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1 Education

Thesis Research

Scanning tunneling microscopy, 1987 to 1990.
Degree received, Ph.D. in Physics from Purdue in August, 1990.
Thesis topic, application of STM to the study of organic polymer structures at length scales above 100 Å.

Graduate Course Work

Graduate courses in physics at Purdue 1972-1975.
Degree earned, M.S. in Physics at Purdue in 1975.
Area of specialization, Condensed Matter Physics.
Additional course work includes, one year of graduate study in Physics at Michigan State in 1971-1972. Also, graduate level courses outside of the physics core include nuclear physics, plasma physics, electronics, computer science, and biology.

Undergraduate Study

Undergraduate study at Purdue.
Degree earned, B.S. in Physics and Mathematics in 1971.
The area of specialization in Mathematics was numerical analysis.
Undergraduate studies included four semesters of chemistry, four semesters of German, and eight semesters of Spanish.

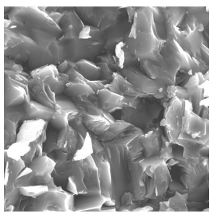

Figure 1: SEM image selected for Kaleidoscope. **Kaleidoscope**: Phys. Rev. B 95, 144310 (2017)

2 Brief Research Highlights

This section brings to focus highlights in research. The total number of papers citing work with my name is now over 40,000. I will point out here a few of the more cited papers and the role I played in the research. I will group the work into four broad categories, reactors, graphene, graphene oxide (GO) and scanning techiques.

The work in reactor design started with a simple goal. Natural carbon (^{12}C) has 0 spin, therefore no NMR. The Ruoff group had been working with graphene oxide (GO) for some time, and Dr. Ruoff wanted to determine the chemical structure by NMR. Weiwei Cai and I set about designing a reactor that could grow graphite from very hot nickel with ^{13}C methane as the carbon source. This graphite was then used to produce GO that does have an NMR signal[1]. The reactor was built in a vacuum chamber and the nickel foil was heated resistively. The experience with this reactor informed the design of the second system which used magnetic induction to heat the metal. Since the coils are outside the reactor, there are no connections inside the reactor. This system was constructed with a grant from the W. M. Keck foundation. This work has lead to two new papers just published[2, 3]. A third, much larger reactor is currently being constructed, and it is anticipated more publications will follow in 2014.

Work on synthetic graphite lead naturally to the synthesis of graphene. It turned into a small cottage industry in the Ruoff group. The most highly cited paper from our group in this area was published in Science[4]. Most of our graphene production has been done in conventional CVD hot wall reactors, until recently. My main role in the graphene effort has concentrated on the analytical tools we have in our group, ie. SEM, Raman, AFM/STM. Of course, I spent much time with our post-docs and students discussing the experiments and making suggestions. It has been a large effort with many people involved. Several other papers of note are [5, 6, 7, 8].

As mentioned above, work on GO led us to graphene research. The Ruoff group is still working with GO. Our most highly cited papers in this field are [9, 10, 11]. This work came out of an effort to exfoliate graphite in solution. It turned out to be impossible. Sasha Stankovich had the idea to convert graphite to GO and then exfoliate that material to get sheets one atom thick. My primary role was to measure the results via AFM. The AFM data was critical to prove that exfoliation was complete. As is often the case, there was feedback between chemistry and measurement of the result.

Finally, we come to scanning point probes (SPM). My first experience with nano-lithography came during my graduate studies[12]. My role here was developing the computer system to control all the STMs in our lab[13]. I also devised the method to create the pattern ($\hbar$) and then read it. Much later, while working in Chad Mirkin's lab at Northwestern, I invented dip-pen nano-lithography (DPN) [14]. This was my most cited paper for quite some time. I have continued working with point probes to date. Given that most of what we work on, graphene and GO, are two dimensional materials, AFM is a critical method to analyze, in great detail, the results of our synthesis efforts.

