OSA Centennial Snapshots

Global Conflict, Thin Films, and Mary Banning

SARAH MICHAUD AND STEWART WILLS

The brief career of a talented, hands-on optical physicist has much to say about the status of optics, and of women scientists, at midcentury.

(Facing page) Mary Banning operates the knife switches powering one of the evaporators at the Institute of Optics, circa 1944. Mary Banning Friedlander/Opt. News **13**(6), 10 (1987).

The year was 1941, and Brian O'Brien, the director of the Institute of Optics at the University of Rochester, N.Y. (USA), faced a dilemma. With World War II entering its third year—and with the United States, though not yet involved in the war, tilting noticeably toward the Allied side—the Institute was increasingly involved in optical research for the U.S. military. Yet the military draft, which had resumed a year earlier, was already putting pressure on the supply of young men, a situation that would only worsen when the United States entered the war. Where could O'Brien find the right staff to keep the wartime optics research effort afloat?

Part of the answer showed up on the Institute's doorstep in summer 1941, in the person of Mary Margaret Banning, a recently minted Ph.D. from Johns Hopkins University. A talented, hands-on optical physicist who, as a woman, was immune from military conscription, Banning would, in the ensuing war years, establish the Institute's first thin-films research lab and help solve problems ranging from the design of multilayer filters to the practical details of anti-glare goggles and night landings of military aircraft.

Recollections from several sources suggest that Banning brought an unusual combination of natural leadership and hands-on enthusiasm to the lab.

This month, with the help of two of her surviving relatives, OPN takes a brief look at the late Mary Banning's career and life before, during and after World War II. It's a story that says much about the priorities of optical science during history's greatest conflict. It also casts light on the challenges confronting talented women scientists at midcentury in the face of social norms and competing family demands—challenges that, in some ways, the community still struggles with today.

Role models

From the beginning, Mary Banning was an unconventional woman, with unconventional roots. She grew up in Duluth, Minnesota, USA, the daughter of Margaret Culkin Banning, a well-known author and early advocate for women's rights. Margaret was an outspoken woman; a Catholic who openly discussed birth control and her divorce within the Catholic Church.

Mary's son Gardner LeRoy Friedlander Jr. says that Margaret taught his mother that "you didn't necessarily have to take what's handed down to you from above; you should think about things and have your own opinions." And, with Mary's father out of the picture early on in the wake of Margaret's divorce, Margaret became Mary's sole parental role model. "Her mother," says Friedlander, "had a great deal of influence on her in terms of her thoughts on the place of women in the world."

In view of Margaret's work as an author, she and Mary were surrounded by literary luminaries of the time, including F. Scott Fitzgerald. But when Mary—following Margaret's earlier example—chose to attend Vassar College, a liberal arts school for women in New York, she opted for a scientific path rather than a literary one. She chose to major in physics because, her son says, she learned she was good at it—both the math and hands-on aspects of the subject. Yet according to Mary's daughter, Margaret Brinig, the choice may also have reflected the independent spirit that Mary had inherited from her mother. "I think my mom wanted to do something different from what my grandmother did," Brinig says. "And she liked to think of herself as rebellious."

After graduating from Vassar, Banning opted to pursue a physics doctorate at Johns Hopkins University. There, she studied the reflectivities of thin metallic films in the far-ultraviolet, under the supervision of August Hermann Pfund (who would become president of OSA for the 1943-1944 term). She also found time during the period to learn how to fly, and obtained a pilot's license in 1941—a credential that would prove surprisingly useful only a few years later, when she was immersed in optics work supporting the U.S. war effort.

From Johns Hopkins to Rochester

Meanwhile, some 450 kilometers to the north, another future OSA president, Brian O'Brien, was working to build an optical-research operation

