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NNF National Nanofabrication Facility at Cornell

NEWS & REFERENCE

Craighead becomes director of NNF

Harold G. Craighead of Bell Communications Research became director of the National Nanofabrication Facility (NNF) in January. Professor Craighead has a joint appointment in the Schools of Applied and Engineering Physics and Electrical Engineering.

Craighead intends to maintain the Facility's lead in technologies advancement. "The NNF can play a leadership role in applying the techniques of microfabrication to photonic devices and optoelectronic circuits, growth areas of global importance," Craighead has said.

The appointment was announced by Joseph Ballantyne, Cornell vice president for research and advanced studies, who said that Craighead will be "very effective in collaborating with a wide range of university, industry, and government users."

Craighead holds B.S. and M.S. degrees from the University of Maryland and a Ph.D. from Cornell University. He joined Bell Laboratories in 1979, and moved to Bell Communications Research after its establishment in 1984 as district manager in the Solid State Science and Technology Laboratory.

His research has included studies of the optical properties of gallium arsenide semiconductors and thin films, and work in the areas of high-energy electron-beam lithography, compound semiconductor processing, and electron microscopy.

Edward D. Wolf, director for the past ten years, will continue as a professor in the School of Electrical Engineering and an active researcher at the facility.

We can play a leadership role in applying the techniques of microfabrication to photonic devices and optoelectronic circuits, growth areas of global importance.

Harold G. Craighead

Not another newsletter!

by Greg Galvin,
Deputy Director, NNF

One of the great promises held out by the electronic information age was freedom from the ever growing barrage of paper. Unfortunately the paper barrage has continued unabated and has been supplemented with electronic mail besides. In light of this dismal situation why should NNF provide yet another newsletter to add to the collection of good intentions on your desk? Because you asked for it.

Perhaps the best way to see if someone reads a newsletter is to stop publishing it and see if they notice. The industrial affiliates program of the NNF, formerly known under the acronym PROSUS, sporadically produced a newsletter entitled PROSUS News. The last issue was produced by Professor Peter Krusius in the Spring of 1987. Since that time I have received a number of questions from our affiliates as to what has happened to the newsletter. I guess at least someone out there noticed.

Hence, back by popular demand is the NNF newsletter. To go with our new name is a new identity for the newsletter. One which we hope will be more readily identified with the facility than in the past. The newsletter will be more oriented to news items, research accomplishments, upcoming events, faculty activities, and the like than its predecessor. We do not intend to publish in depth technical articles — there are reports and journals enough for them. We do need your feedback. The only reason for this newsletter is to communicate to you what is taking place at NNF and Cornell. Without your feedback we will not know if the communication is successful. Give me a call or send me a note (physical or electronic mail) and let me know what you'd like to see in the newsletter.

THE BATON IS PASSED

Rapid pace and broad accomplishments seen for the future

by Edward D. Wolf
Professor, Electrical Engineering

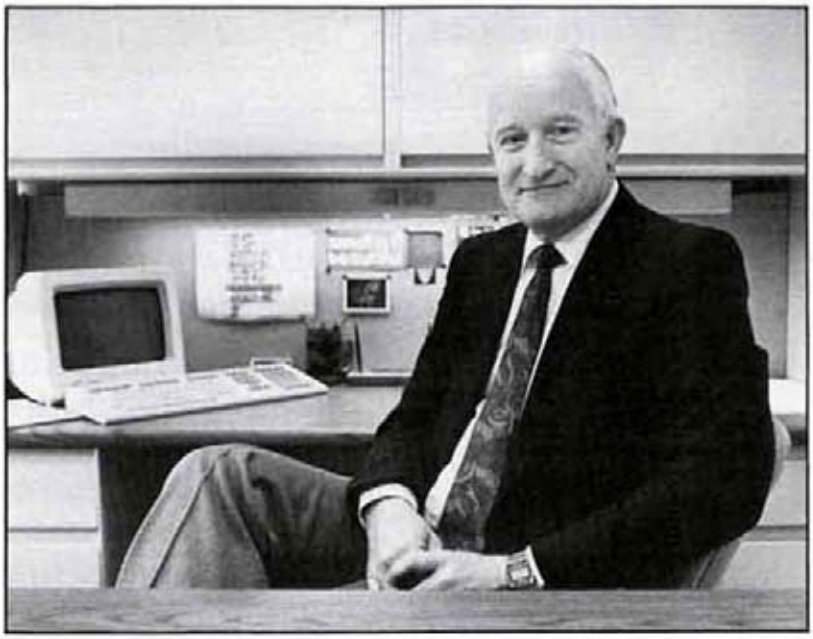
The passing of a baton is both functional and ceremonial. The process permits an assessment of past accomplishments as well as new enthusiasm for things to be. For NNF the course we have mastered and the course yet before us are both exciting. But I favor the things yet to come.