3 Top Skills

This is a brief list of skills. The goal is to give a simple list. Many more details are in the long narrative at the end.

1. Teaching: Teaching has been an important part of everything else I have done. I have done this in all context, class room, teaching labs, and thesis student mentoring.
2. SPM: STM and AFM. Familiar with all modes of operation. Invented a number of tricks to get much better results on challenging samples. Invented dip-pen nanolithography (DPN).
3. Optics: A lot of experience with lasers, spectrometers, imaging systems.
4. Computer technology: Numerical methods, programming, servers, cloud computing, server manager.
5. Other analytical instrumentation: SEM, EBSD, EDS, scanning Raman, optical profilometry, TOF-SIMS.
6. Electronics: Low level signal processing, amplifiers, power, computer interfacing.
7. Vacuum systems: pumps, chambers, measurement, UHV.
8. Surface chemistry: Sample preparation for AFM and other methods. CVD, RF induction, graphene growth.
9. Nuclear physics & accelerators: Linear, and cyclotron. Nuclear physics measurements, radiation safety.

4 Employment History

Details of my work experience and areas of technical expertise are listed in the final section.

Texas Materials Institute (TMI) Characterization Lab, 2014-present

With the end of the Ruoff group, established the TMI Characterization Lab using all of the equipment that had belonged to Professor Ruoff. In addition to maintaining the instruments in the lab, I consult and advise users on best practices both of using the instruments, analyzing results and sample preparation.

Research Group Leader. University of Texas at Austin, ME Dept., 2007-2014

Continuing work of previous position with increased leadership role. Moved with Rod Ruoff from Northwestern to UT in Fall 2007. In addition to mastering new instruments, scanning micro-Raman, SEM/EDS/EBSD and optical profilometry, I contributed to the design of several reactors, most notably a system centered on magnetic induction heating to grow graphene and synthetic graphite[2]. Also increased involvement in grant proposal writing. This resulted in a generous grant from the W. M. Keck Foundation for the construction of the RF reactor. Created servers running MS cloud server and UNIX web and file server.

Senior Research Associate, Northwestern University M.E. Dept., 2000-2007

Moved with Professor Ruoff from Washington University to Northwestern. Set up the new laboratory including both new equipment and moving equipment brought from Washington Univ. Involed in all aspects of the operation, including, advising grad students,writing proposals, managing computing infrastructure including web and file servers.

Research Associate, Washington University Phyisics Dept., 1998-2000

Continuing AFM work started at Northwestern in Chad Mirkin's group. Application of many scanning point probe methods to novel carbon materials and nano structured materials. The Ruoff group moved from Washington Univ. to Northwestern (Fall 2000).

Research Associate, Northwestern University 1995-1998

Research in Chemistry and surface science. Many different kinds of scanning point probe techniques used to study diverse material surfaces; polymers, liquid crystals, high Tc super-conductors, nano-particles, thin films and mono-layers. Invented DPN.

Research Associate, Temple University 1993-1995

Research associate in Electrical Engineering. Built new STM, supervised graduate students, taught graduate and undergraduate courses.

Visiting Faculty 1992-1993

Visiting faculty in Physics Department, Appalachian State University. Taught several physics courses, complete list in last sectiont.

Consultant, Optics Lab 1991-1992

Improvements in optics lab, including new real-time, multitasking, multiuser computer system.

GRA, Thesis Research 1987-1990

Designed and built a scanning tunneling microscope. Used this instrument to study nano-structures.

Instructor, Optics Lab 1976-1986

Upper division physics laboratory course. Taught one lab section, supervised teaching assistants and set up lab equipment. Also maintained lab equipment, designed and built new lab equipment.

GTA, Lower Division Courses 1973-1975

Taught both laboratory and recitation courses. Several different courses were taught with students from outside physics. The students included majors in such diverse fields as engineering, technology and biology.

Michigan State University Cyclotron 1971-1972

Worked as an employee of the lab. Involved in many of the technical aspects of the lab's operation.

