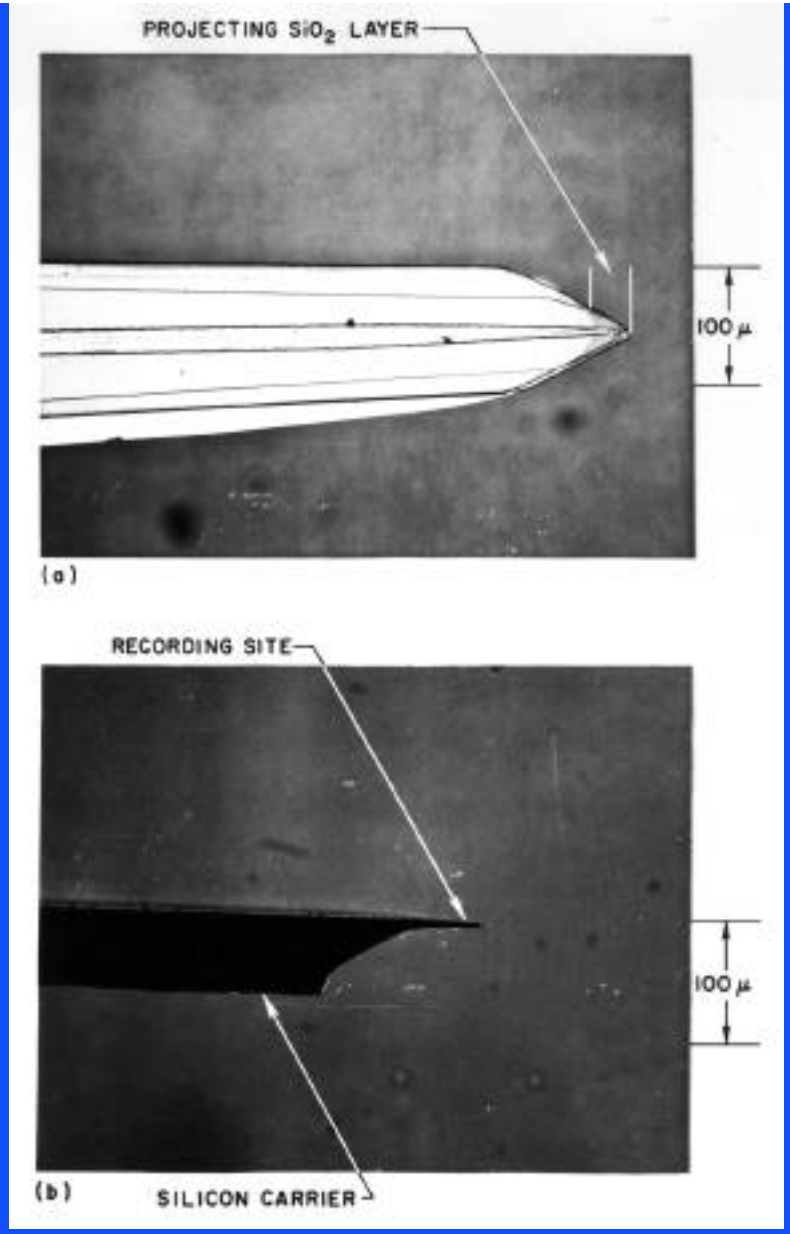
- **Wise - Brain Probes - c. 1966.**
- **Samaun - Relative Pressure Sensor - c. 1969.**
- **Nunn - Micro Strain Gauge - c. 1972.**
- **Terry - Gas Chromatography System - c. 1972.**
- **Roylance - Micromachined Accelerometer - c. 1974.**
- **Barth - Absolute Pressure Sensor - c. 1974.**

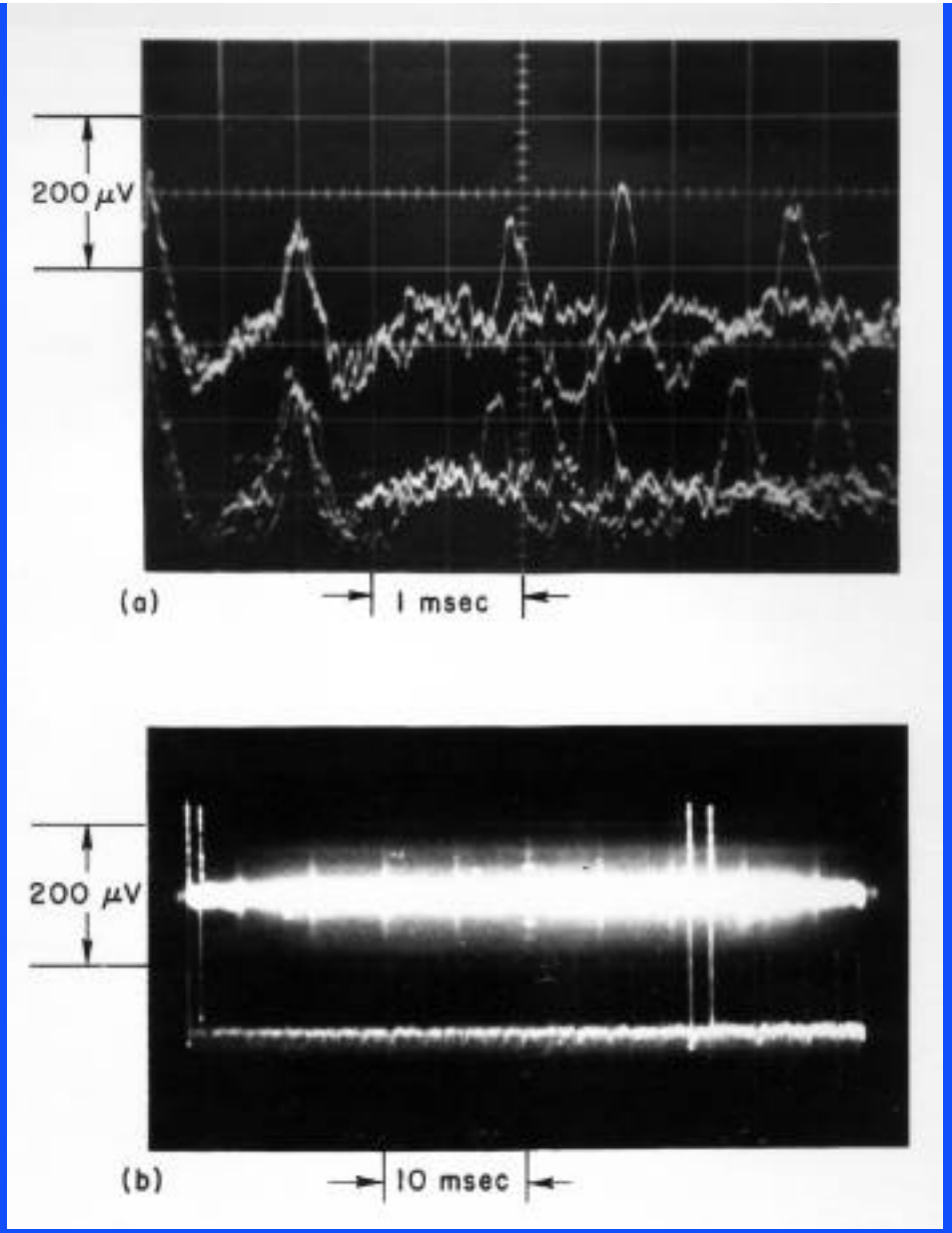
(Thanks to Prof. Jim Angell for his archives and recollections.)

Ken Wise Brain Probe - 1966



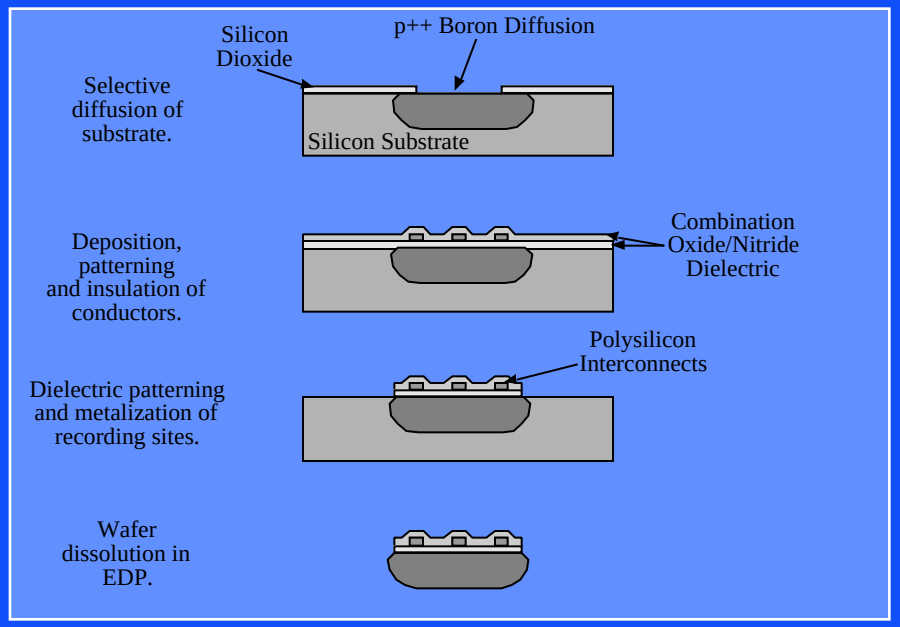
Courtesy Prof. Ken Wise, U. Michigan.

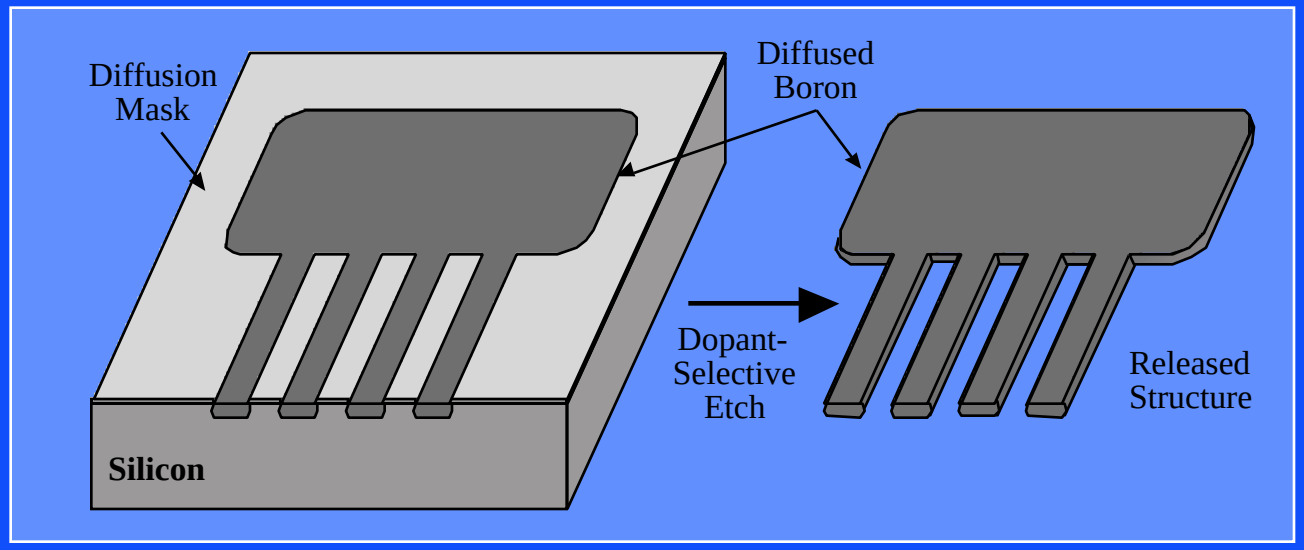


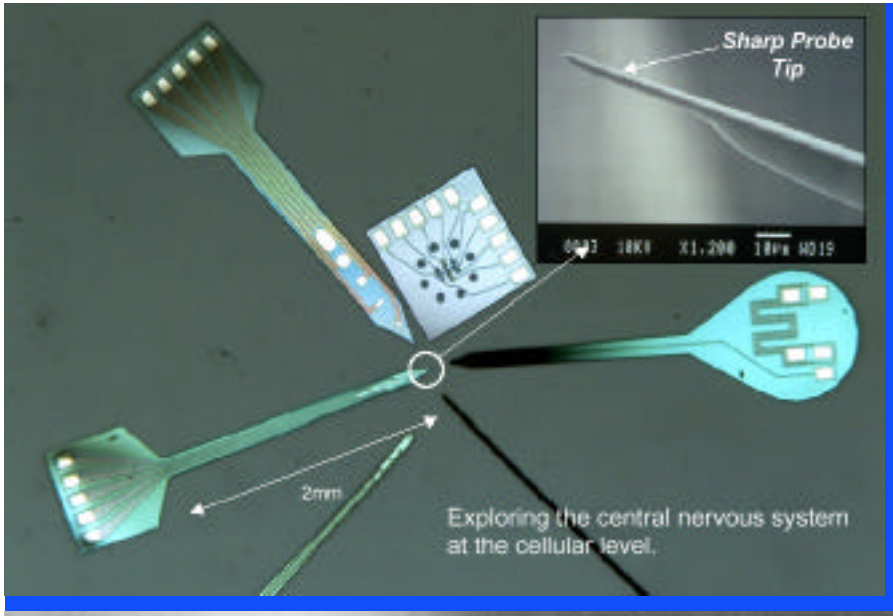


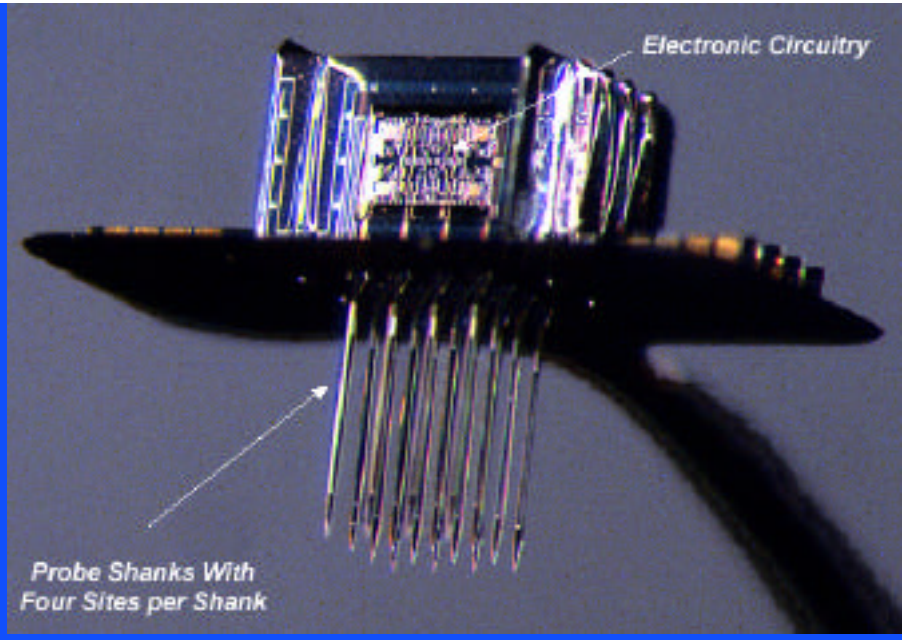
Courtesy Prof. Ken Wise, U. Michigan.