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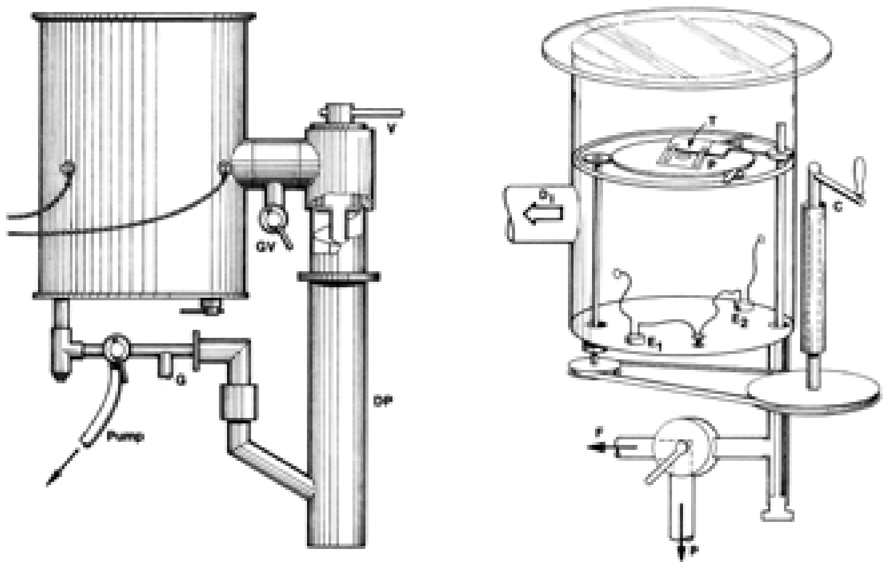


Elevation view of the exterior of the evaporator (left) and isometric view (right), from original contractor report on Banning's war work.
Reproduced in P. Baumeister, Opt. News, **13**(6), 10 (1987).

that could support a U.S. war effort. Named director of the Rochester Institute of Optics in 1938, O'Brien realized earlier than many of his time that the United States would inevitably be drawn into the European war that began in September 1939. As a result, under his leadership, the Institute embarked on an active program of facilities and personnel expansion to be ready, with the work largely under the auspices of the recently formed National Defense Research Committee (NDRC), of which O'Brien was a consulting member.

One area that O'Brien knew he would need to expand at Rochester was optical coatings and thin films. But in addition to the challenge of finding the right person to lead the effort, O'Brien faced the possibility of staff loss through the draft. In September 1940, the United States had re-imposed military conscription through the Selective Training and Service Act, which established the first peacetime draft in the country's history, and its effects were already being felt.

Banning—who had done impressive, hands-on graduate work in metallic films, and who, as a woman, lay safely outside of the draft threat—must have seemed a providential choice when Pfund suggested her to O'Brien. In summer 1941, she moved to Rochester to establish a new laboratory to carry out the NDRC's needs. Only a few months later, after the 7 December 1941 attack on Pearl Harbor, the United States found itself in the world war at last. Banning's work was about to take on a new urgency.

Building from scratch

Recollections from several sources suggest that Banning brought an unusual combination of natural leadership and hands-on enthusiasm to the lab. Her son Gardner recalls her saying that although she was one of the few women in the department, the other scientists and engineers saw her as an equal and did not question her authority. "Since everybody was rowing in the same direction, you needed to have somebody calling out the beat of the oars," says Gardner. "And she had no problem stepping into that role." Philip Baumeister, writing about the Rochester lab in the

U.S. National Defense Research Committee

The U.S. National Defense Research Committee (NDRC), created on 27 June 1940 by U.S. President Franklin D. Roosevelt, was charged with supplementing, coordinating and supervising scientific research activities related to warfare mechanisms and devices. Some of the better known NDRC-facilitated projects included radar, sonar and the atomic bomb. After reorganization in 1942, NDRC was made up of 19 divisions covering a wide variety of topics—including optics and camouflage (Division 16) and physics (Division 17).

Future OSA President George R. Harrison served as chief of Division 16. In a report on NDRC activities during the war, Harrison says Divisions 16 and 17 "… were concerned with the tools of production more than the fighting weapons of war; with gauges, rather than guns; with meters and measuring devices, rather than actual munitions." What came out of the effort, however—including bombsights, aerial cameras, and much else—often went far beyond mere "meters." For example, the "metascope" infrared viewer devised at Rochester found important use in engagements such as the Battle of Okinawa.

June 1987 *Optics News*, noted that Banning "quickly took charge of the coating operation."

Yet Banning was also, according to Gardner, "an experimentalist in a very direct sense. She liked playing with the toys. And I think that what she called the 'fine motor work' was part of what got her interested in optics."

That hands-on streak would serve her well, as Banning and her team (which included, among others, Brien O'Brien Jr., then an undergrad at Rochester) had their work cut out for them. During the 1930s, a number of researchers, both in Europe and the United States, had done important theoretical and bench work on coatings and evaporative deposition. Those figures included Banning's thesis adviser, Pfund; John Strong, who experimented with evaporation of fluorite to create anti-reflection coatings of surprising effectiveness; and even O'Brien himself, who had earlier patented a method for depositing optical coatings for neutral-density filters.