Purdue Tandem Van de Graaff 1970-1971

Worked for one year as an operator of the accelerator. Also involved in maintenance work.

5 Graduate Student Mentoring

I have mentored at least twenty graduate students over the past 15 years. I include here a short list of some of the more outstanding students.

Dr. Ming Feng Yu, Washington University, 1998-2000, now Professor in Aerospace Engineering, Georgia Tech Univ.

Dr. Ting Terry Xu, 2000-2004, Northwestern Univ., now Assoc. Professor in Mechanical Engineering and Engineering Science, UNC Charlotte.

Dr. Weiwei Cai, 2008-2011, Both Northwestern and UT at Austin, grad-student then Post-doc. Now Professor, Department of Physics, Xiamen University, China.

Dr. ShanShan Chen, 2010-2013, grad-student and Post-doc, University of Texas at Austin, Now Associate Professor, Department of Physics, Xiamen University, China

Dr. Ji Won Suk, 2007-2013, University of Texas at Austin, grad-student then post-doc, now beginning Assistant Professor at School of Mechanical Engineering, Sungkyunkwan University spring 2014.

Carl Magnuson, 2009-2013, University of Texas at Austin, Graduated May 2014.

6 Future Research Interest

A successful research program requires both a set of good ideas and the flexibility to adapt to opportunities for collaboration. The development of scanning point probes has opened many new opportunities for research. This class of instruments includes scanning tunneling microscopes (STM), scanning force microscopes (SFM), scanning magnetic probes and scanning optical probes. These instruments have been used to explore topics as diverse as semiconductor surface physics to mapping the surface of living cells.

I am interested in both the development of new instruments and their application to problems in physics and surface science. There are a number of problems in condensed matter physics and materials science which I would like to explore. I would also like to develop collaborations with other scientist both locally and externally. Industrial collaborations can lead to sources of external funding as well. My experience is designing STMs will allow me to develop specialized instruments to meet the needs of others.

To be a little more specific, our work in testing the mechanical properties of nanotubes can be expanded with new MEMS devices which would fit inside an AFM. Further, measurement of electrical properties of nanotubes by STM, EFM, and conducting AFM is a potentially rich area for new research that is still largely unexplored. The nano-sized world is now expanding into 2-dimensional materials such as graphene and h-BN, topological insulators, and layered materials. A second area with great potential is the use of dip pen nano-lithography (DPN). While the lithography method itself is new and a subject of further research, this technique has the potential to be used as a guide for the further assembly of other nano-devices. For example, attachment points for functionalized nano-tubes can be precisely created in specific locations via DPN.

Setup of these instruments requires no special facilities beyond normal lab space and a very quiet floor. Cost is quite modest by modern standards. Probably the best approach to startup, is to purchase a small commercial instrument which can be used to generate results and publications quickly. Building on this, the first instrument can be added to, and new devices and experiments developed over time. The simplicity of the basic concept and the wide range of problems that can be investigated with a scanning probe instrument make it a good field for undergraduate as well as graduate student work.

In addition to surface physics instrumentation, I have gained considerable experience in synthesis of 2 dimensional materials. Graphene, h-Bn, and so on. One of the short falls in many group's efforts in this field is that they do not understand how critical purity is in the process. Using my experience in surface physics to design better reactor systems and eliminate defects can be a very productive research area. I believe that the performance of devices made from these materials can be greatly improved by careful control of not just reactor conditions, but the elimination of contaminates in the reactants.

To summarize, I wish to continue to work in the area of scanning probes, surface science and 2-D materials. But to be flexible and far ranging in their application to a broad range of problems.

7 Teaching Philosophy

It is difficult to outline one's teaching philosophy. However, I will attempt to do so by saying that I believe in treating students as adults. I can teach them, but I can't do the learning for them. Beyond that, I make every effort to inform the students of exactly what is required of them and to grade their efforts in the most objective way possible. I am eager to answer questions outside of class, but I also expect the students to work hard. I have learned by experience that students tend to live up to expectations, so I expect a lot of them.