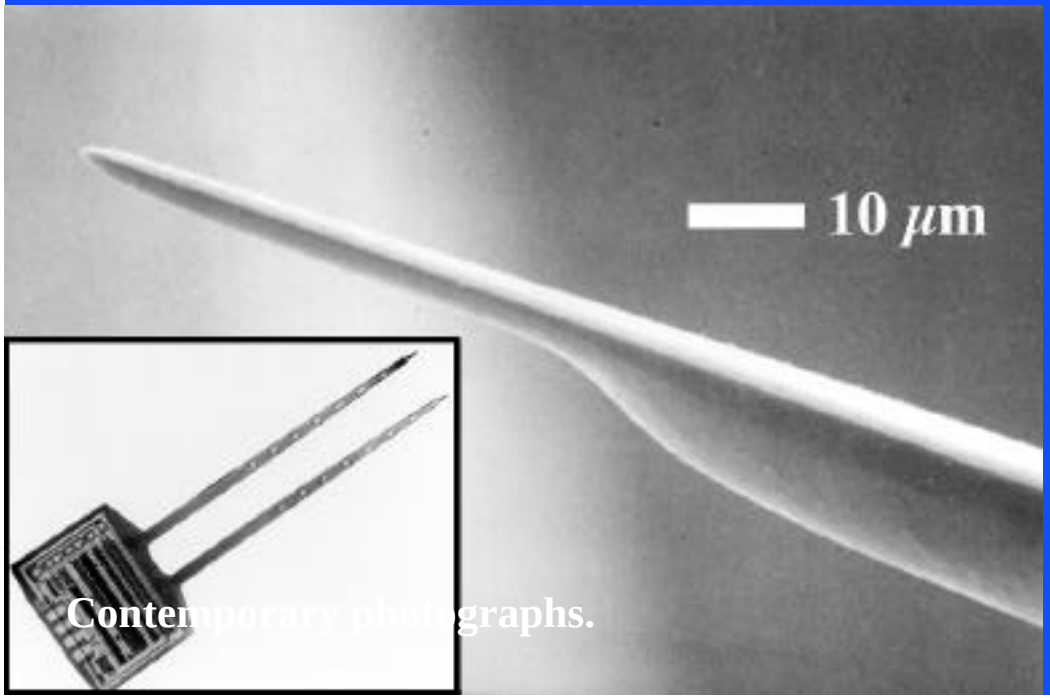
Ken Wise Brain Probe - 1966



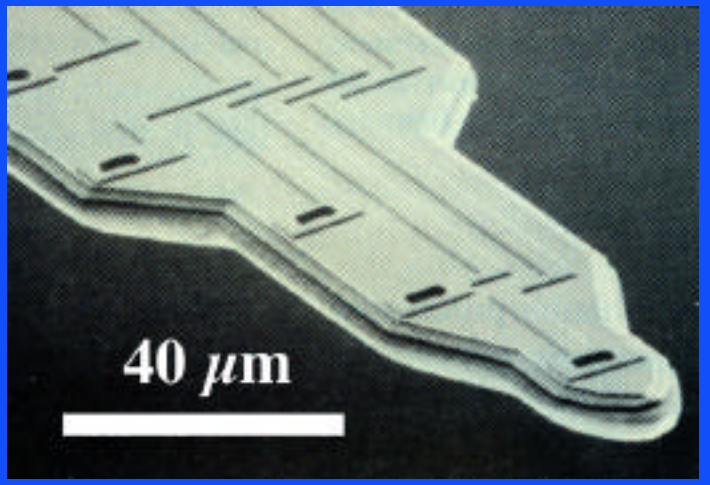






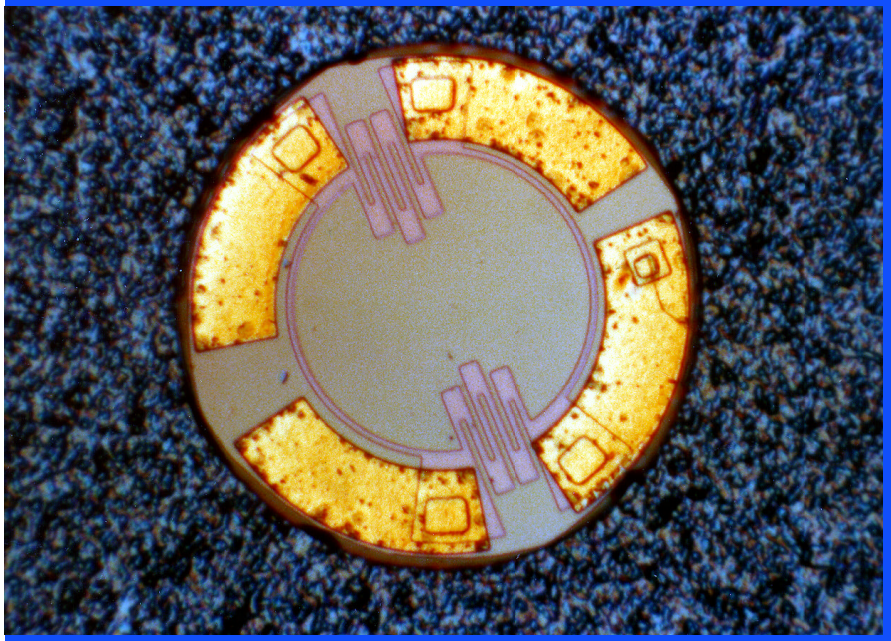


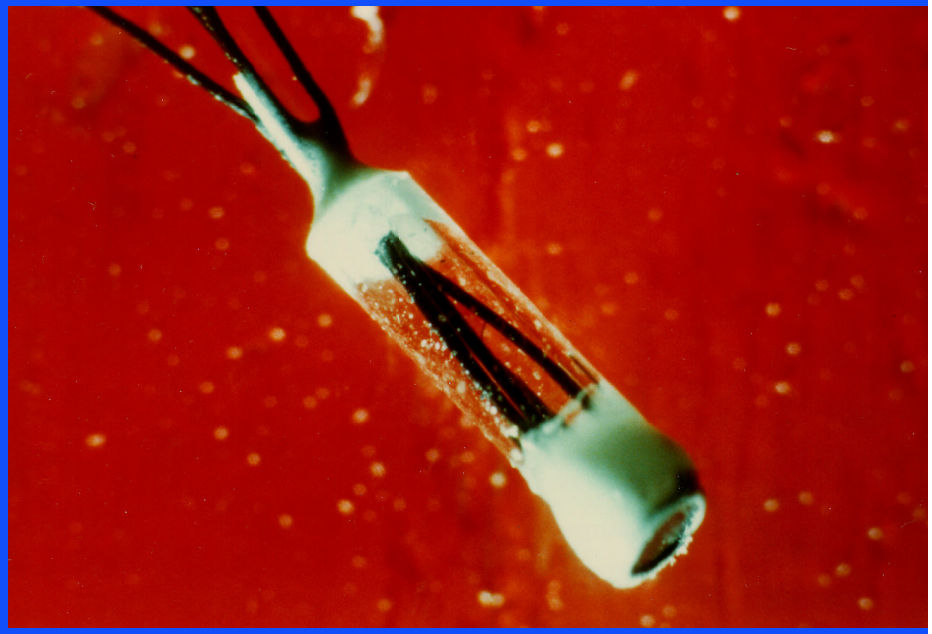
Contemporary photographs.



Courtesy Prof. Ken Wise, U. Michigan.

Samaun Relative Pressure Sensor - 1969





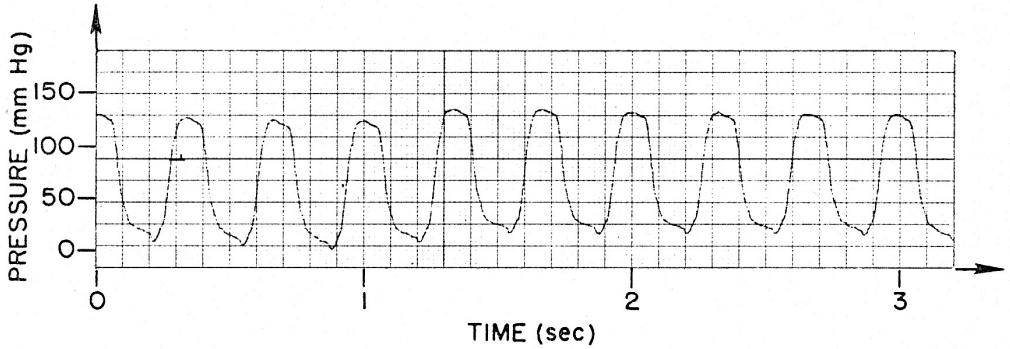
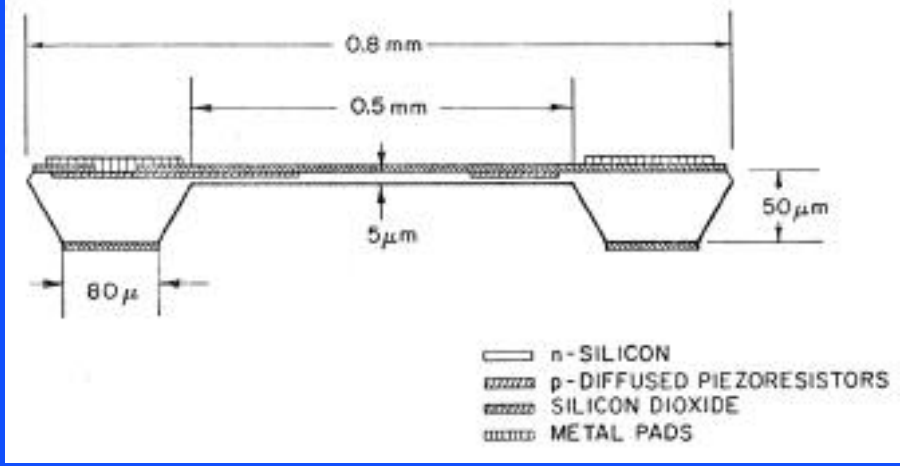
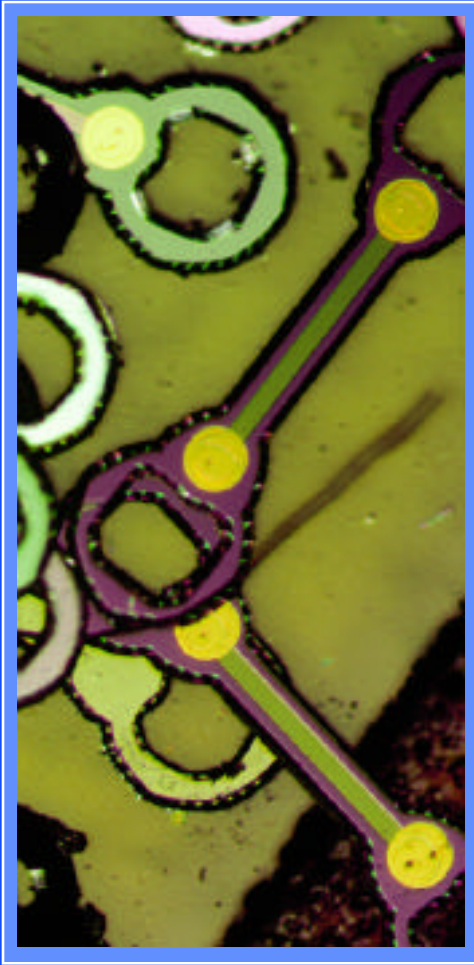


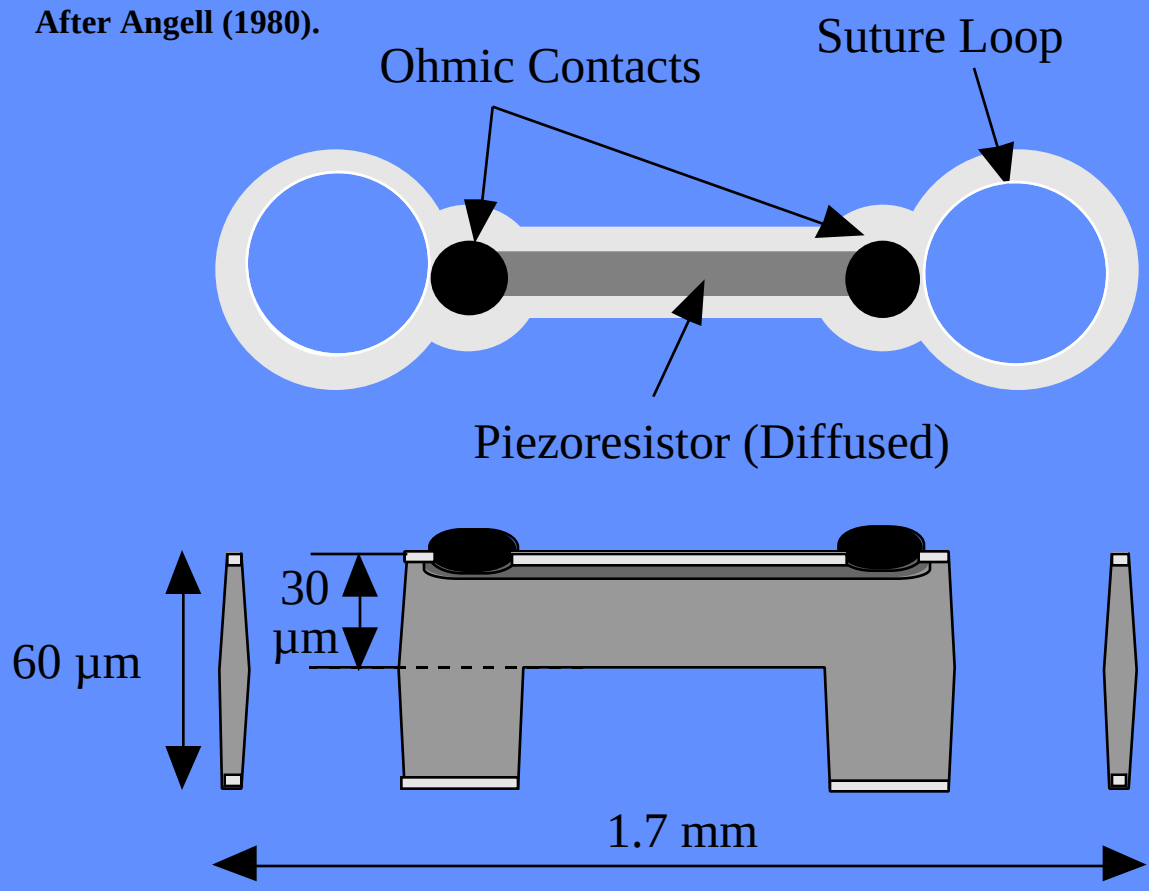
Fig. 5.2. Recording of the blood pressure in the left ventricle of a dog.



