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Enhanced Optical Filter Design

David Cushing

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This book is dedicated to my wife, Helen,
who has helped me make the most of my life.

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Foreword

The University of Arizona College of Optical Sciences got really lucky the day that Dave Cushing found us.

Dave and his wife, Helen, came to Tucson in 2004. It took them a while to pick a house in the area, though. Dave was insisting on finding one zoned for three-phase wiring, so he could install a custom-built coating machine in the garage. He planned to tinker with it as his retirement project. Unfortunately for Dave (maybe fortunately for Helen), the heavy-duty electrical setup in the new place just didn't work out.

That bad news turned into good news for us at COS. Not long after his arrival in Arizona, Dave met up with our director of development at an industry conference. Dave decided to take his coating machine out of storage and donate it to the college. According to Helen, he wanted students "to have hands-on experience, so they knew what they were doing."

We installed that machine on the fifth floor of the Meinel Building, where it rests today. Thus began a brief but extraordinarily meaningful friendship.

* * * * *

David Henry Cushing was born in Boston, Massachusetts, in 1940. He didn't talk much about his life growing up, but from what friends and family could tell, it wasn't great. "He grew up without anything," his wife said. "How he got to where he got is a mystery."

Dave and Helen met through friends and got married in 1961. They started their family right around the time Dave started college, so he chose to find a job to support the household while taking night classes. In a stroke of good luck, he ended up working with thin films pioneer Edgar Barr as a production technician at Baird Atomic, Inc.

It took him ten years to get his degree. By 1969, Dave Cushing had a staff of fifty workers, a BS in electrical engineering from Northeastern University, three children (with a fourth on the way) — and a passion for optical coatings research that would last for the rest of his life.

His next move was bold: he and a partner founded MicroCoatings, Inc. to produce filters for medical electronics and defense purposes. They used vacuum chambers to manufacture laser range finders, semiconductor lithography systems, printers, flame photometers, and supermarket scanners.

Over the next seventeen years, MicroCoatings Inc. became well known for the quality of its work — NASA used their filters in the Galileo and Voyager spacecrafts. When the company was acquired in 1986 by the Optical Corporation of America, Dave stayed on as technical director.

When he left OCA in 1990, he was immediately snapped up by JDS Fitel Inc. for their operation in Canada. According to Helen, JDS Fitel called every David Cushing in the phonebook until they found the right one, and they came to Dave and Helen's home the next day. So, with the kids all mostly grown, the pair headed off to Ottawa. At JDS Fitel, Dave designed equipment for the production of telecom filters and set up the first truly successful production shop for dense wavelength-division multiplexing filters.

In 2001, Dave and Helen moved to Cincinnati, Ohio, where he headed thin films research and development for Corning Precision Lenses. Then, after seven US patents, several worldwide patents, numerous publications, and forty-five years in thin films, David H. Cushing retired in 2004. He and Helen elected to spend their golden years in sunny Tucson, where he had attended many pleasant conferences during his career.

* * * * *

After donating his coating machine to the College of Optical Sciences, Dave came on board as a visiting scientist. He went into the lab for several hours each week, working with students and performing his own research. During his days in the Meinel Building, he spent more time with professor emeritus and fellow optical coatings expert H. Angus Macleod, whom he had known through most of his career.

"He was just an awfully nice person," Angus said, "really a very approachable guy who didn't mind sharing things he knew with people." The college was understandably shocked and saddened, then, by Dave's sudden death on Friday, November 20, 2009.

The last project that Dave worked on at OSC was a decorative Spectralonic coating using aluminum foil as a substrate, wherein vaporized materials were deposited on the metal in a vacuum chamber, forming a permanent layer that was nanometers thick. Dave and fellow artists Henry El Kaim and George Hubbard used the treated foil to make vivid, highly saturated wall sculptures that changed color with the angle of view.

An art gallery here in Tucson displayed a few of these pieces in a posthumous "Aurora Show," held in December 2009. Several more decorate the halls of the Meinel Building, including a place of honor on the sixth floor, not too far from Dave's coating machine. In my office, I keep one of his creations, which he gave me shortly before he died.