In addition, I place a high value on teaching labs. I feel that hands-on experience in the lab is important in teaching physical science. If nothing else, it teaches students that physics is more than just a bunch of equations. Those equations really are related to the world around us. Labs also offer the opportunity for direct interaction between teacher and student. I find this very useful and rewarding.

Diversity Diversity of the student body is of great importance. The value goes beyond just giving an educational opportunity to an individual which otherwise might not get the chance to shine. Students gain from meeting others from very different life experiences, who, none the less, share a passion for physics. Physics always has been an international science. Bringing in as many people from different backgrounds as we can, broadens everyone's perspective. Not only do the students benefit from meeting many different people, but physics itself is improved. Non-traditional students often feel, "I don't belong here" when they arrive at a university. We need to recognize the students feelings and let them know, "Yes, you do belong here." I find that getting to know the students well enough that they can share their feelings, is very helpful for my ability to mentor and encourage all students. I may be a little more sensitive than some, since I was a first generation college student. I must admit to feeling a little lost in the beginning. Finally, never assume anything about a student. Talk to them, then advise.

8 References

The following is a list of references.

Former graduate student:
Associate Professor Dr. Terry T. Xu
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My thesis adviser:
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Post-doc supervisor at Temple University:
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At University of Texas my supervisor:
Prof. Rodney Ruoff
Prof. Ruoff has relocated to a new position in the Republic of Korea. Please note the information below.

Rodney S. Ruoff
Director, Center for Multidimensional Carbon Materials
(Institute of Basic Sciences Center located at the UNIST Campus)
UNIST Distinguished Professor
Department of Chemistry and School of Materials Science
Ulsan National Institute of Science and Technology
http://cmcm.ibs.re.kr/html/cmcm_en/
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Publications: (> 40000 citations)

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9 Projects Funded

This section gives a brief list of funded projects in which I have played a key role. These are not the only projects, but the five most recent. Listed are, Title, Funding Agency, Duration, Amount, and my role.

Large-Area Graphene/Ultrathin-Graphite Films and Foils
W.M. Keck Foundation
3 years, 1 million dollars
This proposal covered efforts to scale up graphene production to larger dimensions. It was centered on use of magnetic induction heating. These experiments were devised by myself, and Dr. Hifeng Li, and Prof. Ruoff. I designed the reactor and many of the experiments.
Graphene membranes as micro- and nano- pressure sensors
Advanced Energy Consortium (AEC), an industry funded group
On going, will probably end this year after 4 years, total funding for our group of 250,000 dollars.
I was involved in concept development and worked with our student and then post-doc JiWon Suk on our parts of this effort which involved mounting graphene membranes on MEMs holes to be used as pressure sensors.
Synthesis and Detailed Chemical Structure of Isotopically Enriched Graphite Oxide, Reduce Graphene Oxides, and Chemically Modified Graphenes
NSF : grant No. DMR 1206986
3 years: 437,000 dollars
I worked with 2 post-docs and Prof. Ruoff to write and re-write this proposal. The goal is to use carbon 13 isotope to produce synthetic graphite. This is then used to make graphene oxide and chemical derivatives. The chemical structure can then be learned from solid state NMR. My main role is designing cold wall reactors to grow the graphite.
Mechanical Characterization of Atomically Thin Membranes
NSF: grant No. CMMI 0969106
3 years, 428,000 dollars
Worked with student and post-doc JiWon Suk on this proposal. Together, we designed experiments using both AFM and optical profilometry to measure the bending of thin membranes under load. This included graphene.
Collaborative Research: Synthesis and Characterization of Single-layer Graphene Films with Large Lateral Dimensions
NSF grant No. DMR 1006350
3 years, 265,000 dollars
My responsibility here was providing advise in the area of growth of graphene. I also was deeply involved in the characterization of the graphene produced, via SEM, Raman, and AFM.