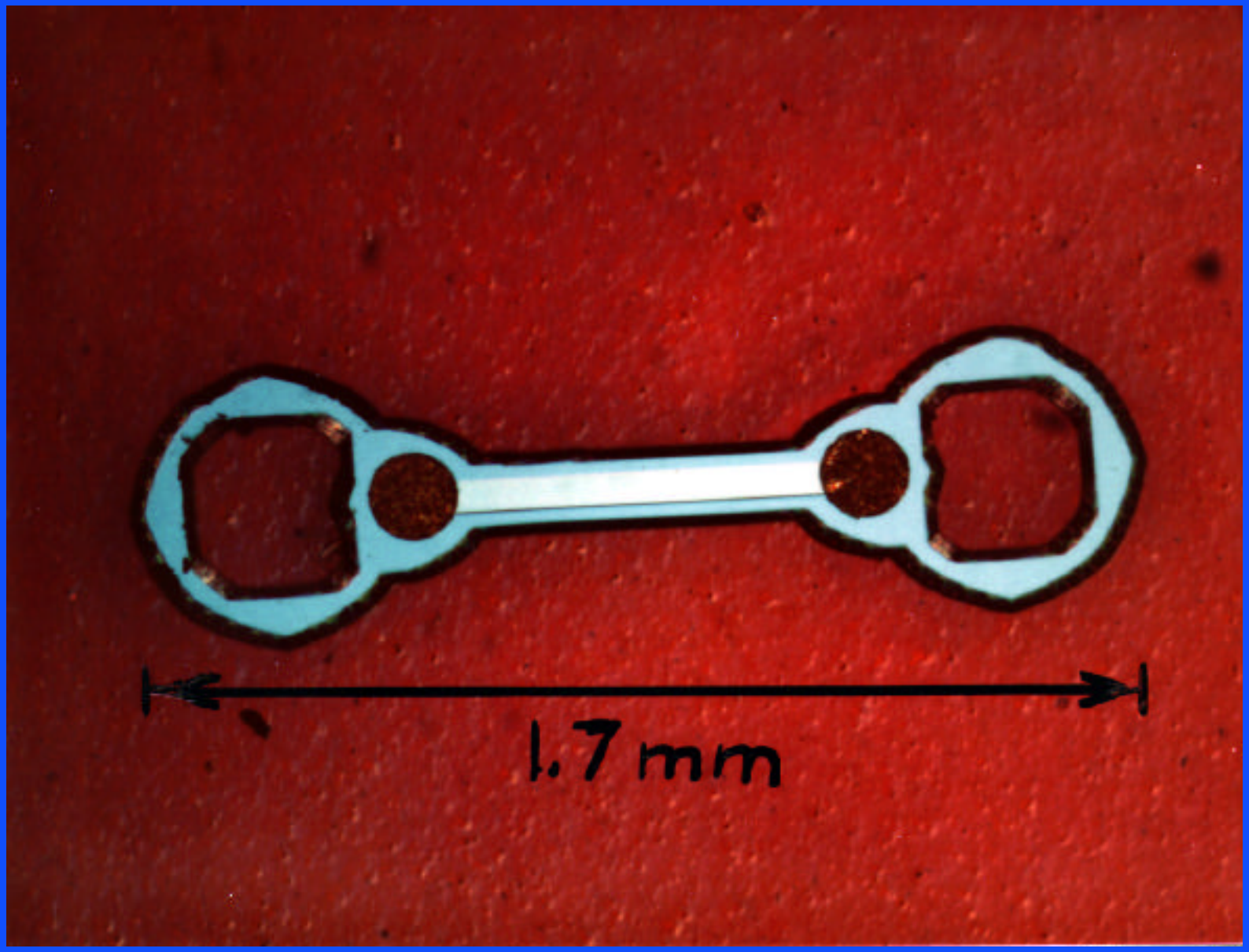
Nunn - Micro Strain Gauge - 1972

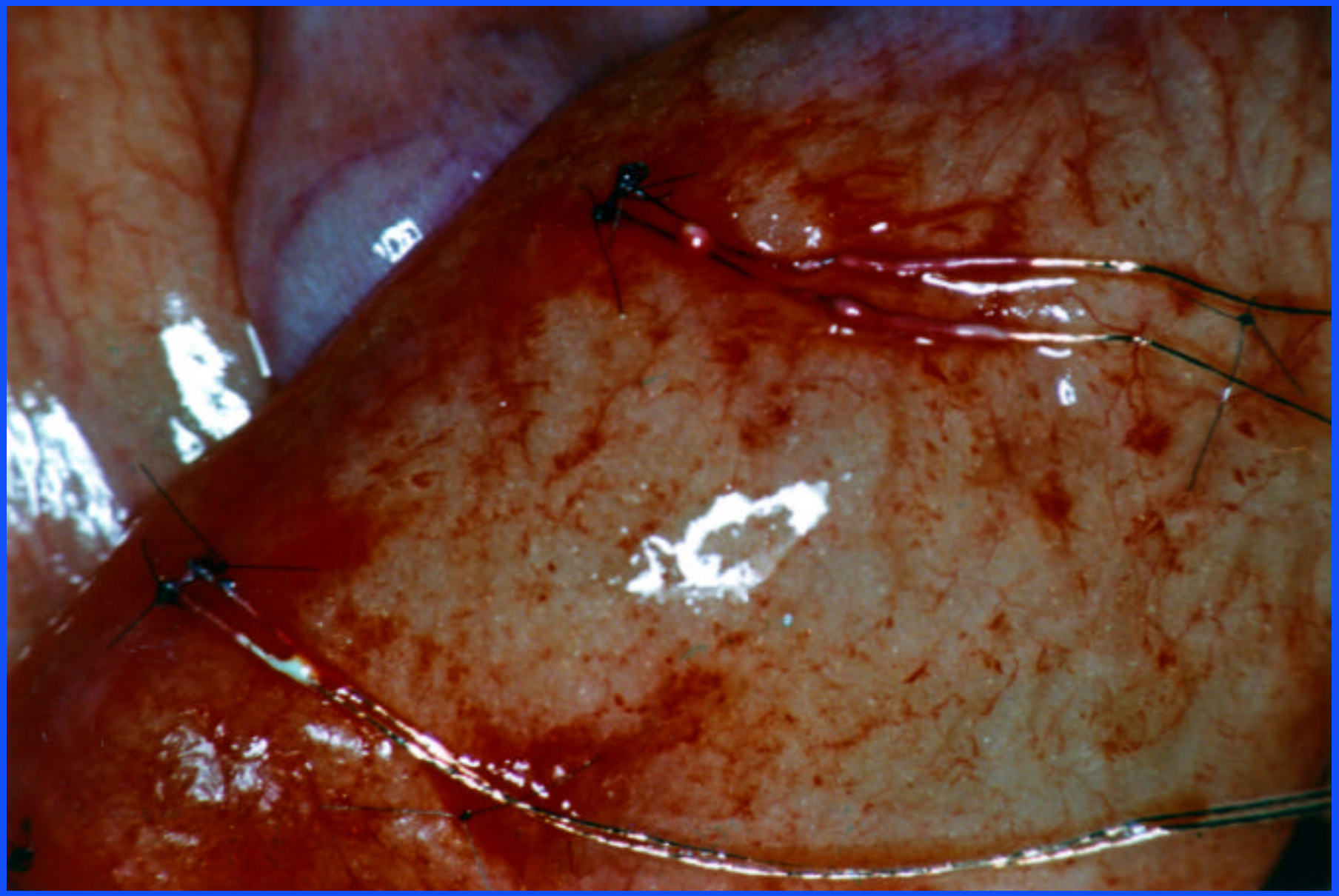


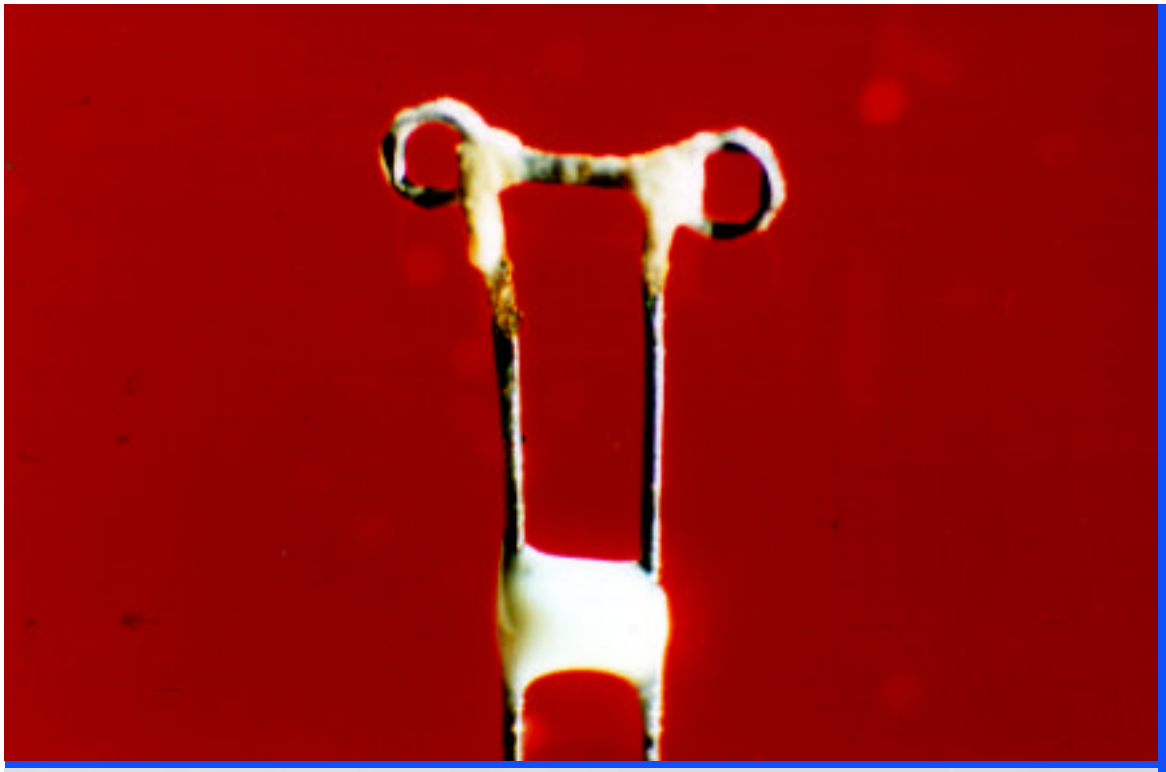
After Angell (1980).

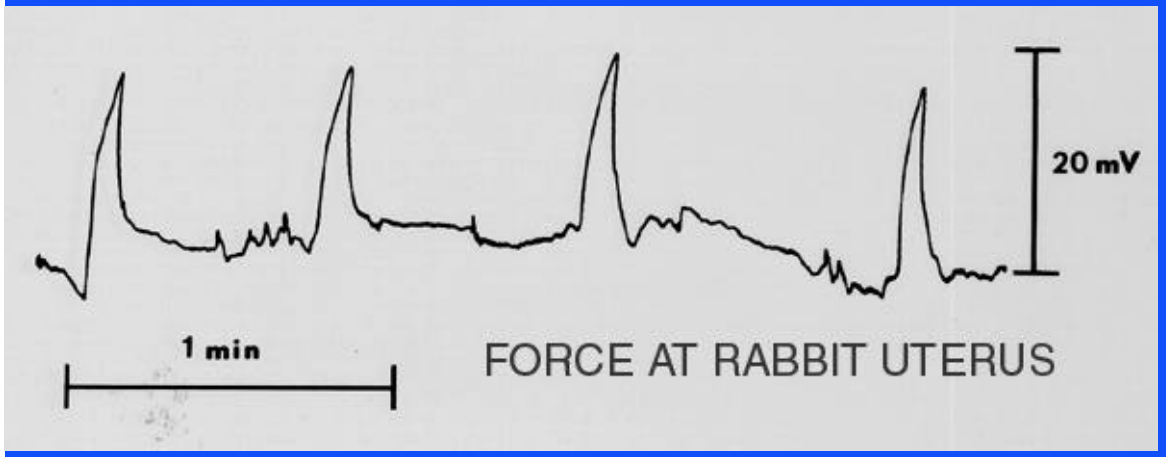


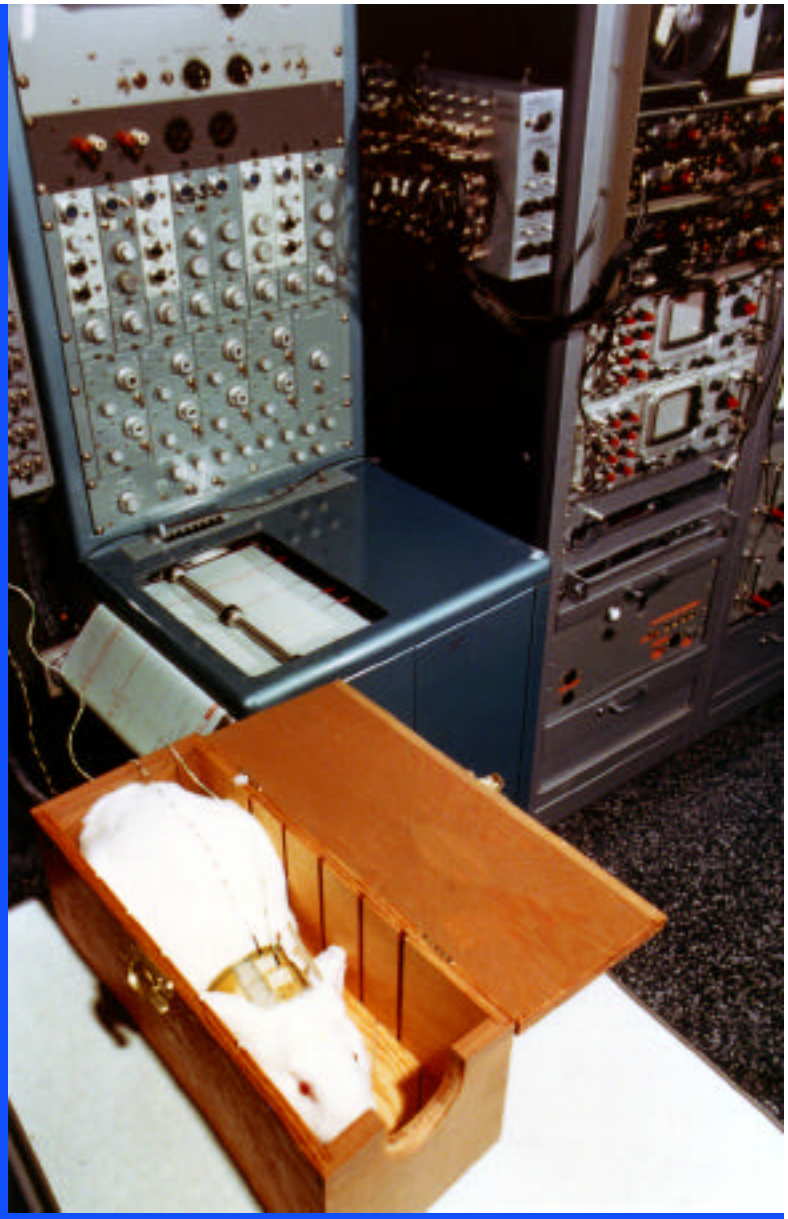
Reference: Angell, J. B., "Transducers for in vivo measurement of force, strain and motion," in "Physical Sensors for Biomedical Applications," Neuman, M. R., Fleming, D. G., Cheung, P. W., and Ko, W. H. [eds.], CRC Press, Boca Raton, FL, 1980, pp. 46 - 53.