Nanofabrication is just now really beginning to provide broad access to areas of research that only a few years ago would not have been considered. Why? Because studying material and conduction processes at sub-100 nanometer dimensions takes us into a whole new arena of novel material behavior at surfaces and edges, into the quantum mechanical regime in the physical sciences and into the large molecules and cell membrane domain in the biological sciences where the distinction between physical and biological phenomena becomes blurred. NNF provides an integrated research facility in which more than 200 students representing more than a dozen disciplines are proving on a daily basis the broad applications of artificially structured materials in the submicrometer and nanometer regimes.

Present Day

How did we get to our present level of accomplishment? By making the tools and processes for micro and nanofabrication the cornerstone of the facility during the early formative period of the facility; by garnering major industrial support which more than doubled our National Science Foundation support; and by actively stimulating interdisciplinary research.

More recently small groups of faculty have begun to focus on key areas of engineering sciences — the Semiconductor Research Corporation Program on Microscience and Technology at Cornell is one example. Other thrust areas are developing and with stimulus from IBM, a new focus on the university as the desired neutral ground for industrial research collaboration is developing. NNF has taken the lead in the broad definition of a new Strategic Technologies Alliance at Cornell — something you will be hearing more about in the future from Drs. Harold Craighead and Greg Galvin. Speaking of them brings me back to the ceremonial aspects of baton passing.



Ed Wolf, retiring director of the NNF.

The support of our affiliates and the NSF have enabled us to make a significant difference in nanofabrication research and education.

Ed Wolf

Continuity Assured

It is with great pleasure and honor that I am able to pass the NNF baton to Harold while Greg continues as deputy director. Greg not only provides the all-important continuity (i.e., a clean pass is assured!), but carried the NNF baton very successfully during my recent sabbatical leave and brought us through the all-important five-year renewal with NSF. He remains a key leader for NNF. Harold brings the expertise to ensure that the fabrication stays in nanofabrication, but he also has interests and experience in quantum devices and optoelectronics — research areas of rapidly growing importance. So the baton is in strong, young hands. The pace will quicken and the accomplishments widen.

The functional and ceremonial baton has been passed. I look forward to continuing my association with NNF as an active participant in its research programs. I hope that all of you will continue your involvement with the facility. The research accomplishments of our national user community and the support of our industrial affiliates and the National Science Foundation have enabled the NNF to make a significant difference in nanofabrication research and education during the last eleven and one-half years.

Ed Wolf was director of the National Nanofabrication Facility from 1978 through 1988.

Recent Appointments

Jack M. Blakely received the PH.D. in 1963 from the University of Glasgow and joined the faculty that same year. He served as a research fellow at Harvard University and is a fellow of the American Physical Society and the Institute of Physics (United Kingdom). Jack was appointed director of the Department of Materials Science and Engineering, succeeding Arthur L. Ruoff. He is a specialist in surface science and catalysis. Recently a significant fraction of his research has been concerned with subnanometer scale surface structures. His group uses the facility for producing unique grating structures on single crystals. Electron diffractions, x-ray scattering and scanning tunneling microscopy are among the major techniques used in this research group.

Several members of the MSE department rely heavily on the lithography and analytical facilities of the NNF.

Robert A. Buhrman, who joined the faculty in 1973 after receiving his Cornell Ph.D., began a five year term as Director of the School of Applied and Engineering Physics July 1 of last year. He succeeds Watt W. Webb. Buhrman is a specialist in the superconductivity of thin films and lithography in the nanometer regime. He served as associate director of the NNF and is currently chairman of the Executive Committee.

Buhrman and three other faculty members of the school were part of the Cornell faculty team involved in the formation in 1977 of the predecessor of the NNF. Eleven years later the connection between the school and the NNF is even stronger. Over half of the faculty research groups are active users of the facility and depend strongly upon the NNF staff and equipment for critical parts of their research activities. The existence and availability of the NNF to Applied and Engineering Physics graduate and post-doctoral students is a key factor in the school's success in attracting top flight applicants to the graduate program and in the continued success of the involved faculty in obtaining research support in an increasingly competitive environment.