10 Patents

All patents listed here are related to Dip Pen Nano-lithography (DPN).

Patent No.	Title	App. Date	Issue Date
8,247,032	Methods utilizing scanning probe microscope tips and products therefor or produced thereby	2007-10-31	2012-08-21
8,187,673	Methods utilizing scanning probe microscope tips and products thereof or produced thereby.	2007-10-31	2012-05-29
8,163,345	Methods utilizing scanning probe microscope tips and products therefor or produced thereby	2009-07-31	2012-04-24
7,569,252	Methods utilizing scanning probe microscope tips and products therefor or produced thereby	2003-06-02	2009-08-04
7,524,534	Methods utilizing scanning probe microscope tips and products therefor or produced thereby	2004-09-10	2009-04-28
7,446,324	Methods utilizing scanning probe microscope tips and products thereof or produced thereby	2004-09-28	2008-11-04
6,827,979	Methods utilizing scanning probe microscope tips and products therefor or produced thereby	2001-05-24	2004-12-07
6,635,311	Methods utilizing scanning probe microscope tips and products therefor or products thereby	2000-01-05	2003-10-21

11 Details of work experience

Manager, TMI Characterization Lab With the end of the Ruoff group, the TMI Characterization Lab was established using all of the equipment that had belonged to Professor Ruoff. In addition to maintaining the instruments in the lab, I consult and advise users on best practices both of using the instruments, analyzing results and sample preparation. Faced with a room full of equipment left behind by Ruoff when he left for Korea, the university decided to transfer ownership to TMI and to use it to establish a new user facility. I was hired to be the first manager of this new facility. Further details of the equipment is described below.

Research Group Leader, University of Texas at Austin The Ruoff group moved from Northwestern to University of Texas in the fall of 2007. In addition to continued research outlined below, we have a new FEI Quanta E-SEM with both EDS and EBSD detectors from Oxford. We also have a Witec Alpha 300 scanning micro-Raman spectrometer and a optical profilometer from Vecco (now Bruker). I am responsible for these instruments as well as our 3 AFMs. I am familiar with the operation and sometimes the repair of all of these instruments. While here at UT, I have also been involved in the design and construction of several CVD reactors. The most notable of these is a reactor which uses RF magnetic field induction to heat the substrate. The details of this design are in ACS Nano,**7**, 7495(2013), (see Publications [2]). Transport measurements from the graphene produced by this novel technique have been published in APL,**103**,183115 (2013) (see Publications [3]). We are now testing a new RF heated reactor which has a much different design and is an order of magnitude larger scale than our first system. From these two systems, I have learned a great deal about inductive heating, both what works well and what doesn't. Results from the first reactor are shown in the figure 2 at the end of this section.

Senior Research Associate, Northwestern University The Ruoff group moved from Washington to Northwestern University in 2000. I played a key role in planning the move and setting up new lab space at Northwestern. During our tenure at Northwestern, our group moved into new areas of materials development. We worked on carbon fibers, and nano-graphenes of various types. Most notable was the move into graphene oxide (GO) and materials derived from GO. We added a FEI FEG SEM to our major instrument set and I learned some of the finer points of scanning electron microscopes.

During my tenure in the Ruoff group, I have played a key role as senior researcher. Duties include advising graduate students, maintaining computer infrastructure, managing file and web server, writing proposals and generating new ideas for all of group research efforts.

Research Associate, Washington University Joined Rod Ruoff's group in 1998. Application of many scanning point-probe methods to novel carbon materials and nano-particles. Research is to better understand the physics and chemistry of novel carbon materials. This mostly involves the manipulation and modification of fullerine tubes and graphene sheets. Work also involves novel nano-particles called designed particles.