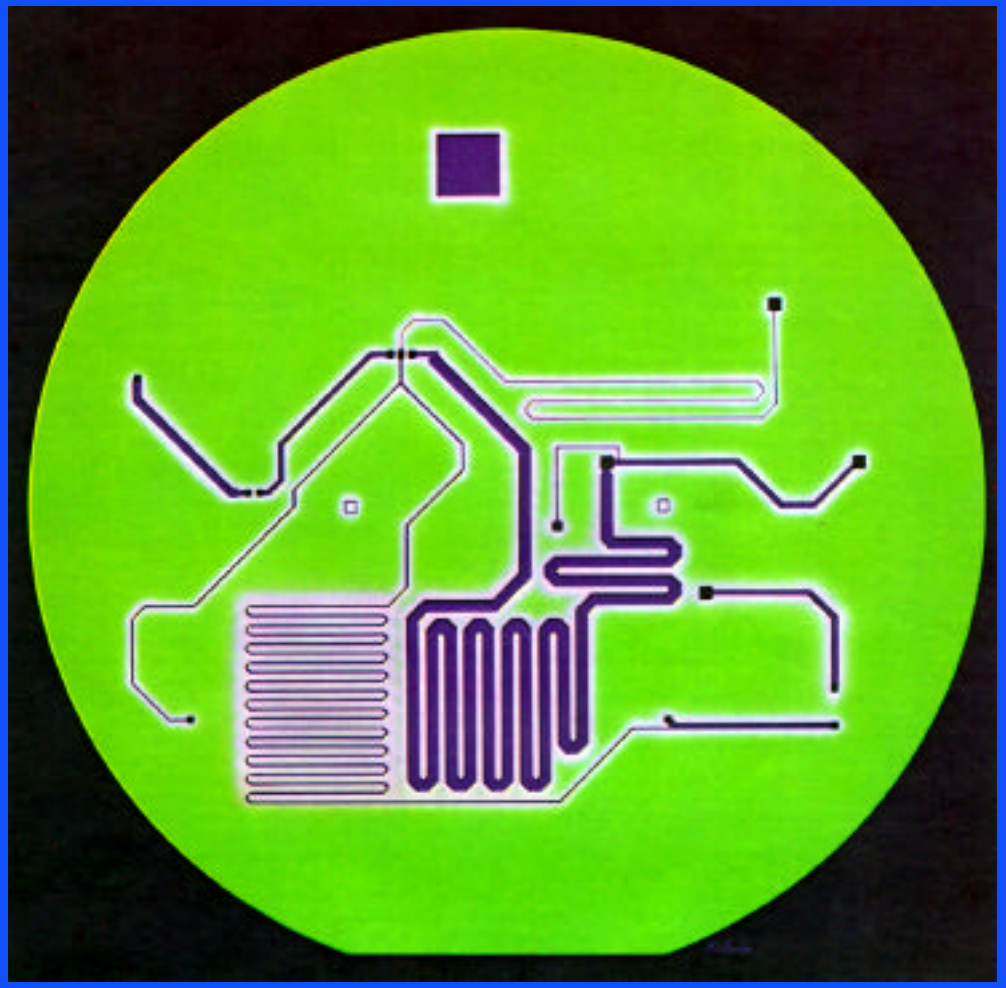


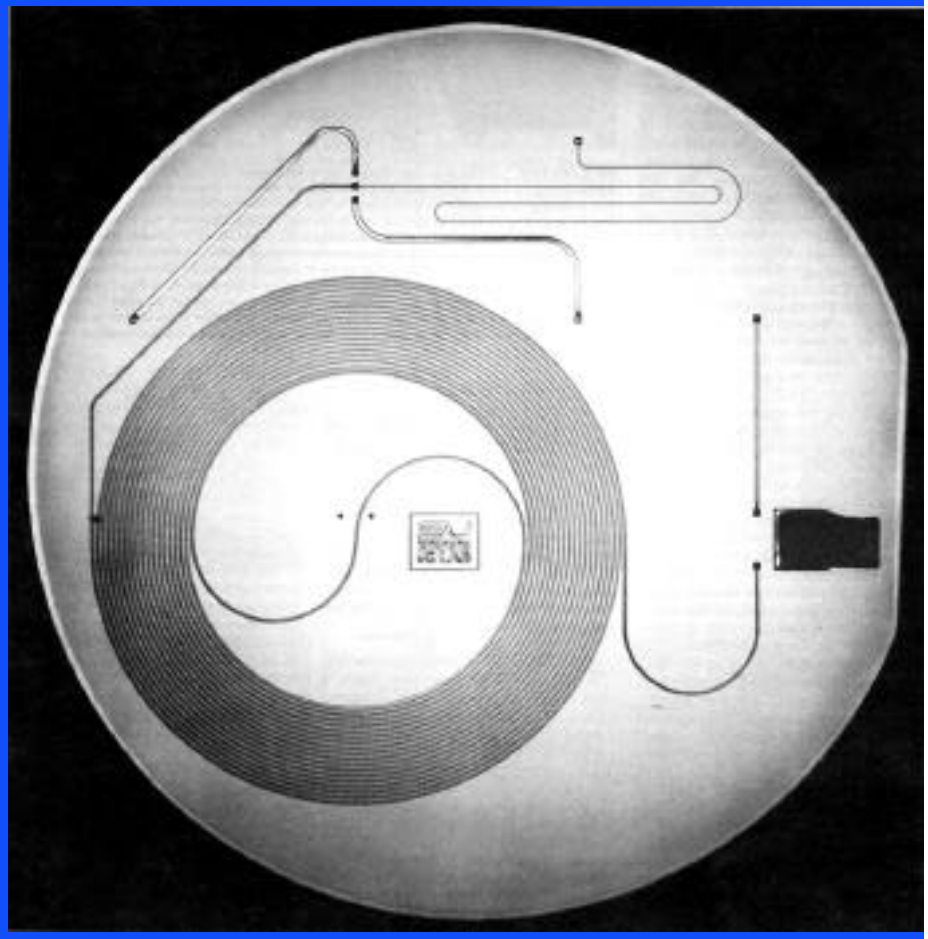




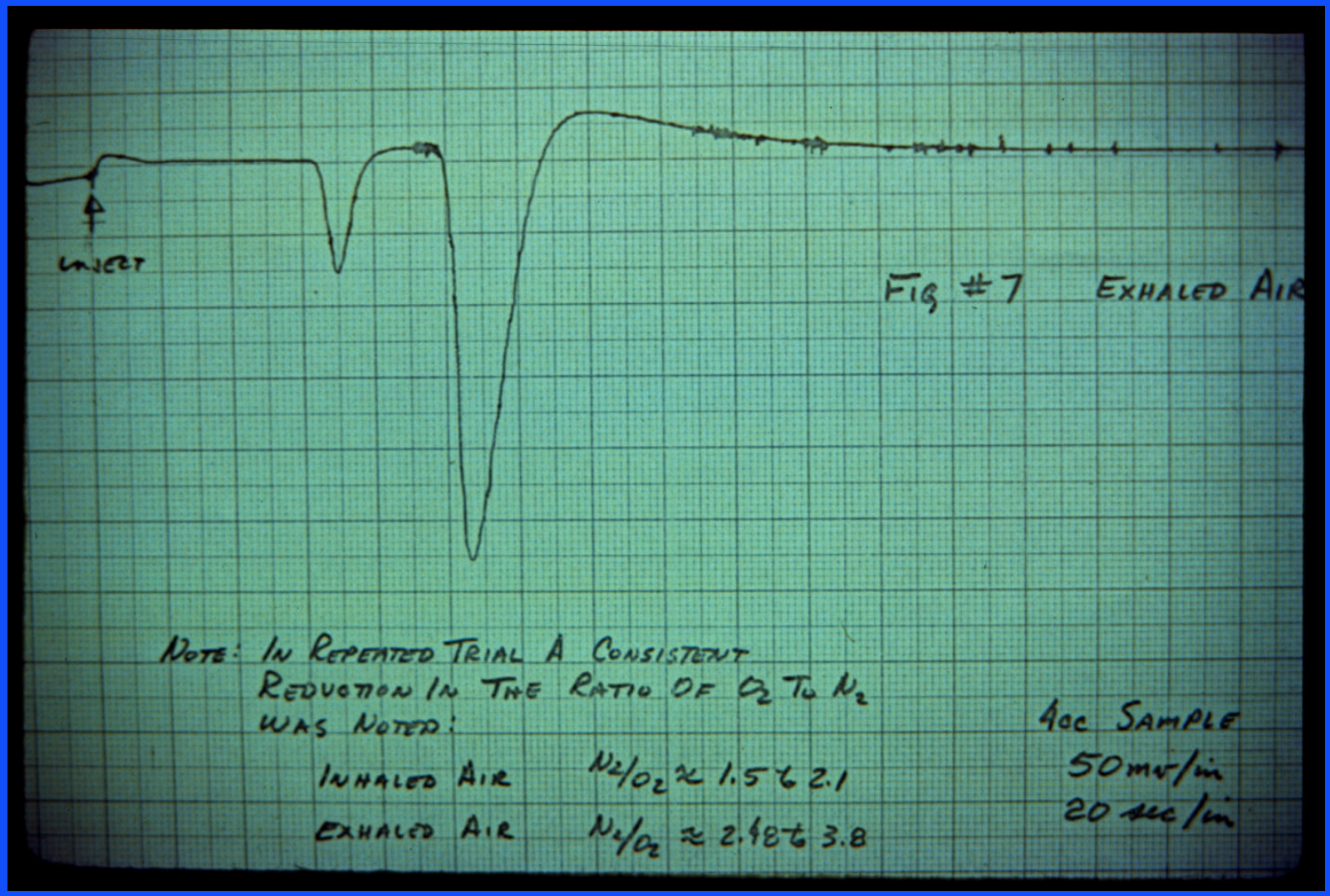


Terry - Integrated Gas Chromatography System - 1972



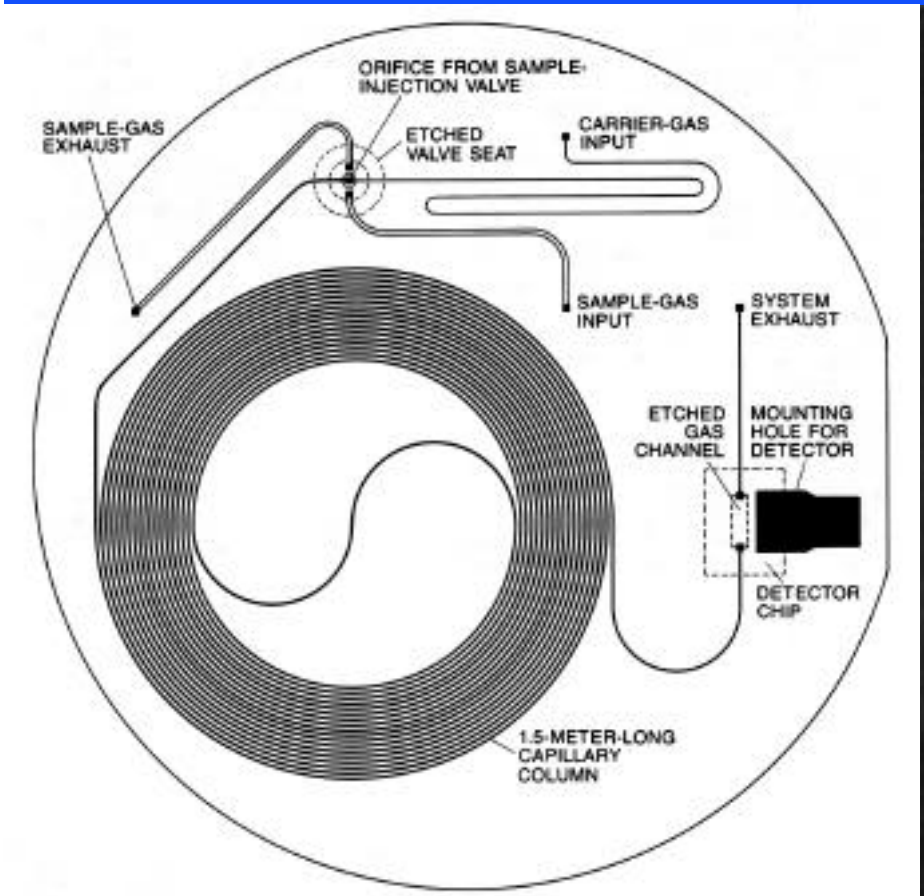


GC Data - 1972



Courtesy Dr. Steve Terry, EG&G IC Sensors.