Laser Pulsed Cathodes for Time-Resolved Microscopy

Colin A. Sanford,
Graduate Student, School of Electrical Engineering

Dr. Noel C. MacDonald,
Professor of Electrical Engineering and Director, Cornell/SRC Program for Microscience and Technology

Introduction

High speed (<100 ps) vacuum electron pulses are required for very fast vacuum electronic devices and stroboscopic electron beam metrology applications. Currently under study are the electron optical characteristics of negative electron affinity GaAs surfaces for the purpose of creating intense pulses of electrons. The primary goal is to develop an electron cathode possessing the brightness of a field emission source, the stability of a thermal emitter, and a switching speed of less than 50 ps.

Process Description

The electron emitters are fabricated by etching thin membranes in (100) GaAs substrates which are then activated to a negative electron affinity condition. This condition is met by applying monolayer quantities of Cs_xO_{1-x} to the surface of the GaAs membrane, which causes the conduction band in the bulk to raise above the vacuum level at the surface shown in Figure 1. Prior to cathode activation, the GaAs surface is cleaned both chemically and thermally. Activation of the surface takes place in UHV environment. Once the cathode is activated, laser radiation incident from the backside of the membrane photoexcites electron-hole pairs. The electrons, which are created very near the surface, diffuse toward the surface where they may escape into vacuum because of the negative electron affinity condition which exists there.

The number of emitted electrons is directly proportional to the number created, and hence to the incident laser power. Fast electron pulses can be created by pulsing the laser using mode locking techniques.

Progress to Date

A prototype electron gun employing a negative electron affinity cathode has been constructed and demonstrated. The cathode was found to possess short term stability as evidenced by the ability to record Auger Electron Spectra and SEM images. An effective electron optical brightness of 10^5 A/cm^2–str was measured at the sample with a beam voltage of 3 kV. The brightness can be improved by decreasing the incident laser power. An electron gun is currently being designed which will address many of the issues our prototype gun has shown to be important. It is expected that this electron gun will possess a brightness of approximately 10^7 A/cm^2–str, and be able to provide electron pulses less than 100 ps in duration. This electron system will be able to perform stroboscopic electron beam metrology which may be applied to the measurement of fast voltage waveforms or micromechanical structures.

Acknowledgements

This work has been supported by the Semiconductor Research Corporation via the Cornell Program for Microscience and Technology. The cathode fabrication was performed at the National Nanofabrication Facility. The expert assistance of Lynn Rathbun is gratefully acknowledged.

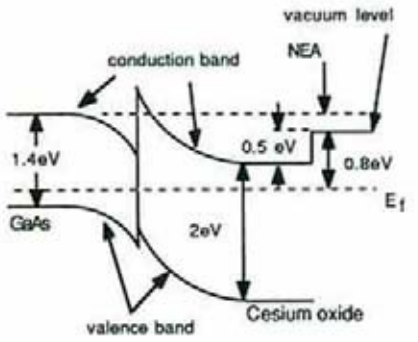


Figure 1.

GaAs/Cs_xO_{1-x} energy band diagram.

Recent Publications

S.R. Stiffler and M.O. Thompson, "Supercooling and nucleation of silicon after laser melting", Phys. Rev. Lett. 60, 2519 (1988).

J.M. Legresy, B. Blanpain and J.W. Mayer, "Solid-state amorphization in Al-Pt thin films", J. Mater. Res. 3, 884 (1988).

L.P. Muray, L.C. Rathbun and E.D. Wolf, "New technique and analysis of accelerated electromigration life testing in multilevel metallizations", Appl. Phys. Lett. 53, 1414 (1988).

T.C. Mele, S.C. Arney, J.P. Krusius and N.C. MacDonald, "Anisotropic reactive ion etching of $MoSi_2$ and In Situ doped n+ and p+ polysilicon using Cl_2 and BCl_3", J. Electrochemical. Soc. 135, 2373 (1988).

E.A. Fitzgerald, P.D. Kirchner, R. Proano, G.D. Pettit, J.M. Woodall and D.G. Ast, "Elimination of interface defects in mismatched epilayers by a reduction in growth area", Appl. Phys. Lett. 52, 1496 (1988).

NNF Offers Summer Short Course

During the week of July 17, 1989 the NNF plans to offer a short course for scientists and engineers working in microfabrication. The Cornell graduates that work in the facility obtain a unique preparation due to their "hands-on" experience with the instruments. In a brief way the proposed course will do the same for twenty-five participants. Lectures on the related theory will be given by Cornell faculty. The facility staff will instruct and assist each participant in the use of several facility instruments.

For further information call Joe Edminister at (607) 255-8972.

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