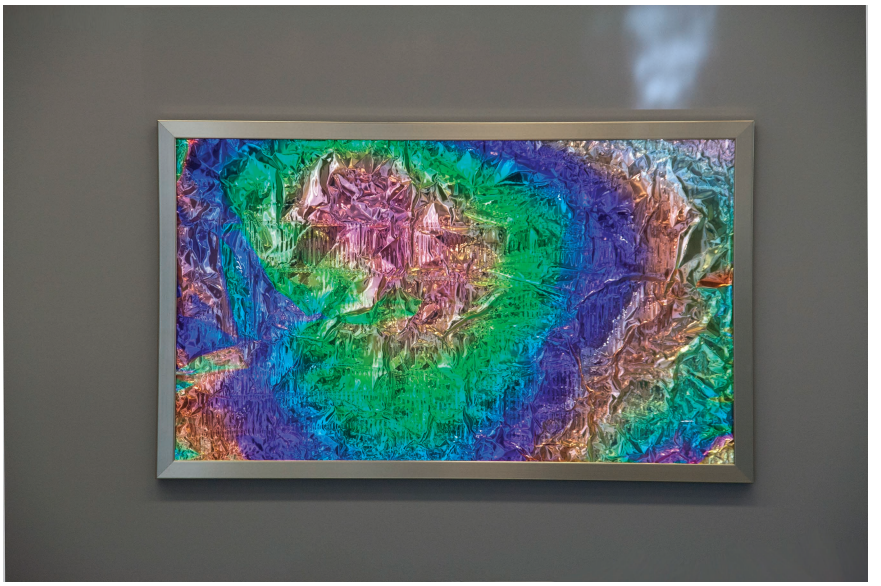
One of David's most lasting legacies, however, is the scholarship that Helen created at the College of Optical Sciences in his name, in memory of the many years they spent together and his passion for thin films. Each year, the award goes to an undergraduate student, preferably one interested in optical coatings, for

use toward tuition. Dave knew from his own experiences, after all, how important undergraduate training could be, and how much of a challenge it was to fund that training.

On April 25, 2011, with Helen Cushing present, we named Gregory Jacob the first winner of the David H. Cushing Endowed Scholarship in Optical Sciences. With the Cushings' generous support, the College of Optical Sciences looks forward to educating the next generation of passionate and personable engineers and optical scholars according to Dave's incredible example.

James C. Wyant, Dean
University of Arizona College of Optical Sciences
September 2011

From left, Carl Maes, Gregory Jacob, Helen Cushing, and James Wyant.



David Cushing's artwork, *Untitled*, on display at the University of Arizona College of Optical Sciences.

David Cushing's artwork, *Untitled*, on display at the University of Arizona College of Optical Sciences.

Preface

This book started as a short supplement to demonstrate how to improve the performance of coatings beyond the techniques described in the standard texts by Macleod and Baumeister. The coatings are designed with TFCalc®, but any of the available programs provide similar answers. The approach to designing is not mathematical in nature, but intuitive. I have more than 40 years experience building coatings and filters, and I mostly used an optical monitor as the primary control because the desired results were optical coatings, and other available methods of monitoring were unreliable. Early work used thermal sources without ion assistance, and the results for crystal monitoring were inconsistent. The stability of crystal monitoring has vastly improved with the energetic sources now available. This allows for nonquarterwave layers that can be counted on to be within a reasonable tolerance. I have made edge filters with 30 layers that follow the theoretical curves within a few nanometers of cutoff tolerance.

I have not manufactured many of the films described in this book; the concepts were originally depicted for papers presented at conferences. One can only present what is allowed by the employer(s). Typically, one cannot talk about the work that is currently being pursued, and the equipment for producing the described coatings may not be available when moving on to a new job. I anticipate that the designs are fairly easy to accomplish based on the work that I was able to do.

The designs were produced using TFCalc; copies of the designs, materials, and targets are supplied in the TFCalc format. I have also copied the designs into a new freeware program called OpenFilters. This program is available from École Polytechnique de Montréal, described in *Applied Optics* (Vol. 13, May 2008, p. c219). It is freely available on the website http://www.polymtl.ca/larfis.

The materials I used are also provided and need to be added to those given in the program. For the most part I have not supplied targets for these designs.

David Cushing
Tucson, Arizona
September 2009