Yet the refinement of bench techniques for vacuum deposition of coatings, and their scaling up to industrial use, lay in the future. It took the cataclysm of World War II to provide the rude shove that, in the words of Angus Macleod, woke up a subject "that had slumbered for more than 100 years." It also laid considerable practical pressure on Banning's new lab. As she later noted in a letter to Baumeister, "We worked usually on things that should have been done yesterday."

Faced with that pressure, Banning and the team improvised, adapting equipment already available at Rochester and building from scratch whatever else they needed to advance their coatings research.

At the heart of the effort were several brass deposition tanks (described in detail in Baumeister's 1987 *Optics News* article), topped with a glass window for observing the sample and attached to a diffusion pump that maintained vacuum. High-voltage leads through the tank bottom heated the materials to be evaporated—commonly zinc sulfide, various fluoride minerals, or metals, depending on the desired optical properties of the layer. Banning added a lubricated hand crank to the apparatus to allow the sample to be steadily rotated for even deposition. Power to the unit was controlled with a series of knife switches, which afforded a decidedly do-it-yourself look to the entire apparatus.

Operating the unit was a painstaking process involving carefully rotating the specimens in the thin-film evaporators for a uniform coating, and monitoring, in real time, their reflected color (from

The official history of Division 16's wartime activities reserved special praise for the accomplishments of the lab that Banning led.

OSA Centennial Timeline 1936-45

www.osa.org/100

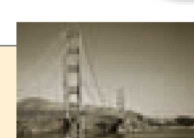
OSA HISTORY

1936
OSA Celebrates Its 20th Anniversary

1939
OSA Board Establishes the Adolph Lomb Medal

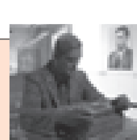
POLITICAL/ SOCIAL

1936
Spanish Civil War Begins



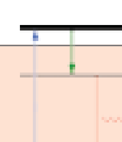
1937
Golden Gate Bridge Opens

SCIENCE/ ENGINEERING



1936
Birth of the "Turing Machine"

1938
First Xerographic Image



1939
Population Inversion Proposed

a fluorescent light source) as a proxy for layer thickness—a seemingly primitive but surprisingly successful approach. Banning's fascination with the evaporators and their technology proved an asset. Her son, Gardner, remembers his mother saying that many of her colleagues were too impatient for this work, but she could remain focused.

Accomplishments in the lab

Banning's hard work and attention to detail, and that of her team, resulted in some notable successes for the lab, both in basic research and in practical results for the NDRC effort. Brian O'Brien Jr., quoted in the Institute of Optics history *Jewel in the Crown*, recalled working in the lab on "multi-layer low-reflecting coatings, nickel neutral density filters, partial reflecting coatings, etc." And Mary Banning, later recalling the work to her son Gardner, stressed that she and her colleagues were not cogs in a war-time machine, but problem solvers, continually presented with diverse problems by the U.S. military that needed practical and timely solutions.

On the research front, one of Banning's most important contributions was in multilayer dielectric coatings. Through painstaking work, the lab developed methods to build up filters consisting of up to seven layers, each one-quarter of a wavelength thick, using the reflected colors of each layer to monitor the thickness in real time as the layer was built up. Banning had, in essence, devised a practical method for building a quarter-wave stack—a structure that had been first described in the literature only in 1939, and that was later characterized by Angus Macleod as "a basic building-block for many types of thin-film filters."

Banning's practical multilayer films found immediate use in a new device for military rangefinders and other optics. Following up in March 1943 on a suggestion and design by Stephen MacNeille of Eastman Kodak, Banning used her thin-film techniques to construct a highly effective polarizing beamsplitter that, by tweaking the Brewster angle of the light across the film layers, was able to reflect half of the incident light and transmit half, to an efficiency of more than 98 percent. (MacNeille patented the design after the war, in 1946, and the device became known as a MacNeille polarizer.)

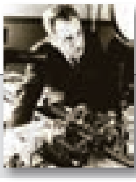
Assessing Banning's work

Within the hothouse atmosphere of the wartime Institute of Optics, Banning's talents were enlisted on a variety of other projects, including triple-mirror collimators to allow for night landings (see p. 44). She not only authored the final Institute report on her lab's activities for NDRC, but also wrote the detailed, classified technical summaries of the lab's activities in image-forming infrared receivers ("metascopes"), infrared-sensitive phosphors, autocollimators and antiglare devices.

