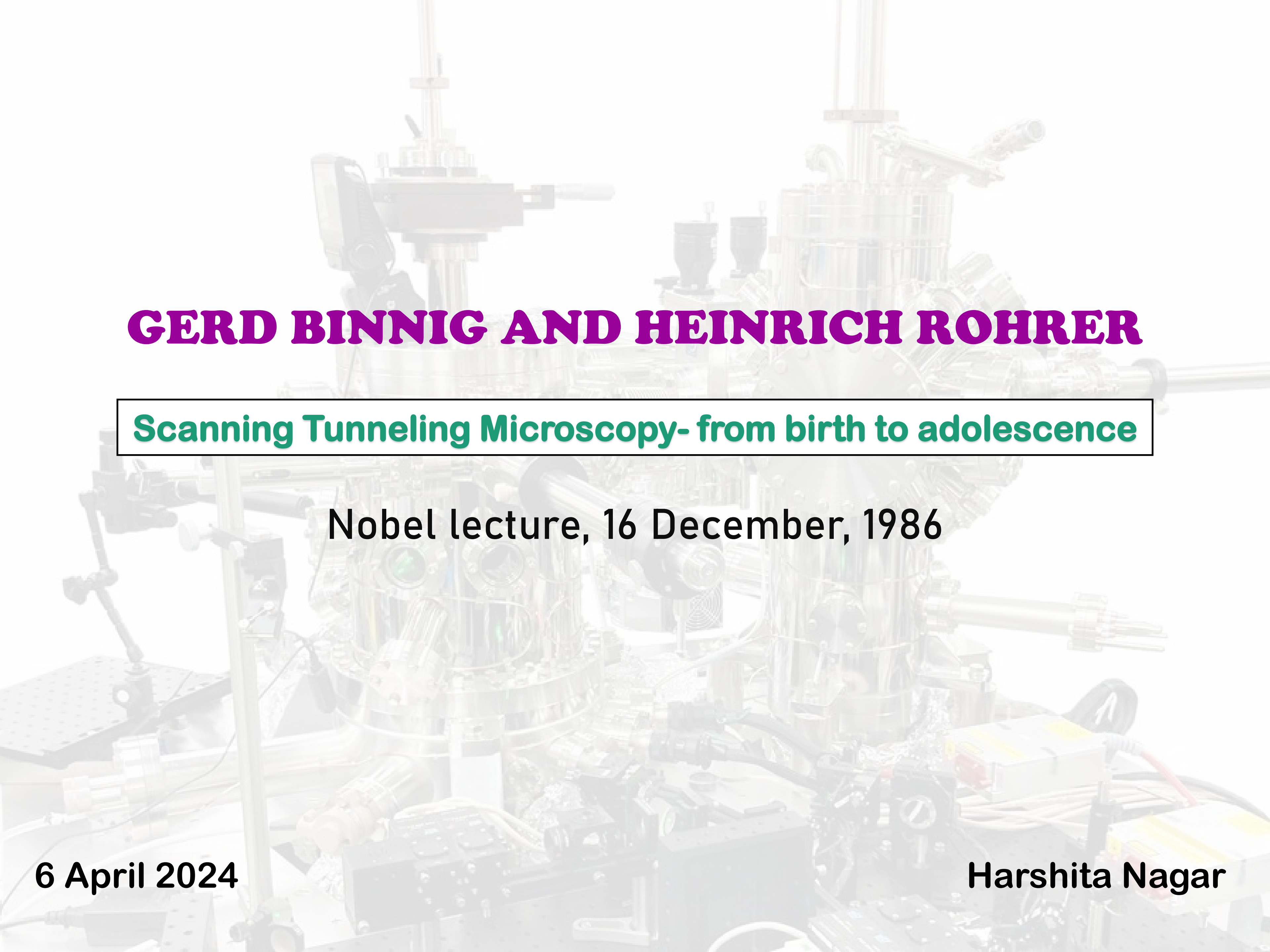


GERD BINNIG AND HEINRICH ROHRER

Scanning Tunneling Microscopy- from birth to adolescence

Nobel lecture, 16 December, 1986

6 April 2024

Harshita Nagar

"After having worked a couple of years in the area of phase transitions and critical phenomena, and many, many years with magnetic fields, I was ready for a change. Tunneling, in one form or another had intrigued me for quite some time. Years back, I had become interested in an idea of John Slonczewski

problems in the fabrication of Josephson junctions. So the local study of growth and electrical properties of thin insulating layers appeared to me an interesting problem, and I was given the opportunity to hire a new research staff member, Gerd Binnig, who found it interesting, too, and accepted the offer. Incidentally,