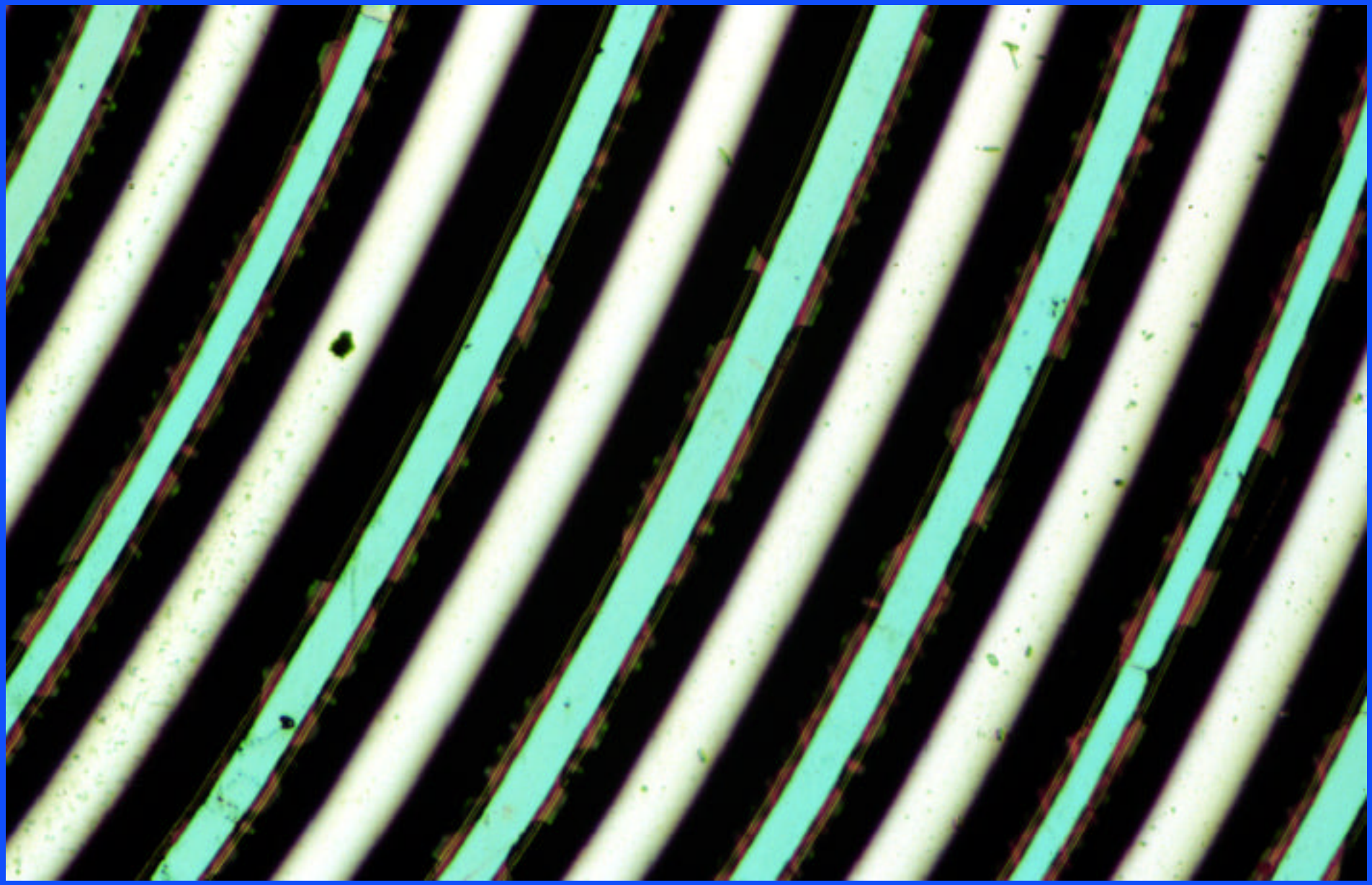
GAS CHROMATOGRAPHY SYSTEM

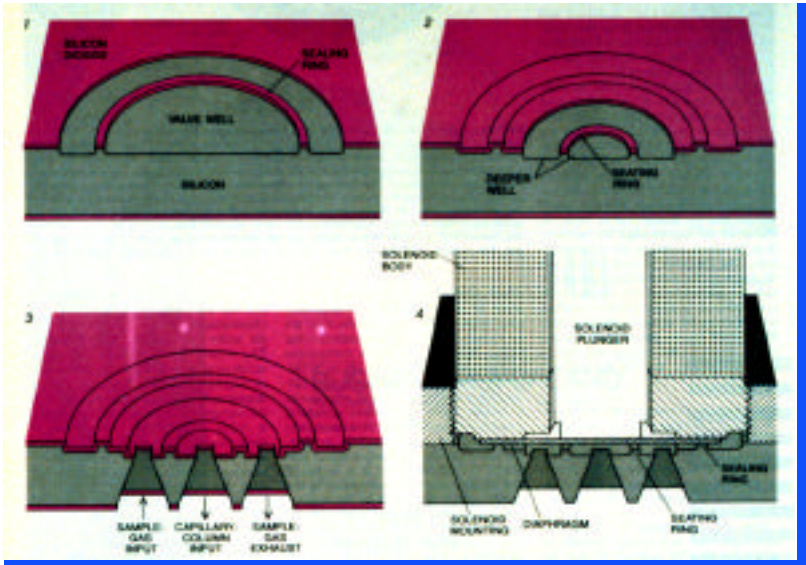


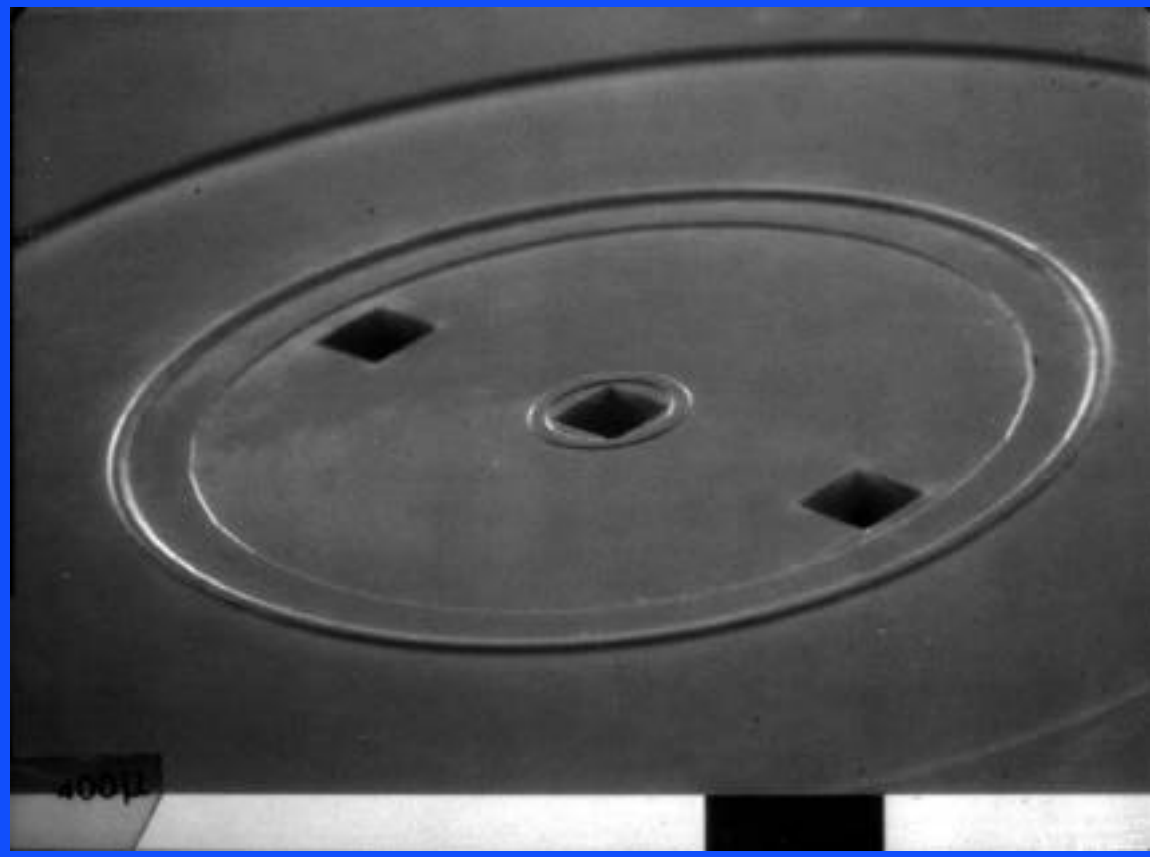
Source: Terry, S. C., Jerman, J. H., and Angell, J. B., "A Gas Chromatographic Air Analyzer Fabricated on a Silicon Wafer," IEEE Transactions on Electron Devices, vol. ED-26, no. 12, Dec. 1979, pp. 1880 - 1886.

Courtesy Dr. S. Terry, EG&G IC Sensors, Inc.

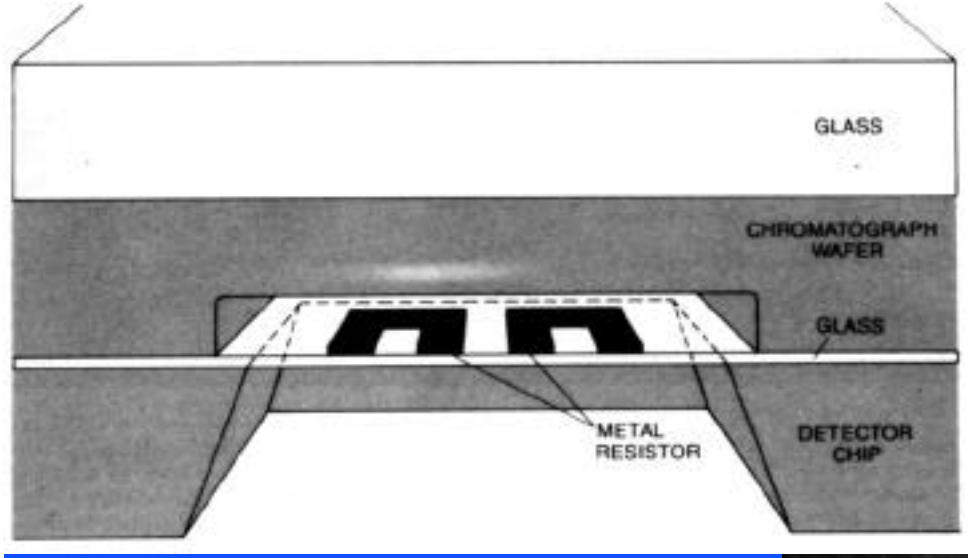
1.5 meter GC column on 2" wafer.