Research Associate, Northwestern University Research position in the Chemistry Department in Chad Mirkin's group. Research involves atomic force microscope (AFM) studies of the interface between polymer surfaces and liquid crystals. This includes lateral force measurements. Other research studies include self assembled mono-layers on metal surfaces, nano-particles assembled with DNA molecules and surface modification of high temperature super-conducting materials. We have expanded our scanning point probe instrument to make many different kinds of measurement, these include, STM, AFM, LFM, FMM, and EFM. I have gained experience in new techniques such as electrostatic force microscopy and learned a lot of chemistry as well. Also learned how to use AFM to write lines of self-assembled mono-layers on gold surfaces (DPN).

Research Associate, Temple University Position was research associate in the Electrical Engineering Department at Temple University. Research involved STM studies of silicon field emitter arrays, other nano-structures, and tunneling physics. I constructed a new UHV Scanning Tunneling Microscope. This new instrument was used to explore the physics of laser radiation in the tunnel gap. I also supervised several graduate students in our lab. As for teaching, I taught a junior level course in Electricity and Magnetism. I also taught a graduate level core course on solid state device physics. I have now taught physics at all levels, from introductory courses for non-majors, to graduate level.

Visiting Faculty Appalachian State University Courses I taught include lower division lab courses, vector calculus for physics majors, a senior level optics lab course and work with senor physics majors in a special lab project class. The optics course includes a lab also. While there, I added several new improvements in the optics lab equipment. In addition, I worked with Dr. P. Allen on a couple of small research projects with her Atomic Force Microscope (AFM).

Optics Between completion of my thesis and moving to Appalachian State, I returned to work on the optics lab at Purdue to work as consultant. My primary task was to implement a new computer system for the lab. The new system is a real-time, multiuser, multitasking system. The system is also a full internet node, allowing remote logins and FTP access via the network. Students may analyze or down load data from anywhere on the net, even while real-time data acquisition is going on during class.

Thesis Work In 1986, I left the position as instructor of the optics lab, to pursue a Ph.D. under Professor Reifenberger. My thesis required the design and construction of a temperature compensated scanning tunneling microscope (STM). The design is based on a piezoelectric tube. The mechanical design of the scanning unit is not a copy of previous designs. The STM is run by a special computer system which I integrated myself. The unique aspect of the computer is its high speed. This system is used to directly control tunnel barrier width thus eliminating the usual analog feedback control. I have learned about computer digital control systems from this project. The materials studied with this instrument have been organic polymer structures, such as films and single crystals. From this work I learned about the use and limitations of the STM in the study of nano-structures. We did a number of other studies. These include, optical storage media and compact disk, optical diffraction gratings, metal clusters, films grown of metal clusters, evaporated metal films and sputtered metal films. During the course of the work, our group had done a great deal of collaboration with engineers and scientists from outside our lab.

Optics From 1976 to 1986 I taught an upper division physics lab in optics. I began teaching this course as a GTA, however this quickly evolved into an instructor level position. The course material covered almost all of optics from lenses to holograms. I was responsible for almost all aspects of the course. During this time, I rewrote all of the course materials. I improved both the equipment and techniques for every experiment. I designed new interferometers, which are scanned with piezoelectric stacks. I also designed new scanning light detectors, new lasers, and many other small items. A high quality holography experiment was developed. In addition, computers were introduced to the lab. I developed a microcomputer system which could take student data from several experiments simultaneously. The data was transferred to a mainframe for analysis after class. This allowed computer analysis of data from experiments such as normalized transmission curves for optical filters or Fourier transform optics. Some of the concepts learned by teaching this course were invaluable in the design of the STM used in my thesis research.

While teaching optics, I became familiar with many techniques, methods, and instruments in the field. Here is a partial list: stops and illumination in optical lens systems, Schlieren optics, Foucault testing, Moire fringes. interferometers, Michelson, Fabry-Perot, and Mach-Zehnder. Dispersive instruments, prisms and gratings, spectrometers, transmission spectra. Interference and diffraction, in one and two dimensions, Fresnel diffraction, Fraunhofer diffraction, zone plates, and Fresnel lenses. periodic objects and Fourier optics. polarization, linear polarization as a function of reflection and refraction, circular polarization, double refraction and optical activity. In addition to the many areas of optics mentioned above, my optics experience includes use of large ion lasers operating in both the visible and UV region, and fiber optics.