I had shared this dream with many other scientists, who like myself, were working on tunneling spectroscopy. Strangely enough, none of us had ever

We became very excited about this experimental challenge and the opening up of new possibilities. Astonishingly, it took us a couple of weeks to realize that not only would we have a local spectroscopic probe, but that scanning would deliver spectroscopic and even topographic images, i.e., a new type of microscope. The operating mode mostly resembled that of stylus prolilometry [6],

tunnel current flowing between them. Roughly two years later and shortly before getting our first images, we learned about a paper by R. Young *et al.* [7] where they described a type of field-emission microscope they called "topografiner". It had much in common with our basic principle of operating the STM, except that the tip had to be rather far away from the surface, thus on high voltage producing a field-emission current rather than a tunneling current and resulting in a lateral resolution roughly that of an optical microscope. They suggested to improve the resolution by using sharper field-emission tips, even attempted vacuum tunneling, and discussed some of its exciting prospects in spectroscopy. Had they, even if only in their minds, combined vacuum tunneling with scanning, and estimated that resolution they would probably have ended up with the new concept, Scanning Tunneling Microscopy. They came

During the first few months of our work on the STM, we concentrated on the main instrumental problems and their solutions [8]. How to avoid mechanical vibrations that move tip and sample against each other? Protection against vibrations and acoustical noise by soft suspension of the microscope within a vacuum chamber. How strong are the forces between tip and sample? This seemed to be no problem in most cases. How to move a tip on such a line scale? With piezoelectric material, the link between electronics and mechanics, avoiding friction. The continuous deformation of piezomaterial in the angstrom and subangstrom range was established only later by the tunneling experiments themselves. How to move the sample on a line scale over long distances from

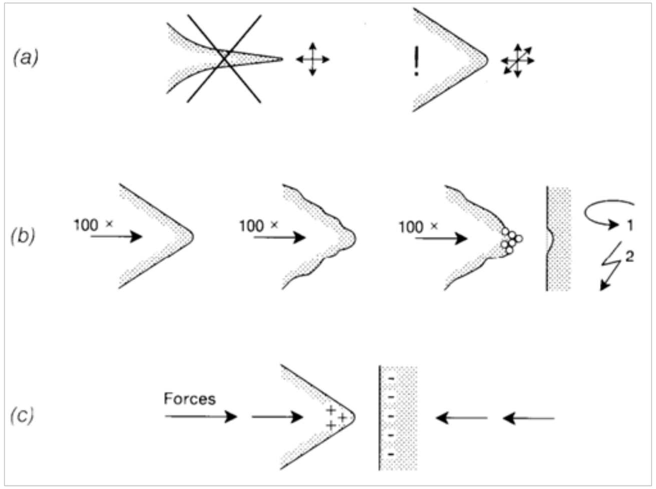


Fig. Tips (a) Long and narrow tips. (b) A mechanically ground or etched tip shows sharp mini tips. (c) Electrostatic and interatomic forces between tip and sample do not deform a blunt tip, or a rigid sample, but they make the tunnel gap mechanically unstable when the tip carries a whisker.

vibration-isolation system within the vacuum chamber. Our first set-up was designed to work at low temperatures and in ultra-high vacuum (UHV). Low

temperatures guaranteed low thermal drifts and low thermal length fluctuations, but we had opted for them mainly because our thoughts were fixed on spectroscopy. And tunneling spectroscopy was a low-temperature domain for both of us with a Ph.D. education in superconductivity. The UHV would allow preparation and retention of well-defined surfaces. The instrument was beautifully designed with sample and tip accessible for surface treatments and superconducting levitation of the tunneling unit for vibration isolation. Construction

Next, we protected the STM from vibrations by a double-stage spring system with eddy-current damping [8], and incorporated it in a UHV chamber not in use at that moment. We added sputtering and annealing for sample treatment, but no other surface tool to characterize and monitor the state of the sample or tip could yet be combined with that STM. Although the superconducting

gap of a superconductor, and later even plotted its spatial dependence. Spectroscopic imaging was not really surprising, yet it was an important development. We now had the tools to fully characterize a surface in terms of topographic and electronic structure. Although it is usually quite an involved

