Lecture Notes on

PRINCIPLES OF PLASMA PROCESSING

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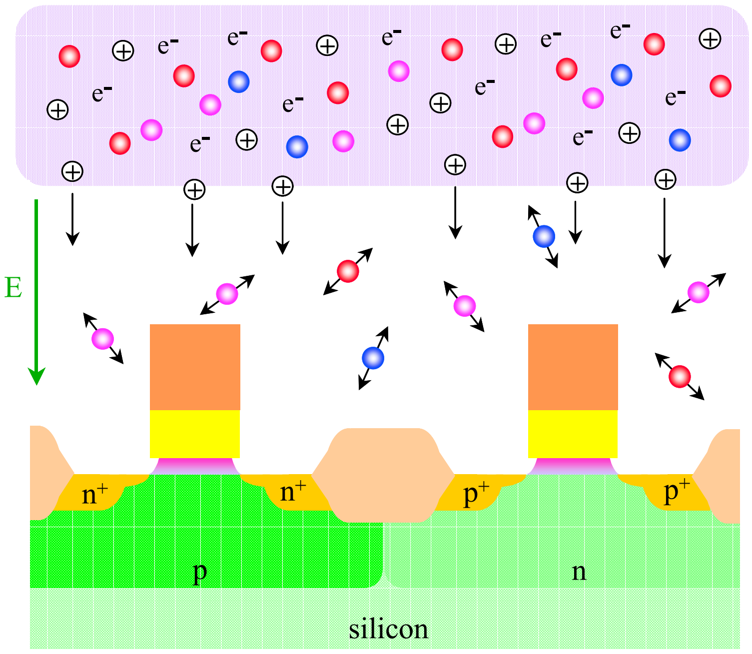

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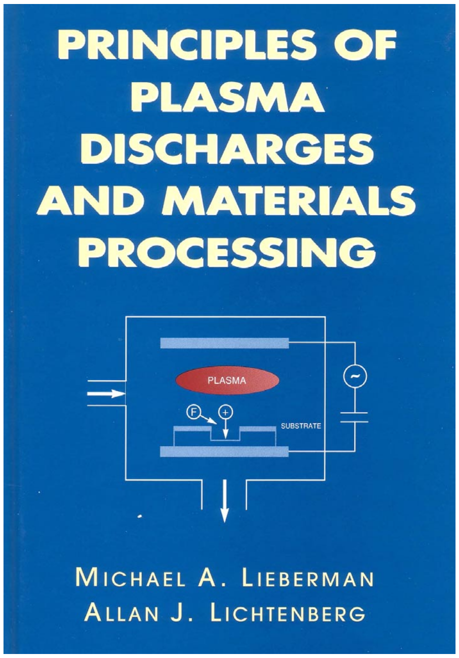

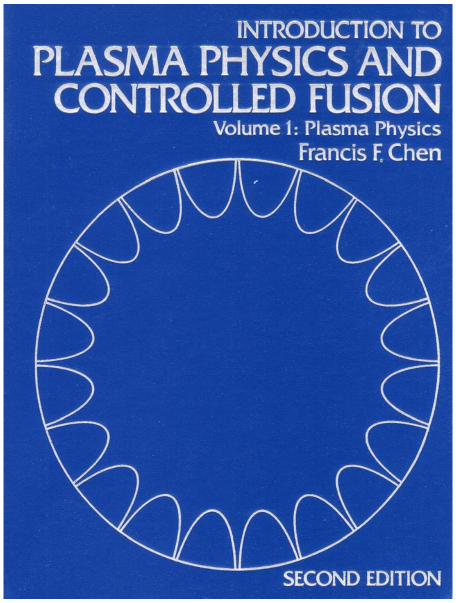

Reference books used in this course

PRINCIPLES OF PLASMA PROCESSING

PREFACE

We want to make clear at the outset what this book is NOT. It is *not* a polished, comprehensive textbook on plasma processing, such as that by Lieberman and Lichtenberg. Rather, it is an informal set of lecture notes written for a nine-week course offered every two years at UCLA. It is intended for seniors and graduate students, especially chemical engineers, who have had no previous exposure to plasma physics. A broad range of topics is covered, but only a few can be discussed in enough depth to give students a glimpse of forefront research. Since plasmas seem strange to most chemical engineers, plasma concepts are introduced as painlessly as possible. Detailed proofs are omitted, and only the essential elements of plasma physics are given. One of these is the concept of sheaths and quasineutrality. Sheaths are dominant in plasma "reactors," and it is important to develop a physical feel for their behavior.