Accelerators During my year as a graduate student at Michigan State, I worked as a technician at the cyclotron lab. During my stay there, the cyclotron underwent a complete overhaul. I was part of the team that took the machine apart. Dissection of a cyclotron is a very educational experience. I learned the inside workings of the accelerator. I was even between the pole faces to clean and inspect them. The other big project I was involved with while there was the reassembly of a small cyclotron that was Navy surplus. Other tasks I performed at the lab included scanning plates from the mass spectrometer and designing and building a target cooling system. While I was at MSU, I learned a great deal about laboratory techniques. I also learned about vacuum systems, machine tools, and electronics.

During my senior year at Purdue, I was an operator at the Tandem Van de Graaff lab. From this I got very good experience in tuning ion beam machines. In addition to running the accelerator, I was involved in the major maintenance work done there. From this, I learned about the inner workings of Van de Graaff accelerators.

Other areas of experience I have done a great deal of programming on systems of all sizes. I have worked on the CDC 6000 series machines at PUCC. I have done work on Z80 based microcomputers. I have also done programming on several different systems under the UNIX OS. These include, VAX 750, ISI (68000/VME), and PDP 11/44. In addition, my work on the STM was on a VME based system under OS9/68000. I am currently working on a 80386 machine running OS9000 and MS-DOS 4.0. Both OS9/68000 and OS9000 are multi-user, multi-tasking real time operating systems.

The types of languages that I have used are FORTRAN, Pascal, C, BASIC, and assembly. The machines that I have programmed in assembly are the CDC 6000 series, Z-80, Motorola 680x0, and PDP 11/44. I have a lot of experience in FORTRAN since it is the language most often used for numerical work and physics.

Most of my experience is in two broad categories of computing tasks. The first is real time data acquisition and control. The STM was controlled by software that I wrote. I also wrote data acquisition software for a Z-80 based system used in a teaching lab, Physics 350 and Physics 450. The software ran in real time and was multiuser. This required a lot of embedded assembly code since the operating system did not support this. I also did some work at the device driver level in assembly on both of these systems.

The second broad category is numerical analysis. I have taken two courses in numerical methods at Purdue. Over the years I have used numerical methods to solve many different physics problems. These range from numerical integration of Fresnel integrals for the Fresnel diffraction problem in optics, to calculation of tip-sample convolution for the STM work.

A third area that I have some familiarity with is computer graphics. This ranges from simple plotting routines to 3D graphics to imaging done on the STM. We wrote all of the image rendering software for our STM systems.

Since joining the Ruoff group, I have been responsible for group servers. While at Washington and Northwestern University, these were UNIX based web and file servers. When we moved to the University of Texas, I created a MS based cloud server. This allowed us to centralize computing software. Copies of software for all of our instruments were placed on this cloud. This allowed users to upload data to the cloud for later analysis. Analysis software could be run from anywhere with a internet connection. This also allowed shared files when creating papers, proposals, or presentations.

And finally, I have some experience with ultra high vacuum techniques, including ion pumps. I also have some experience with large electromagnets and microwave equipment.