In the following few months, the situation changed drastically. R. Feenstra and coworkers came up first with cleaved GaAs [34], C.F. Quate's group with the 1 X 1 structure on Pt(100) [35], and J. Behm, W. Hoesler, and E. Ritter with the hexagonal phase on Pt(100) [36]. At the American Physical Society March Meeting in 1985, P. Hansma presented STM images of graphite structures of atomic dimensions [37], and when J. Golovchenko unveiled the beautiful results on the various reconstructions of Ge films deposited on Si(111) [38], one could have heard a pin drop in the audience. The atomic resolution was official and scanning tunneling microscopy accepted. The IBM Europe Instiatomic level. Imaging of individual atoms or atomic structures, however, is still reserved for specific problems, expertise, and extraordinary equipment. The appeal and the impact of STM lie not only in the observation of surfaces atom by atom, but also in its widespread applicability, its conceptual and instrumental simplicity and its affordability, all of which have resulted in a relaxed and

Outside the physics and surface-science communities, the various imaging environments and imaging capabilities seem as appealing as atomic resolution. Images obtained at ambient-air pressure were first reported in 1984 [47], followed by imaging in cryogenic liquids [42], under distilled water [48], in saline solutions [48], and in electrolytes [49]. Scanning tunneling potentiometry appears to have become an interesting technique to study the potential distribution on an atomic scale of current-carrying microstructures [50]. More recent advances include interatomic-force imaging with the atomic-force microscope [51], with which the structure and elastic properties of conductors and insulators are obtained, and combined imaging of electronic and elastic properties of soft materials [52]. Also the use of spin polarized electron tunneling to resolve magnetic surface structures is being explored.

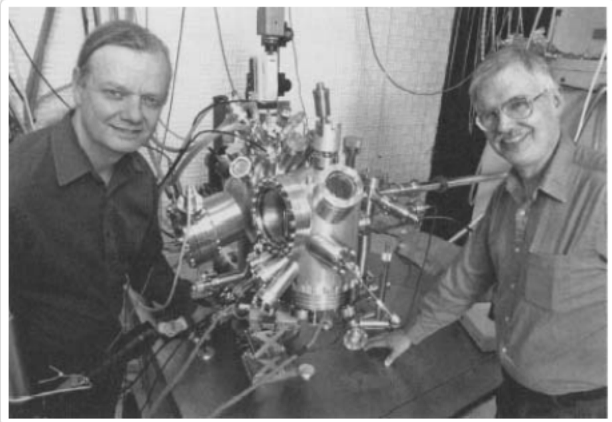
Finally, we revert to the point where the STM originated: The performance of a local experiment, at a preselected position and on a very small spatial scale down to atomic dimensions. Besides imaging, it opens, quite generally, new possibilities for experimenting, whether to study nondestructively or to modify locally: Local high electric fields, extreme current densities, local deformations,

The STM's "Years of Apprenticeship" have come to an end, the fundamentals have been laid, and the "Years of Travel" begin. We should not like to speculate where it will finally lead, but we sincerely trust that the beauty of atomic structures might be an inducement to apply the technique to those problems where it will be of greatest service solely to the benefit of mankind. Alfred Nobel's hope, our hope, everybody's hope.

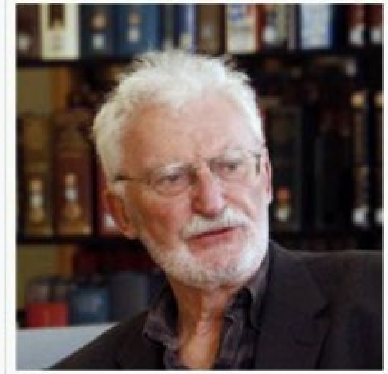
Gerd Binnig

Binnig in 2013

Born	20 July 1947 (age 76) Frankfurt am Main, Allied-occupied Germany
Alma mater	Goethe University Frankfurt
Known for	Scanning tunneling microscope Scanning probe microscopy Atomic force microscope
Awards	Klung Wilhelmy Science Award (1983) EPS Europhysics Prize (1984) King Faisal Prize (1984) Nobel Prize in Physics (1986) The Elliott Cresson Medal (1987) Kavli Prize (2016)
Scientific career	
Fields	Physics
Institutions	IBM Zurich Research Laboratory
Doctoral advisor	Werner Martienssen Eckhardt Hoenig
Doctoral students	Franz Josef Giessibl



Heinrich Rohrer



Heinrich Rohrer in 2008

Born	6 June 1933[1] Buchs, St. Gallen, Switzerland
Died	16 May 2013 (aged 79) Wollerau, Switzerland
Known for	Scanning tunneling microscope[1] Scanning probe microscopy
Awards	EPS Europhysics Prize (1984) King Faisal Prize (1984) Nobel Prize in Physics (1986) Elliott Cresson Medal (1987) Fritz London Memorial Lecture (1992)
Scientific career	
Fields	Physics
Institutions	University of California, Santa Barbara Tohoku University