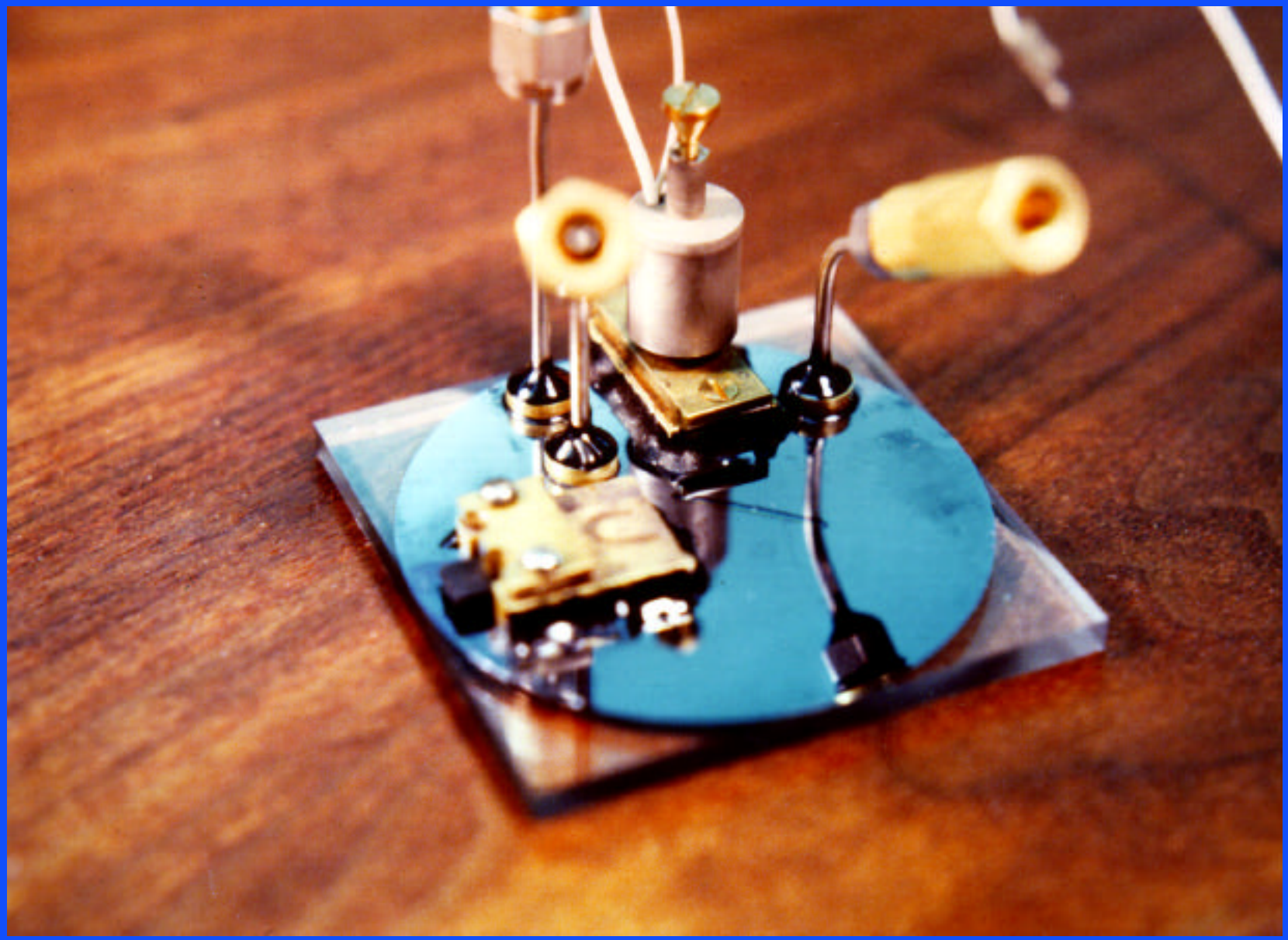




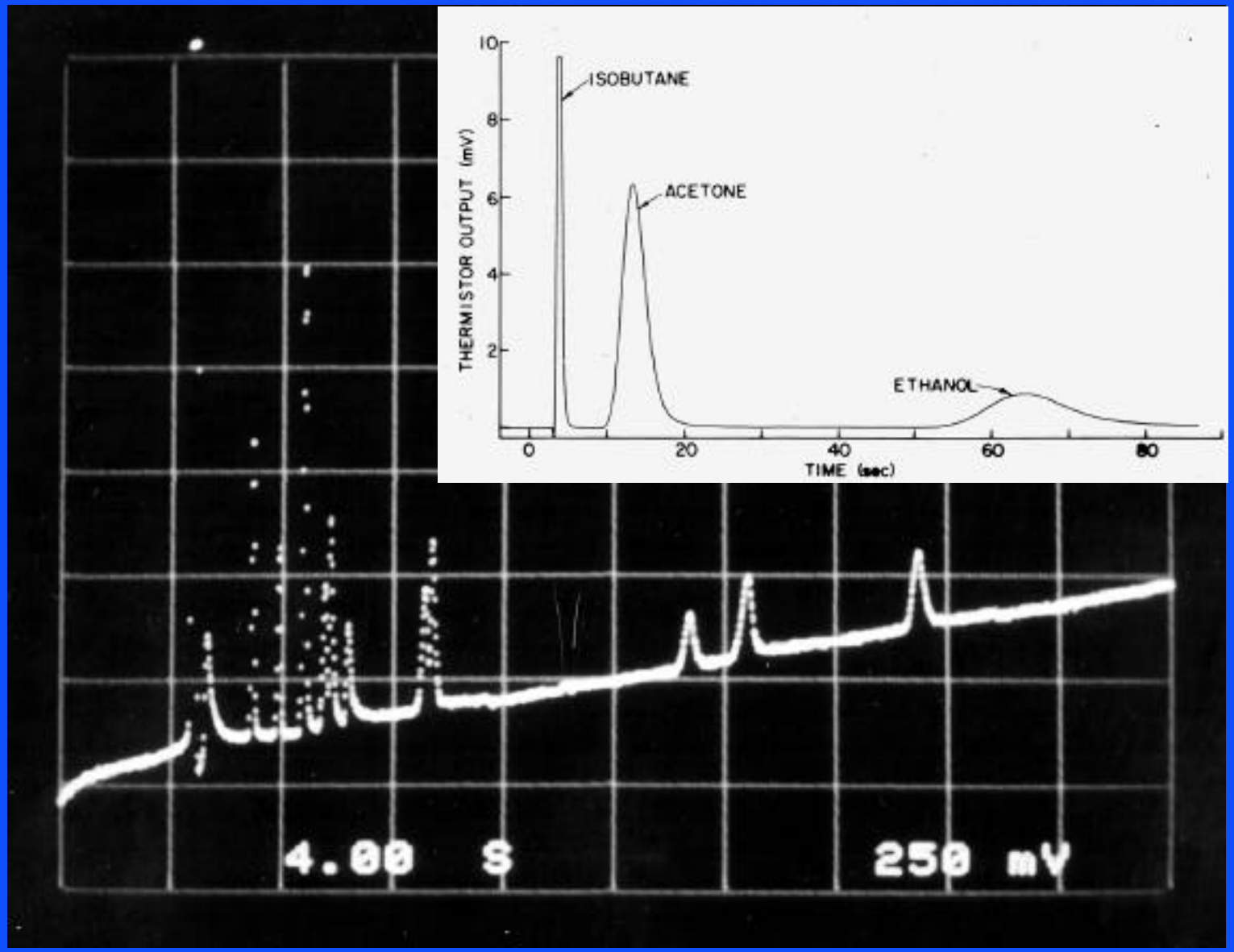
Courtesy Dr. S. Terry, EG&G IC Sensors, Inc.



Courtesy Dr. S. Terry, EG&G IC Sensors, Inc.

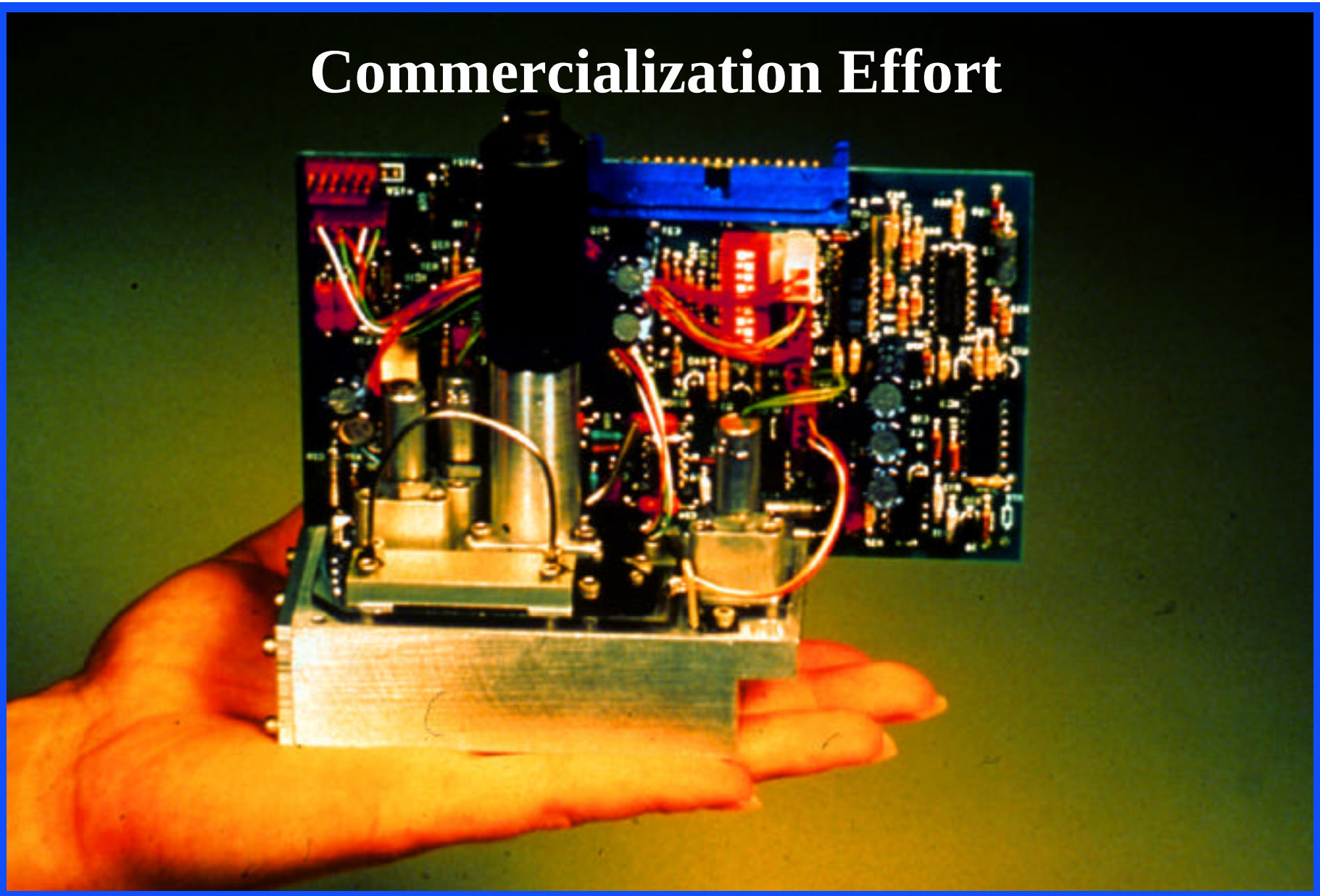


Courtesy Dr. S. Terry, EG&G IC Sensors, Inc.



Courtesy Dr. S. Terry, EG&G IC Sensors, Inc.

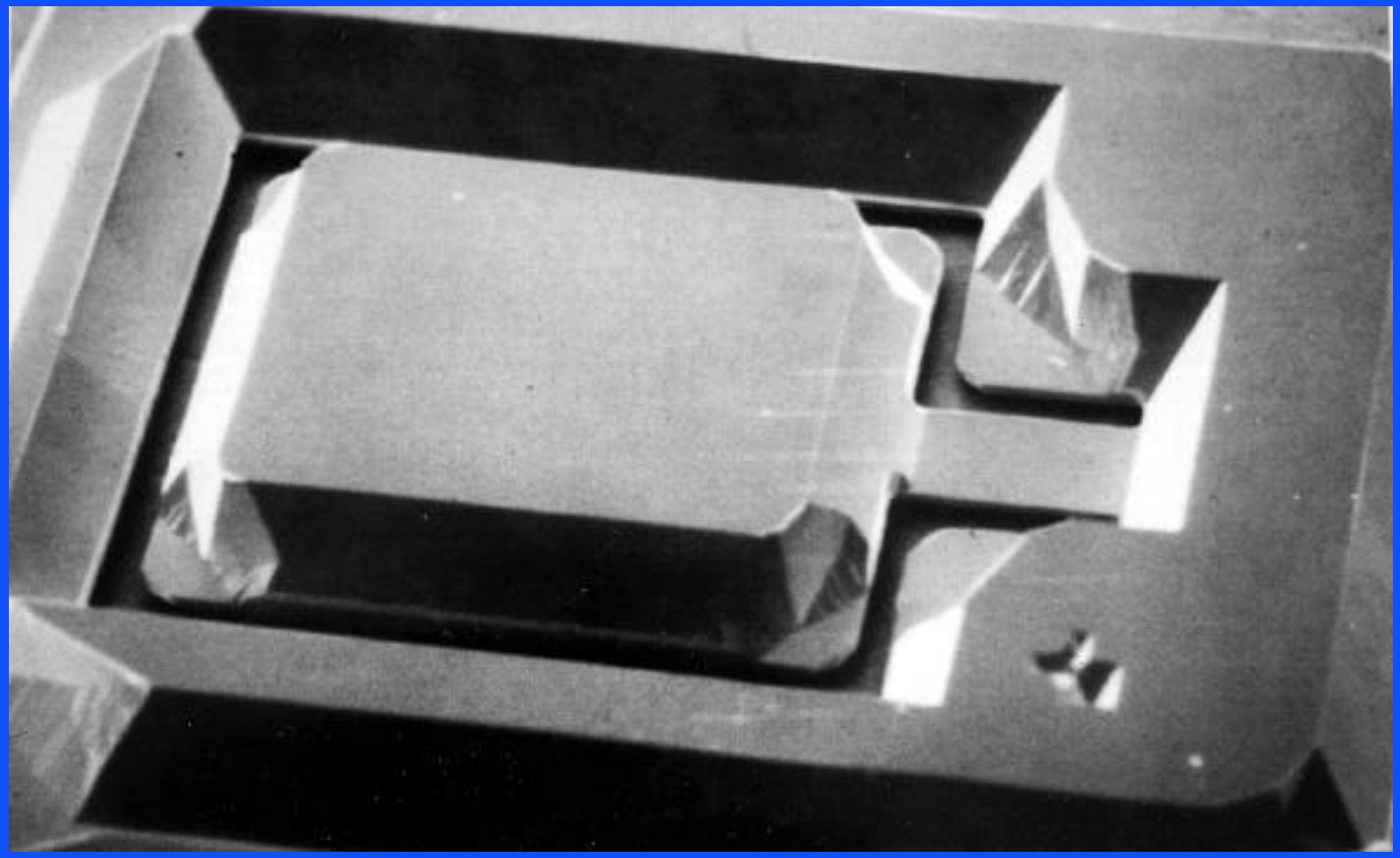
Commercialization Effort

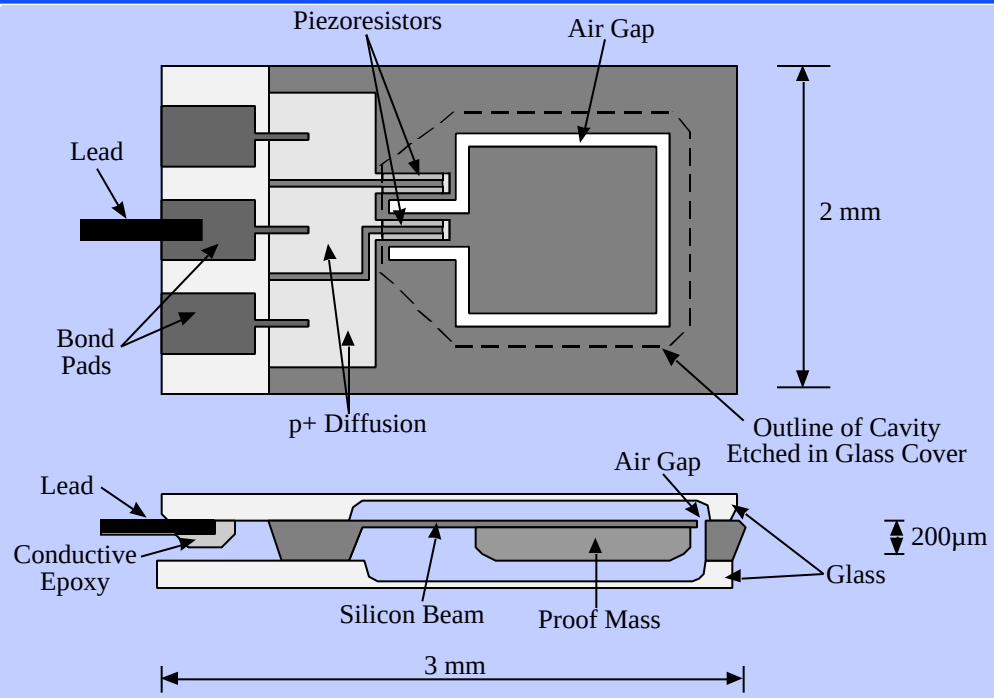


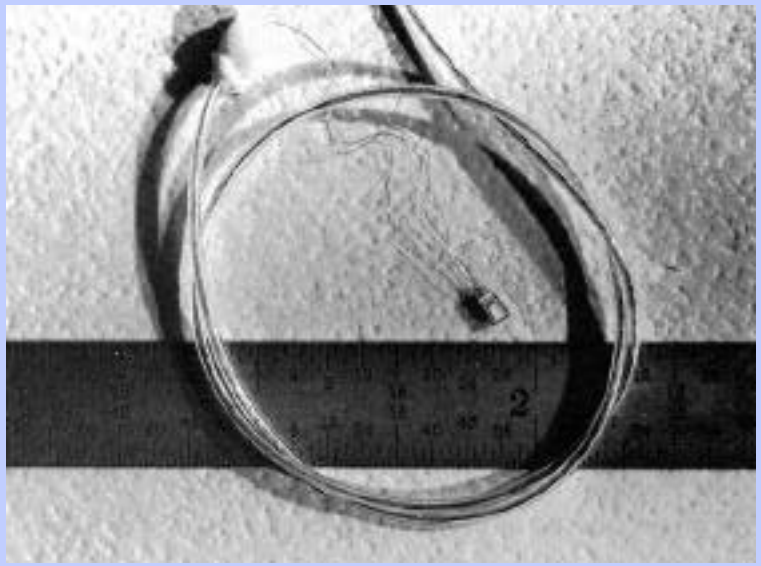
Courtesy Prof. K. Petersen, Stanford University.

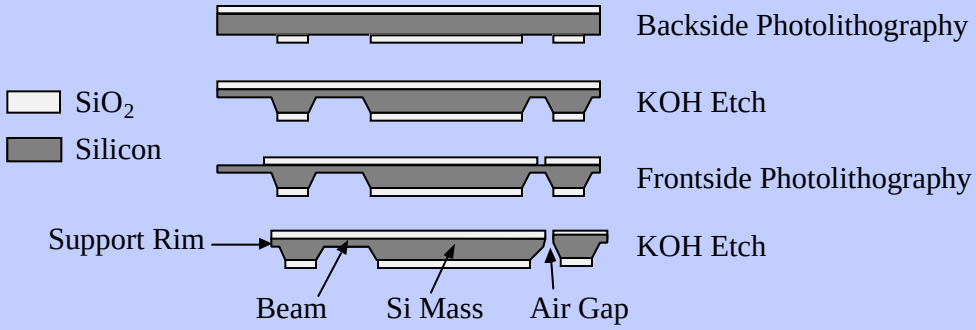
Courtesy Dr. S. Terry, EG&G IC Sensors, Inc.