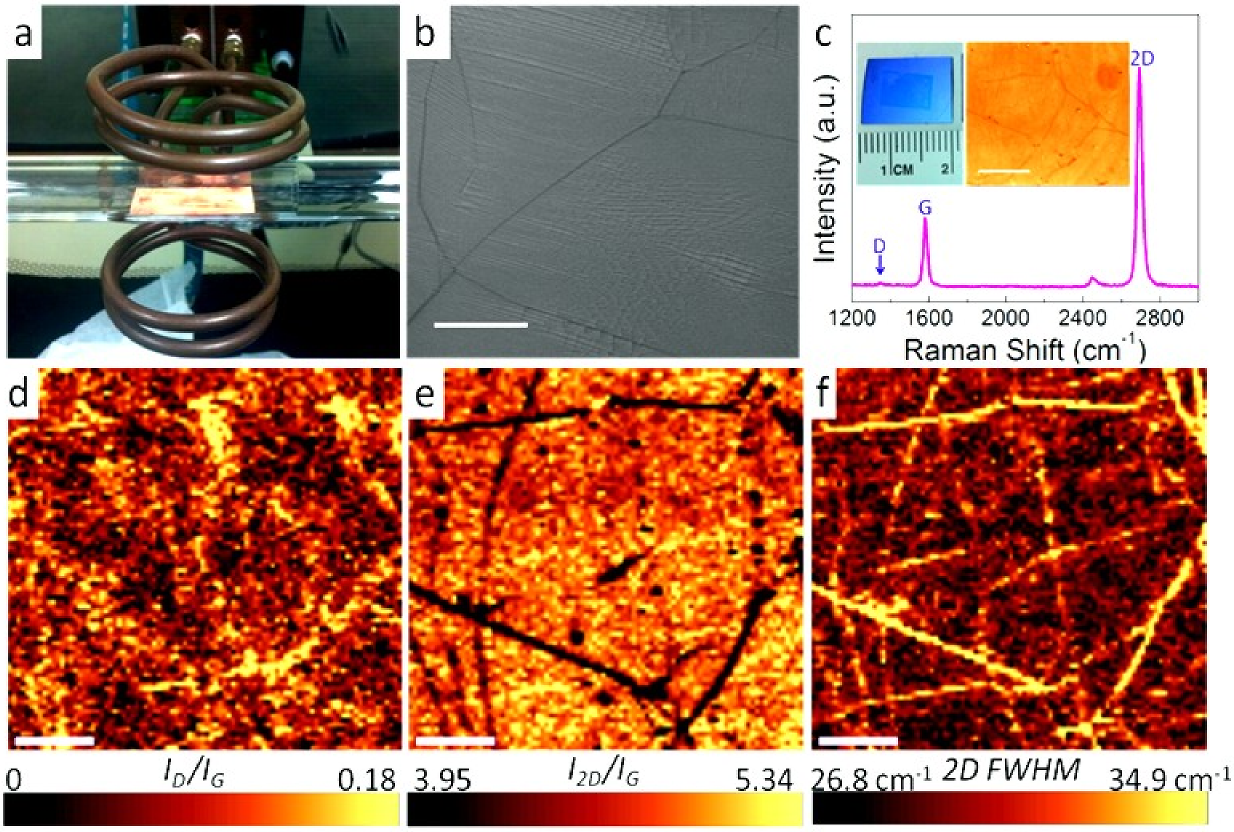

Figure 2: Figure taken from ACS Nano paper [2]. This figure shows results of using RF heating to generate graphene. Photograph, SEM and Raman Characterization of RF graphene growth. (a) Photograph of a heated copper foil and RF coil. (b) SEM image of as-grown monolayer graphene on copper foil substrate, showing copper steps and graphene wrinkles. Scale bar is 3 μm. (c) Raman spectrum, G peak at 1582 cm^{-1}, 2D band at 2695 cm^{-1} (bandwidth 30 cm^{-1}). Inserts are photograph and optical microscopic image (scale bar is 20 μm) of transferred graphene on a SiO_2/Si substrate with 285 nm thick thermal oxide layer. (d-f) Raman mapping of transferred graphene film. (d) The intensity ratio of D band (region from 1300 to 1400 cm^{-1}) to G band (1540 to 1640 cm^{-1}), ID/IG. (e) The intensity ratio of 2D band (2600 to 2800 cm^{-1}) to the G band, I2D/IG. (f) FWHM of the 2D band. Dark lines in (e) and bright lines in (f) are from wrinkles. Scale bars are 6 μm.