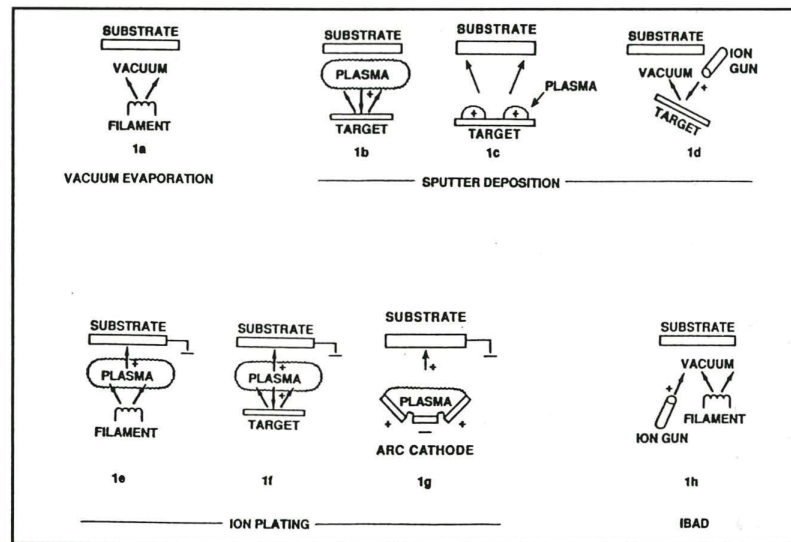


# HANDBOOK OF PHYSICAL VAPOR DEPOSITION (PVD) PROCESSING

Film Formation, Adhesion, Surface Preparation and Contamination Control



by  
Donald M. Mattox

NOYES PUBLICATIONS

Copyright © 1998 by Noyes Publications  
No part of this book may be reproduced or utilized  
in any form or by any means, electronic or  
mechanical, including photocopying, recording or  
by any information storage and retrieval system,  
without permission in writing from the Publisher.  
Library of Congress Catalog Card Number: 97-44664  
ISBN: 0-8155-1422-0  
Printed in the United States

Published in the United States of America by  
Noyes Publications  
169 Kinderkamack Rd., Park Ridge, NJ 07656

10 9 8 7 6 5 4 3 2

Library of Congress Cataloging-in-Publication Data

Mattox, D. M.  
Handbook of physical vapor deposition (PVD) processing / by  
Donald M. Mattox.  
p. cm.  
Includes bibliographical references and index.  
ISBN 0-8155-1422-0  
1. Vapor-plating--Handbooks, manuals, etc. I. Title.  
TS695.M38 1998  
671.7'35--dc21 97-44664  
CIP

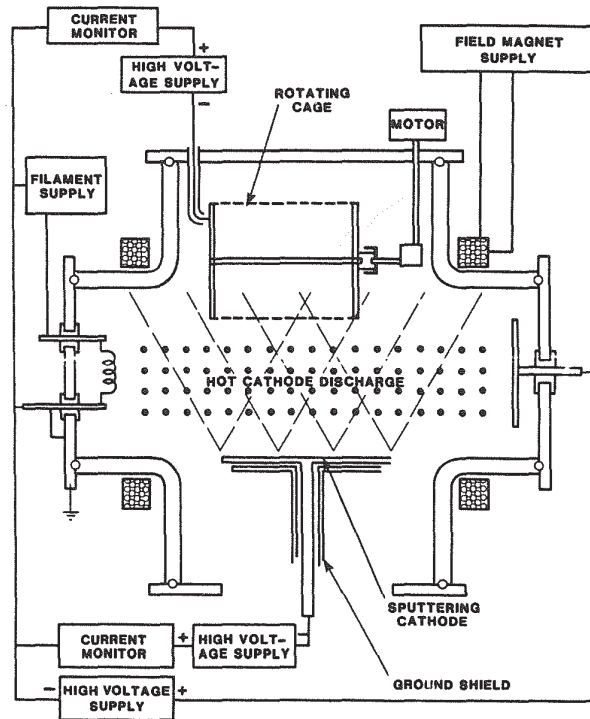


Figure 4-6. Barrel ion plating system configuration with a triode DC discharge.

The DC diode discharge cannot be used to sputter dielectric target materials, since charge buildup on the cathode surface will prevent bombardment of the surface. If there are reactive gases in the plasma their reaction with the target surface can lead to the formation of a surface that has a different chemical composition than the original surface. This change in composition leads to "poisoning" of the cathode surface and thus changes the plasma parameters. In the extreme, poisoning will cause bombardment of the cathode to cease due to surface charge buildup. If an insulating surface forms on the DC cathode, charge buildup will cause arcing over the surface.