Roylance - Micromachined Accelerometer - 1974



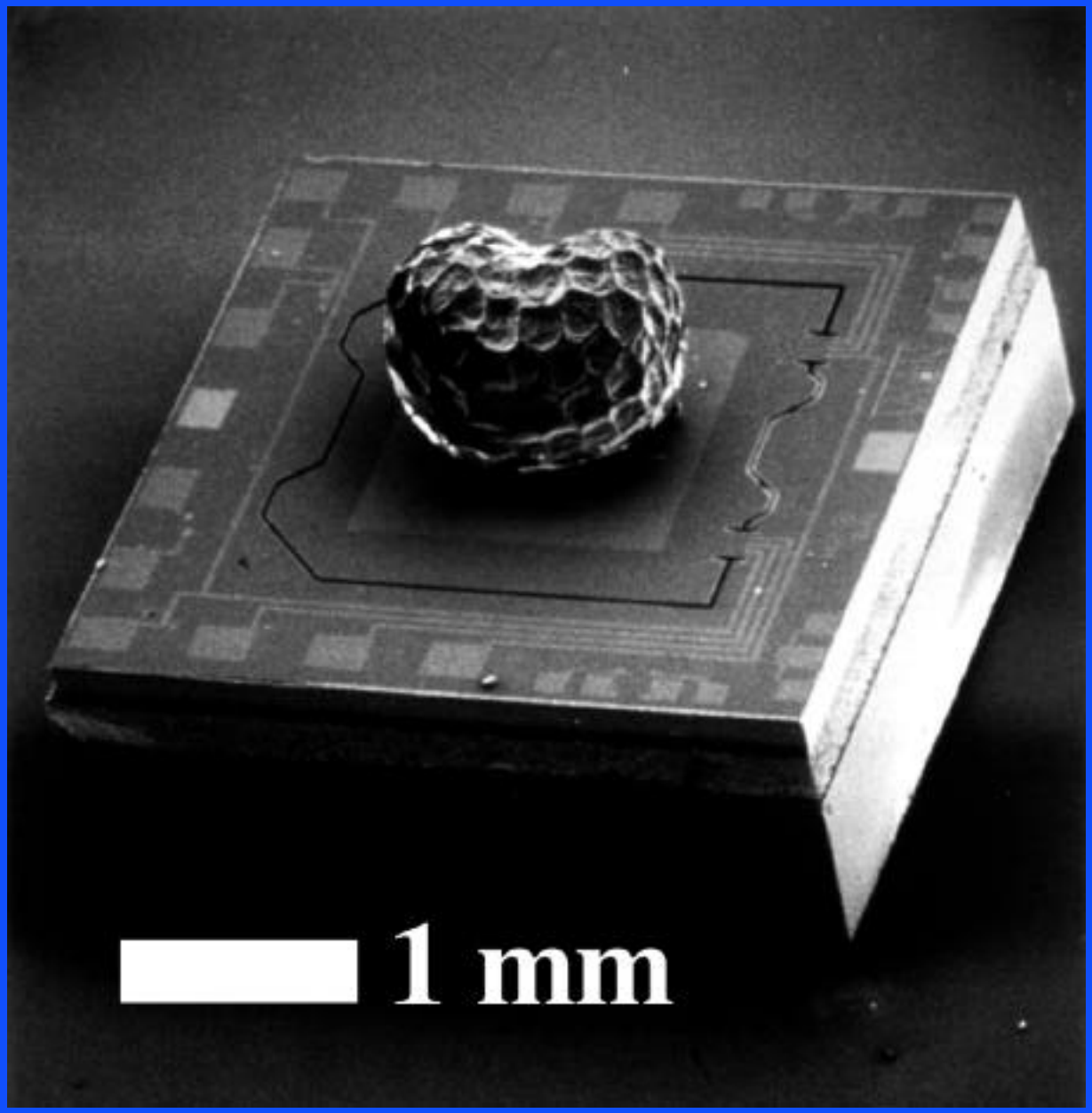






Reference: Roylance, L. M. and Angell, J. B., "A Batch-Fabricated Silicon Accelerometer," IEEE Transactions on Electron Devices, vol. ED-26, no. 12, Dec. 1979, pp. 1911 - 1917.

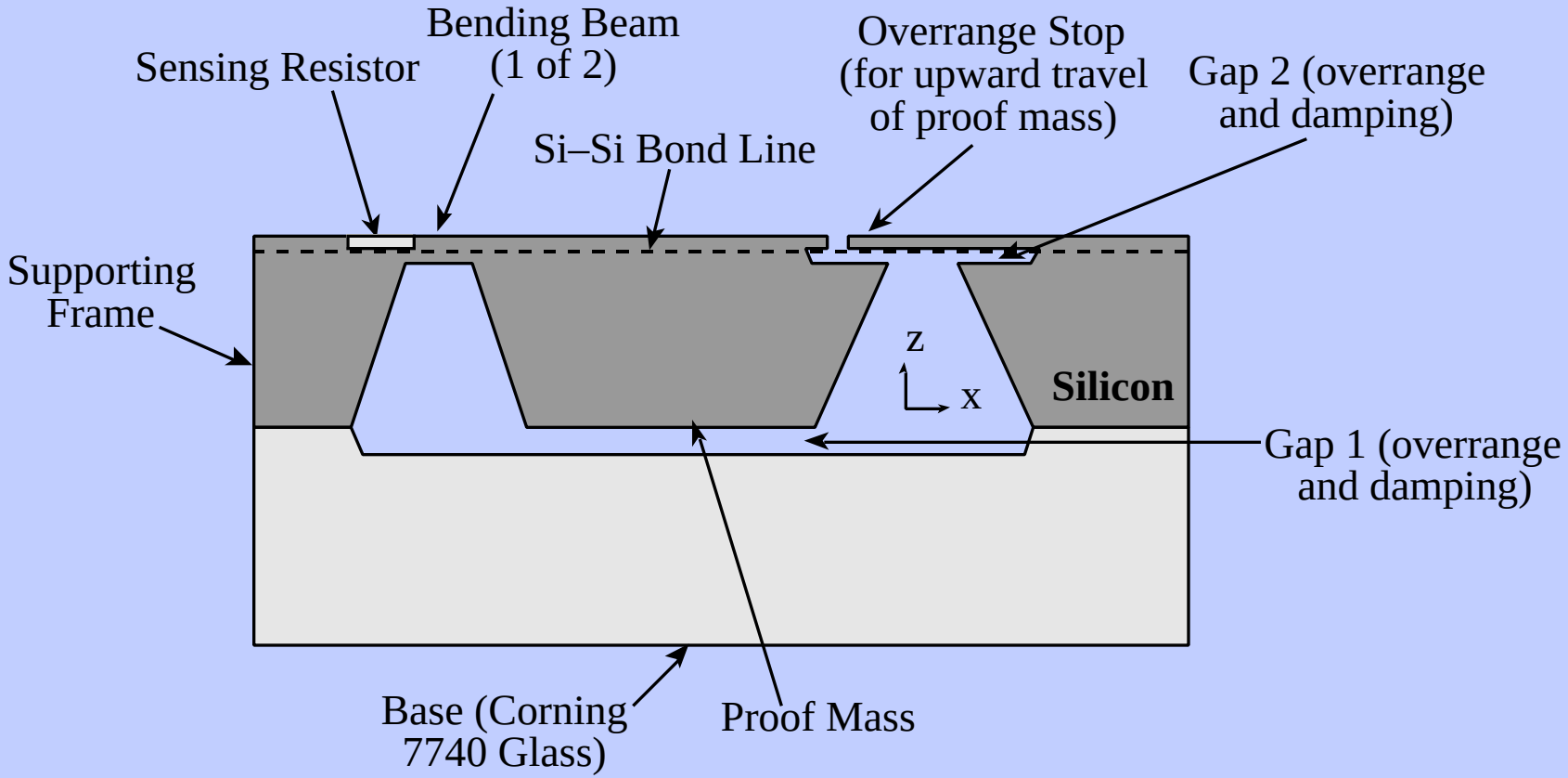
After Roylance and Angell (1979).



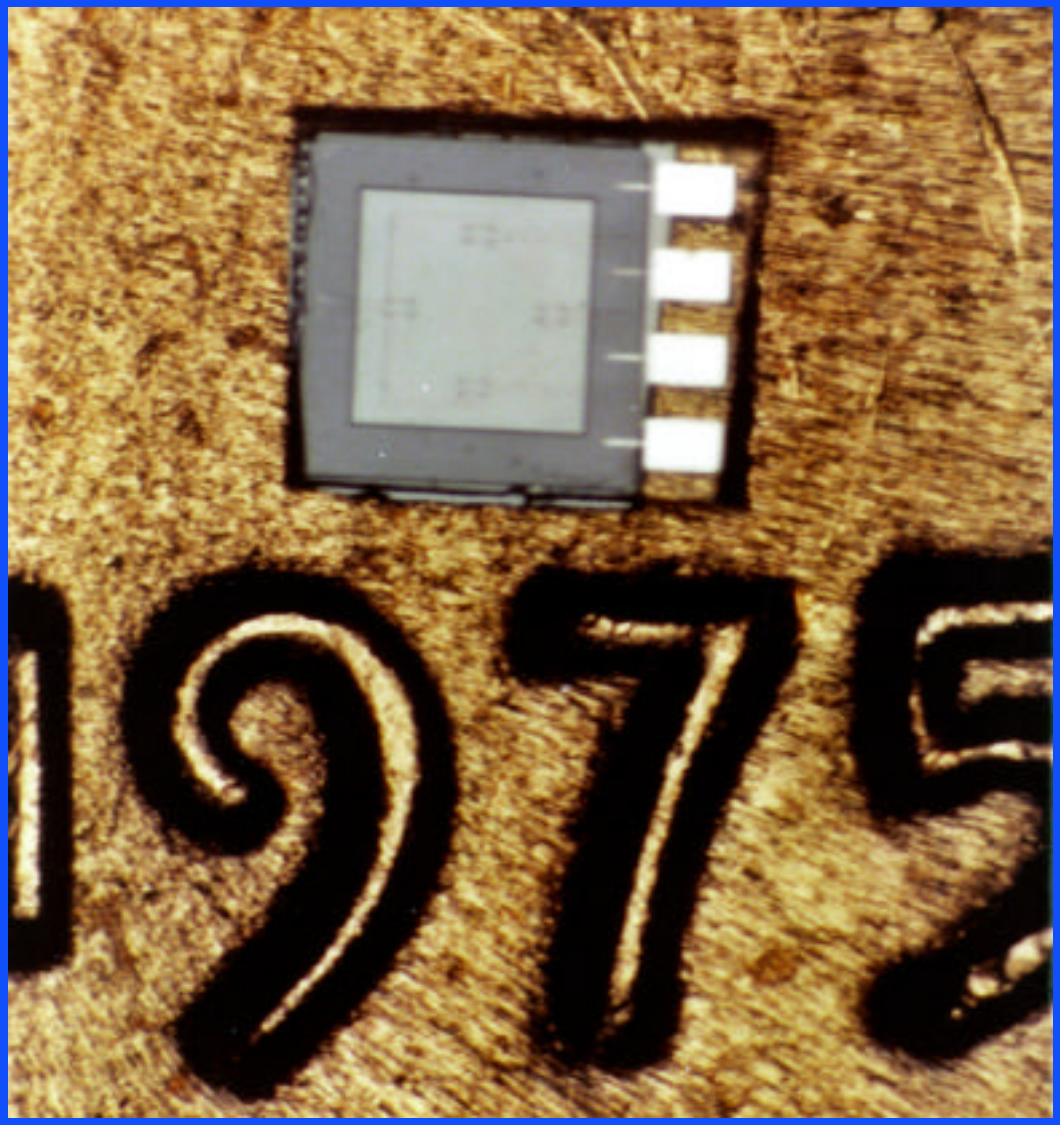
Modern Silicon Accelerometer

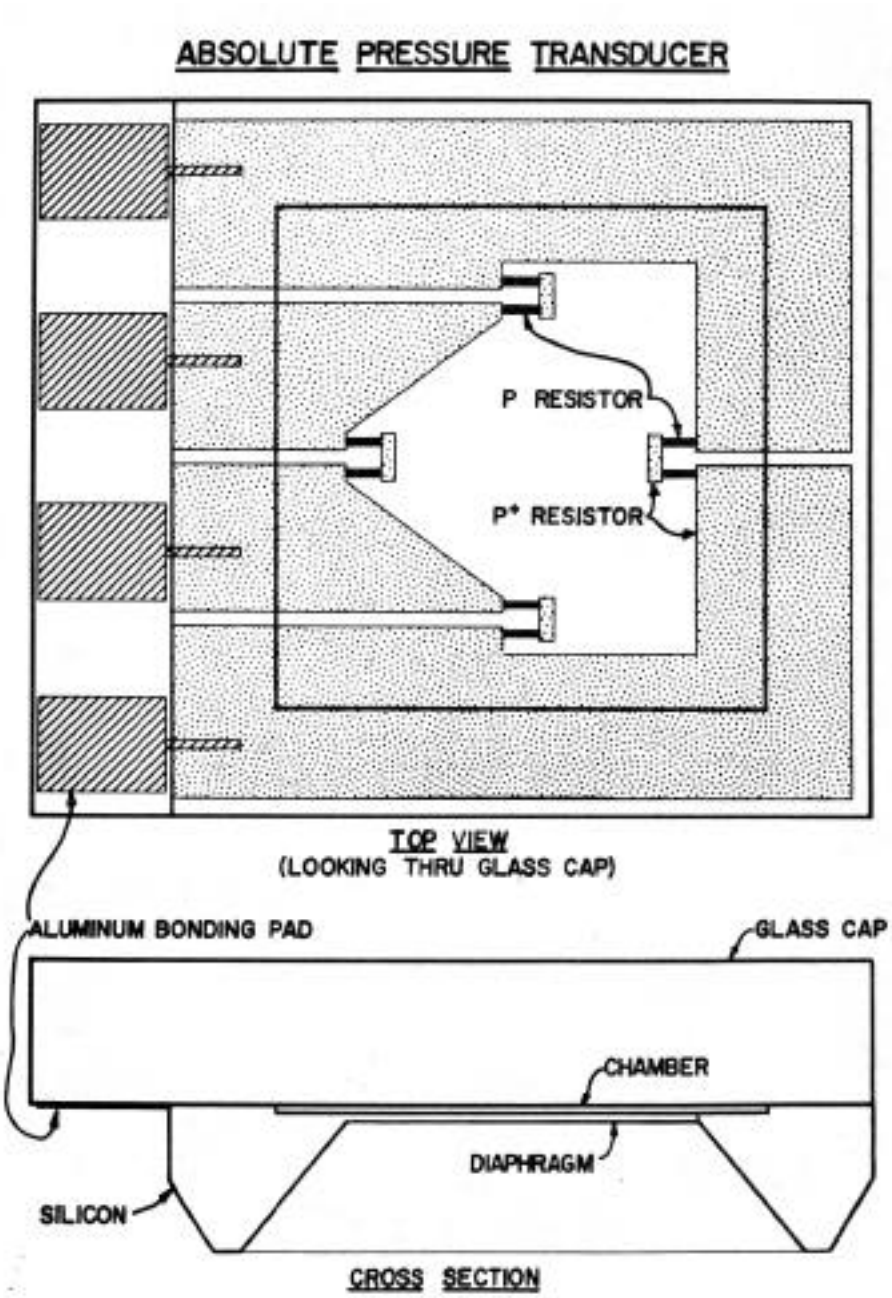
Courtesy of Dr. Kurt Petersen, Lucas NovaSensor