Good textbooks do exist. Two of these, to which we make page references in these notes for those who want to dig deeper, are the following:

M.A. Lieberman and A.J. Lichtenberg, *Principles of Plasma Discharges and Materials Processing* (John Wiley, New York, 1994).

F.F. Chen, *Introduction to Plasma Physics and Controlled Fusion*, Vol. 1, 2nd ed. (Plenum Press, 1984).

In addition, more topics and more detail are available in unpublished notes from short courses offered by the American Vacuum Society or the Symposium on Plasma and Process Induced Damage. Lecture notes by such specialists as Prof. H.H. Sawin of M.I.T. are more comprehensive. Our aim here is to be comprehensible..

The lectures on plasma physics (Part A) and on plasma chemistry (Part B) are interleaved in class meetings but for convenience are printed consecutively here, since they were written by different authors. We have tried to keep the notation the same, though physicists and chemists do tend to express the same formula in different ways. There are no doubt a few mistakes; after all, these are just notes. As for the diagrams, we have given the source wherever possible. Some have been handed down from antiquity. If any of these are yours, please let us know, and we will be glad to give due credit. The diagrams are rather small in printed form. The CD which accompanies the text has color figures that can be expanded for viewing on a computer monitor. There are also sample homework problems and exam questions there.

Why study plasma processing? Because we can't get along without computer chips and mobile phones these days. About half the steps in making a semiconductor circuit require a plasma, and plasma machines account for most of the equipment cost in a "fab." Designers, engineers, and technicians need to know how a plasma behaves. These machines have to be absolutely reliable, because many millions of transistors have to be etched properly on each chip. It is amazing that this can be done at all; improvements will certainly require more plasma expertise. High-temperature plasmas have been studied for decades in connection with controlled fusion; that is, the production of electric power by creating miniature suns on the earth. The low-temperature plasmas used in manufacturing are more complicated because they are not fully ionized; there are neutral atoms and many collisions. For many years, plasma sources were developed by trial and error, there being little understanding of how these devices worked. With the vast store of knowledge built up by the fusion effort, the situation is changing. Partially ionized, radiofrequency plasmas are being better understood, particularly with the use of computer simulation. Low-temperature plasma physics is becoming a real science. This is the new frontier. We hope you will join in the exploration of it.

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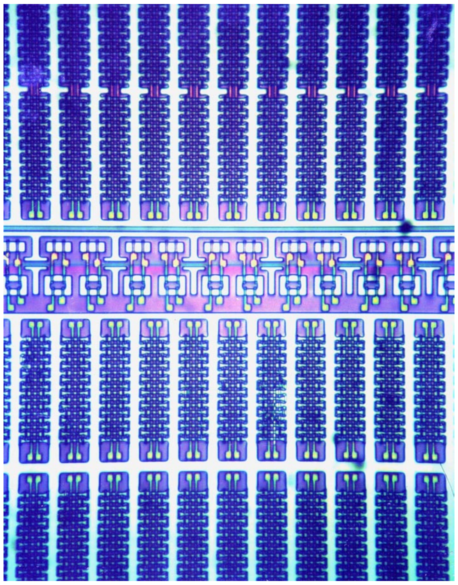
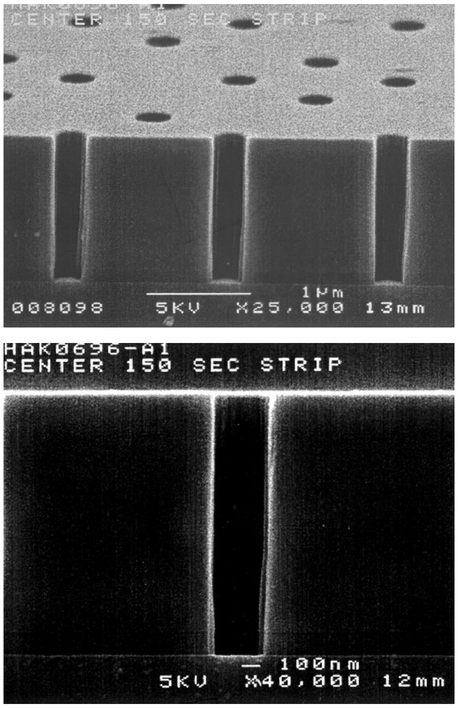


A small section of a memory chip.



Straight holes like these can be etched only with plasmas

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