The suppression of arcs generated in the DC discharge (arc suppression) are important to obtaining stable performance of the DC power supplies particularly when reactively sputter depositing dielectric films.<sup>[46]</sup> Arcing can occur anytime a hot (thermoelectron emitting) spot is formed or when surface charging is different over surfaces in contact with the plasma. Arc suppression is obtained by momentarily turning off the power supply or by applying a positive bias when an arc is detected.

### **Pulsed DC**

When a continuous DC potential is applied to a metal electrode completely covered with a dielectric material, the surface of the dielectric is polarized to the polarity, and nearly the voltage, of the metal electrode. If the surface potential is negative, ions are accelerated out of the plasma to bombard the surface giving sputtering, secondary electron emission, "atomic peening," and heating. However, since the secondary electron emission coefficient is less than one the surface will buildup a positive surface charge and the bombardment energy will decrease then bombardment will cease. This problem can be overcome by using a pulsed DC rather than a continuous DC.

Pulsed DC uses a potential operating in the range 50–250 kHz where the voltage, pulse width, off time (if used), and pulse polarity can be varied.<sup>[47]</sup> The voltage rise and fall is very rapid during the pulse. The pulse can be unipolar, where the voltage is typically negative with a no-voltage (off) time, or bipolar where the voltage polarity alternates between negative and positive perhaps with an off time. The bipolar pulse can be symmetric, where the positive and negative pulse heights are equal and the pulse duration can be varied or asymmetric with the relative voltages being variable as well as the duration time.<sup>[48]</sup> Figure 4-7 shows some DC waveforms. Generally in asymmetric pulse DC sputter deposition, the negative pulse (e.g., -400 V) is greater than the positive pulse (e.g., +100 V) and the negative pulse time is 80–90% of the voltage cycle and the positive pulse is 20–10% of the voltage cycle.

In pulse DC sputtering, during the positive bias (and off-time), electrons can move to the surface from the plasma and neutralize any charge build-up generated during the negative portion of the cycle. During the negative portion of the cycle, energetic ion bombardment can sputter dielectric surfaces.

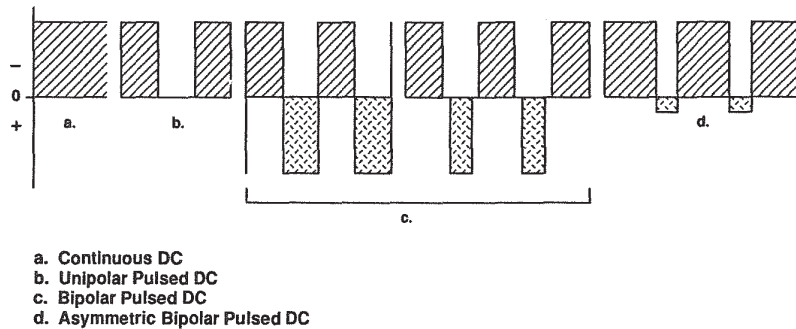


Figure 4-7. DC waveforms.

Pulsed DC power can be obtained by switching a continuous DC or sinewave power supply with auxiliary electronics<sup>[49]</sup> or can be obtained from a specially designed pulsed power supply that generally allows more flexibility as to waveform. The pulsed power supply generally incorporates arc suppression that operates by turning off the voltage or by applying a positive voltage when the arc initiates. Pulsed plasmas are also of interest in plasma etching and plasma enhanced CVD (PECVD).<sup>[50]</sup>

#### 4.4.4 Magnetically Confined Plasmas

##### Balanced Magnetrons

In surface magnetron plasma configurations the electric ( $E$ ) (vector) and magnetic ( $B$ ) (vector) fields are used to confine the electron path to be near the cathode (electron emitting) surface. An electron moving with a component of velocity normal to the magnetic field will spiral around the magnetic field lines and its direction will be confined by the magnetic field. The frequency of the spiraling motion and the radius of the spiral will depend on the magnetic field strength. The interaction of an electron with the electric and magnetic fields depends on the magnitude and vector orientation of the fields ( $E \times B$ ). For example, if the magnetic field is parallel to a surface and the electric field is normal to the surface an electron leaving the surface will be accelerated away from the surface and will spiral around the magnetic field. There will also be a resulting motion

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

## LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

## FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

## E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.