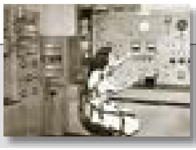
Of course, Banning's work needs to be assessed in the context of the enormous amount of work that was being done across NDRC's Division 16, which itself constituted only one corner of a vast U.S. and global scientific and technical effort supporting the war. Even in the area of thin films, substantial war work was going on at other labs, including Polaroid and Eastman Kodak, as well as overseas in the United Kingdom, in France and, on the Axis side, in Germany—all of which would have important benefits and applications in the postwar world.

Nonetheless, the official history of Division 16's wartime activities, edited by George R. Harrison and published in

1940
25th Anniversary of OSA's Precursor, Rochester Association for Advancement of Applied Optics



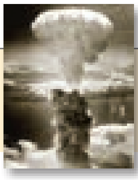
1941
George Harrison Takes JOSA's Reins



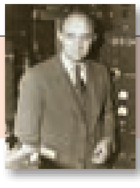
1943
Spectroscopy Dominates 1943 Meeting

1939
World War II Begins

1940
Nylon Stockings Debut: DuPont's Revolutionary New Synthetic Fiber

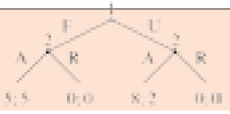


1945
Atomic Bombs Dropped on Hiroshima and Nagasaki



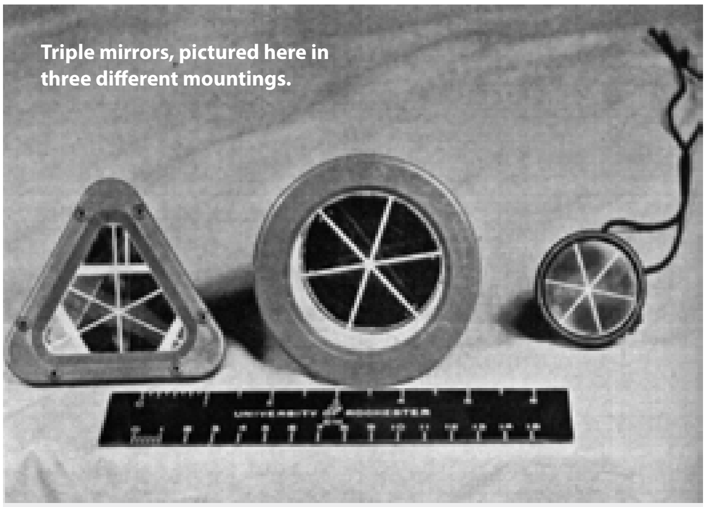
1942
Fermi Achieves Self-Sustaining Nuclear Chain Reaction

1943
The Norden Bombsight's Combat Debut



1944
Birth of Game Theory

Source: Wikimedia Commons and OSA Historical Archives


Triple mirrors, pictured here in three different mountings.

Courtesy of Carlos R. Stroud Jr., Institute of Optics, University of Rochester, N.Y., USA

Zeroing in on night landings

In addition to her work in the coatings lab, Mary Banning found herself involved in other wartime projects at Rochester—sometimes in unexpected ways. One project that, by her son Gardner's account, she was fond of recalling in later years involved the use of optics to solve a very particular military problem.

That problem, handed to the Institute at the end of 1942, involved how to make a secure landing in hostile territory at night, in complete darkness, to remain undetected by enemy forces. Neither the airfield nor the aircraft could be illuminated—though the military allowed that the pilot might shine a very faint light for a minute or so before the landing without endangering the operation's security.

The team at Rochester quickly hit upon a possible solution, using a shipment of triple mirrors that had arrived from the Mt. Wilson Observatory for another purpose only the day before. These devices—essentially three reflectors with mutually perpendicular faces—can, if produced with sufficient precision, return a beam of light almost exactly back to its point of origin, without detection in any other direction. The idea was that a triple mirror would be placed on the unlit airfield, and the pilot would wear a head-mounted light source; a return beam from the source would signal the location of the mirror, and the airfield.

According to Gardner, Mary Banning later recalled that her coatings lab helped to boost the mirrors' precision by making "a very precise film on the reflecting surfaces." And, as a licensed pilot, she went aloft as copilot, calling out altimeter readings, when the system was tested at the Rochester airport, which she knew well. At an altitude of 30 feet, Mary, in the co-pilot's seat, could see nothing on the darkened runway—but the pilot with the head-mounted light, only inches away from her, exclaimed that he could see a bright light reflecting back. Clearly, the triple mirrors were doing their job, and the night-landing problem was solved.