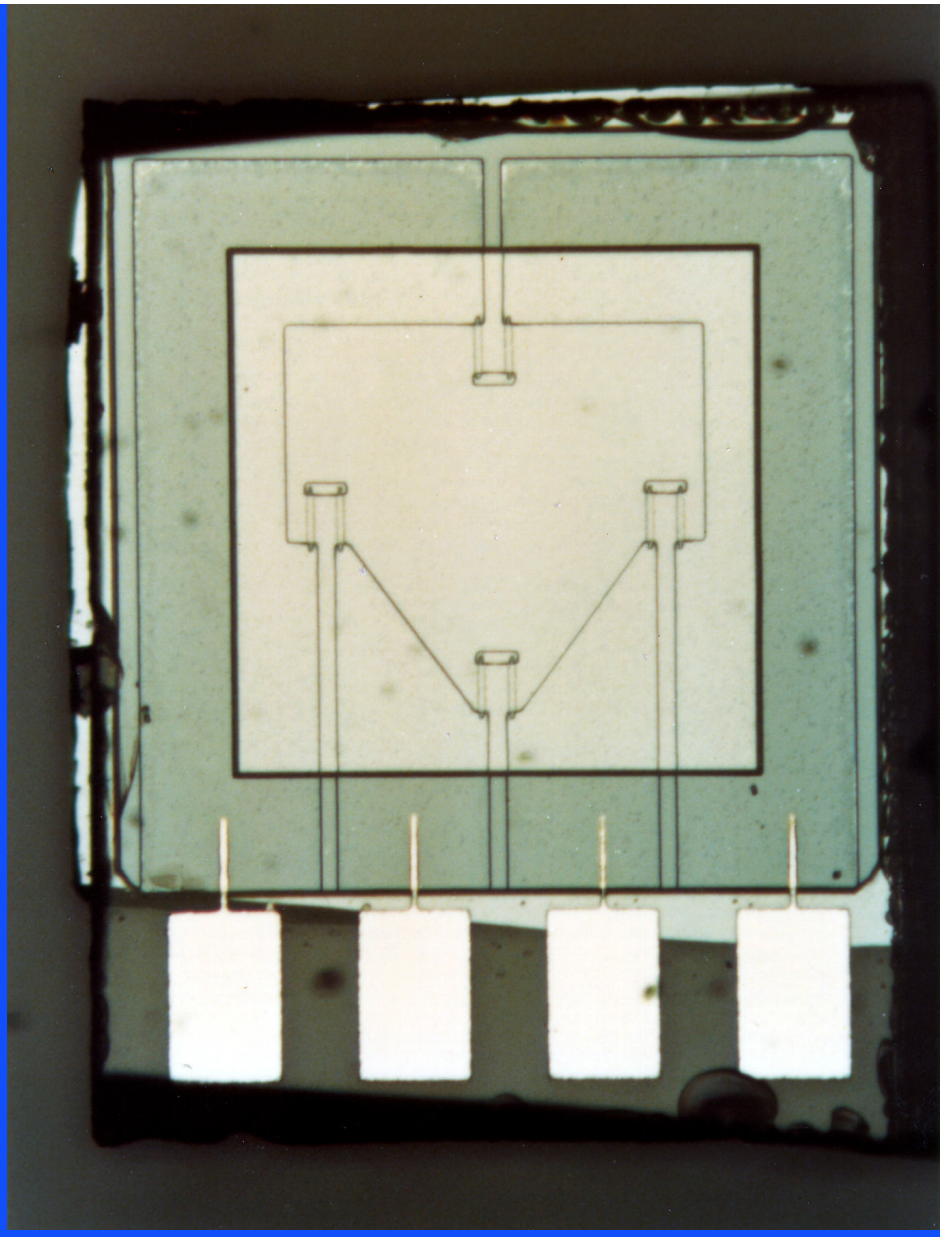
MODERN MICROMACHINED ACCELEROMETER (STRAIN GAUGE TYPE)



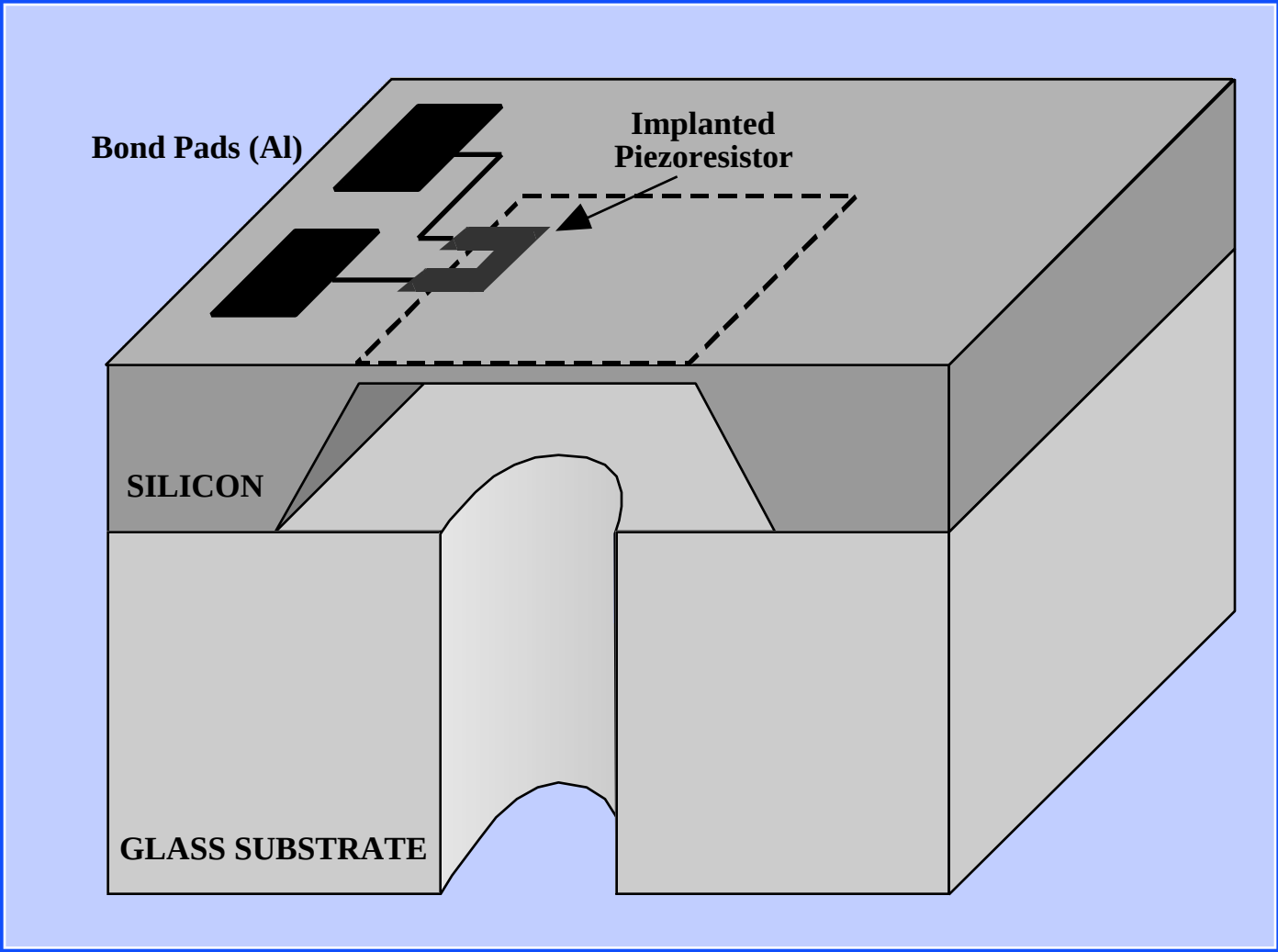
Barth - Absolute Pressure Sensor - 1974



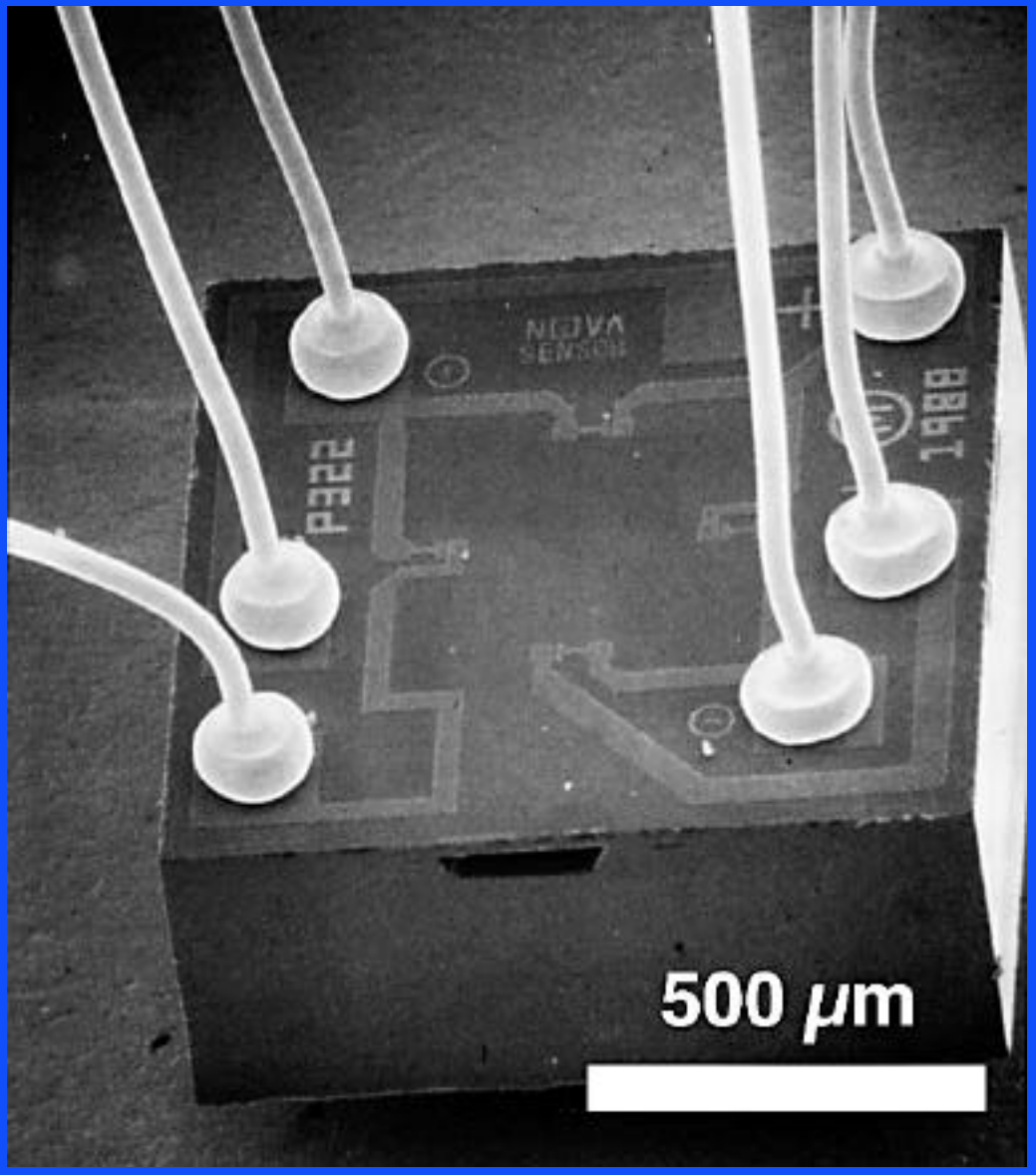


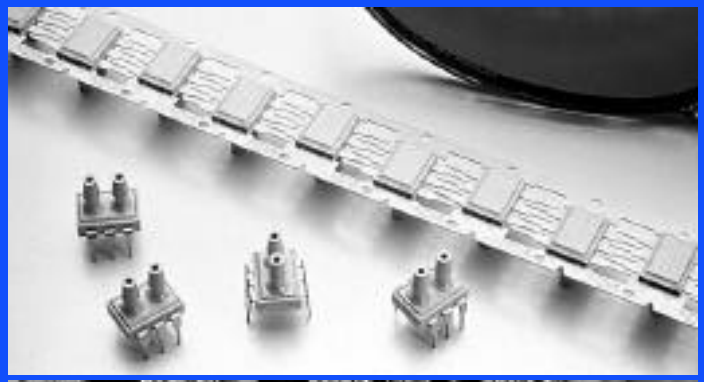


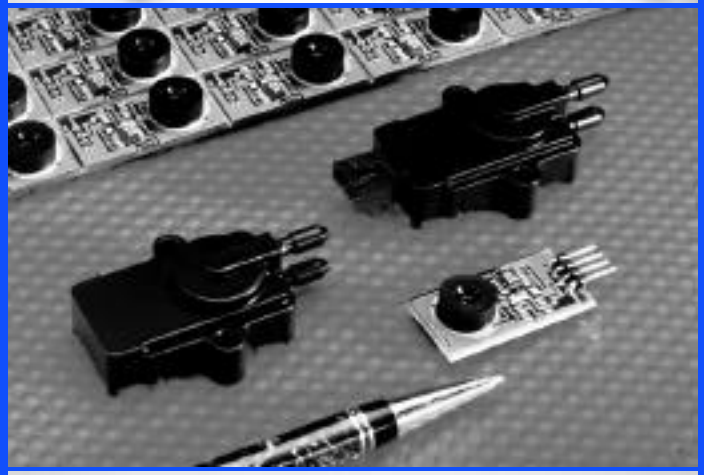
Modern Pressure Sensor



Reference: Bryzek, J., Petersen, K., Mallon, J. R., Christel, L., and Pourahmadi, F., "Silicon Sensors and Microstructures," Lucas NovaSensor, 1055 Mission Court, Fremont, CA, 1991.







Images courtesy of Lucas NovaSensor.

Back Then, We Also Had a Space Station...