"That was a story she loved telling," said Gardner, because it involved both "a practical application and some fun theory," as well as some very precise engineering. "And it worked."

1948, reserved special praise for the accomplishments of the lab that Banning led (though she herself was never named):

"Trying to deposit a filmy layer of metal on a glass surface was a tricky process before the war, but wartime research made it relatively simple through the application of recently discovered high-vacuum evaporation techniques … [T]he bulk of the work … was done … principally at the University of Rochester, where spectacular work on a laboratory scale was done on various types of films. Outstanding among the University of Rochester's achievements was the development of a highly successful beam-splitting prism, a special requirement for one military instrument … ."

A traditional turn

Banning herself summarized her wartime work in three papers published in 1947 in the *Journal of the Optical Society of America*—one of which, on the deposition of quarter-wave stacks and the construction of the polarizing beamsplitter, has been called a classic. Those papers, however, proved to be Banning's last published output of any significance. For her life, which until the war's end had been highly unconventional, would thereafter take a surprisingly traditional turn.

Banning's son Gardner compares her experience to the image of "Rosie the Riveter," the U.S. icon that represented the women who stepped in to assume traditionally male roles and tasks to meet the needs of World War II. But with the war's end in mid-1945, and males returning home to reclaim their jobs, women were expected to recede once again into the background. Mary was also personally torn, according to her children—while reluctant to leave the lab and the fascination of scientific work, she also very much wanted to get married and have children, in keeping with the norms of the time.

So Banning stayed a short time at Rochester after the war's end, writing up her work, and left the university in the summer of 1946 to return to her hometown of Duluth. "This shift was not something that seemed at all strange to her," says her son, Gardner, "although she never liked it and I don't think she really ever accepted it." Through a friend of her stepfather's, she met a young man roughly her own age—a signal officer returning from the war, named Gardner Louis Friedlander, who like Banning happened to be physicist. After a short courtship, they were married and settled in Milwaukee, Wisconsin, in 1947. In subsequent years they would have four children.

In her new role as Mary Banning Friedlander, stay-at-home wife and mother, Banning retained her interest in optics, reading about the new discoveries coming out of Rochester and remaining in contact with her colleagues—but now as an outside observer. When her children were a little older, she did some adjunct teaching work at the local university and consulting work from home, only some of it related to optics. She also decided, at one point, to get more seriously back into the field by applying for a full-time faculty position. But she did not pursue that opportunity—in large part, her children suggest, because her husband, whose politics were conservative and whose values reflected the traditional norms of the time, strongly objected.

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The "coolest mom" in town

Instead, Mary became, according to her daughter Margaret, "the coolest mom" in her circle. "A lot of the other mothers were fairly stodgy and our mother was not." Her children remember Mary putting her inquisitive mind and scientific talents into projects such as electronic "Heathkits," including one for a color television; creating physics demonstrations for local school children; and tinkering in her home lab. Margaret recalls seeing formulas on "every scrap of paper" all over the house, as Banning would "come up with an idea and be working it out at home in random places." Even one of Banning's evaporators from her Rochester days—affectionately named "Eva"—was a fixture at the house as Gardner and Margaret were growing up.

Yet her children's recollections also suggest that Banning, who spent her last days with her daughter in Iowa City, Iowa, and died in 2001 at age 85, retained a sense of something lost. "She was proud of us [the children] and wouldn't trade us for anything," shares Margaret. "But I think she felt that she would have had some happier years if she hadn't tried to channel all her creative, scientific energy into other stuff. She kind of conquered this male-dominated discipline, and then was told that she couldn't participate in it the way she wanted to. I think it was really hard on her."

In the five and one-half decades of her life after the war, Banning saw many changes in the roles available to women. And, though both men and women in science today still face many challenges balancing work and family life, it's tempting, in view of her independent spirit and early accomplishments, to wonder how Banning's career might have played out had she been born a few decades later.

Yet much like her own mother, Mary Banning found ways, through her example, to influence the next generation. Once, Gardner Jr. recalls, his mother took a walk with his son and daughter after a rainstorm. His son was running and jumping through the puddles in the road, while his four-year-old daughter noted the swirled, iridescent colors in some of the puddles. Mary and her granddaughter started talking about the colors, and why a thin film of gasoline or oil on the water's surface would cause different colors in the reflection. Years later, Gardner's daughter would credit her choice of physics as a major in college to her grandmother. OPN

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