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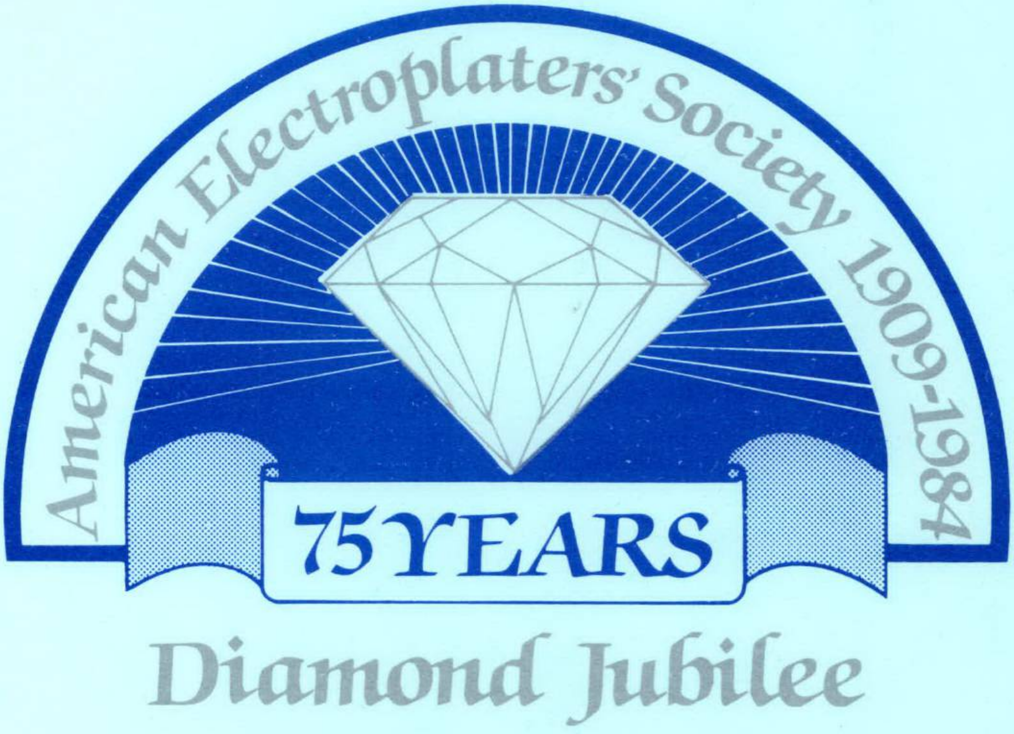
American Electroplaters' Society
SUR/FIN '84

71st Annual Technical Conference



July 16-19, 1984
New York Hilton
New York, NY

Session A - Vacuum Coatings

AMERICAN ELECTROPLATERS' SOCIETY, INC.

71ST ANNUAL TECHNICAL CONFERENCE - NEW YORK CITY

VACUUM COATINGS

SESSION A

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Vacuum Coatings
Session A

A Review of Commercial Physical Vapor Deposition Systems

Russell J. Hill
Temescal/Div. of BOC Group, Inc.
Berkeley, CA

A REVIEW OF COMMERCIAL PHYSICAL VAPOR DEPOSITION SYSTEMS

Russell J. Hill, Temescal a Division of BOC Group, Inc.,
2850 7th Street, Berkeley, CA., 94710

Physical vapor deposition is used to coat substrates with both thick and thin films, with the ability of depositing pure metal, metal alloy, inorganic compounds, ceramic and in certain cases organic polymer films. A review of production equipment designed for high throughput of coated parts is presented and categorized with respect to the type of parts to be coated, as follows:

1. Discrete Parts
    a) Simple small flat
    b) Complex shape
2. Continuous or Semi-continuous Parts
    a) Flexible
    b) Rigid

The systems contain three key elements no matter what type of substrate they are designed to coat. The coating is applied in vacuum, the parts are introduced to the vacuum proper through a vacuum load lock, and various types of energy are applied to sources to produce a suitable vapor. The load lock is a small chamber separated from the main vacuum chamber by a vacuum valve. The load lock can be vented to atmosphere, the parts to be coated are introduced, and it is separately pumped to vacuum again. In this way the main chamber does not have its vacuum integrity disturbed nor is the vapor source contaminated by repeated venting to atmosphere. The parts to be coated are moved by various techniques from the load lock through the vacuum valve and into the main chamber where they are coated. The coated parts are withdrawn again into the load lock, which is vented after the vacuum valve between it and the main chamber has been closed. The coated parts may then be removed and replaced by further uncoated parts and the cycle repeated.

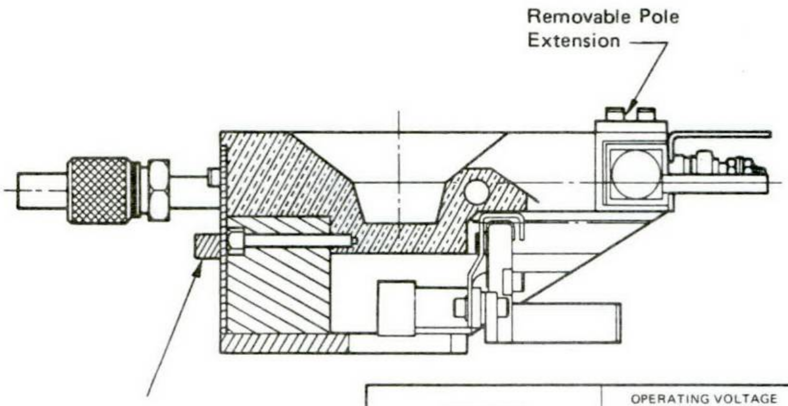
The most popular sources of vapor for continuous production coatings are electron beam evaporation and high rate magnetron sputtering sources. In general an electron beam source can be considered as a point evaporation source and consequently the vapor distribution on a plane collector placed above the source will be circularly symmetric with the thickness having a cosine distribution along any radius, modified by the inverse square dependence of flux intensity with distance from the source. In contrast, a planar magnetron can provide a remarkably even distribution of vapor flux along its length. Thus even very wide substrates, if moved perpendicularly across the length of a planar magnetron, will receive remarkably uniform coatings. The vacuum requirements of the two sources are different in that electron beams will work at 10^{-4} torr (10^{-7} atmosphere) or below whereas high rate magnetrons need a supply of argon gas at about 10^{-3} torr (10^{-6} atmosphere) to sustain the glow discharge sputtering process. In terms of general usefulness, sputtering is a glow discharge process that lends itself to the production of thin films generally less than 1 μmeter thick (almost 4 μ inch) whereas electron beams are used to produce coatings up to hundreds of μmeters thick (several mils).

Further material on physical vapor deposition beyond this brief introduction can be found in the literature.

References:

Vacuum Deposition of Thin Films by L. Holland, published by Chapman & Hall, London, 1966.

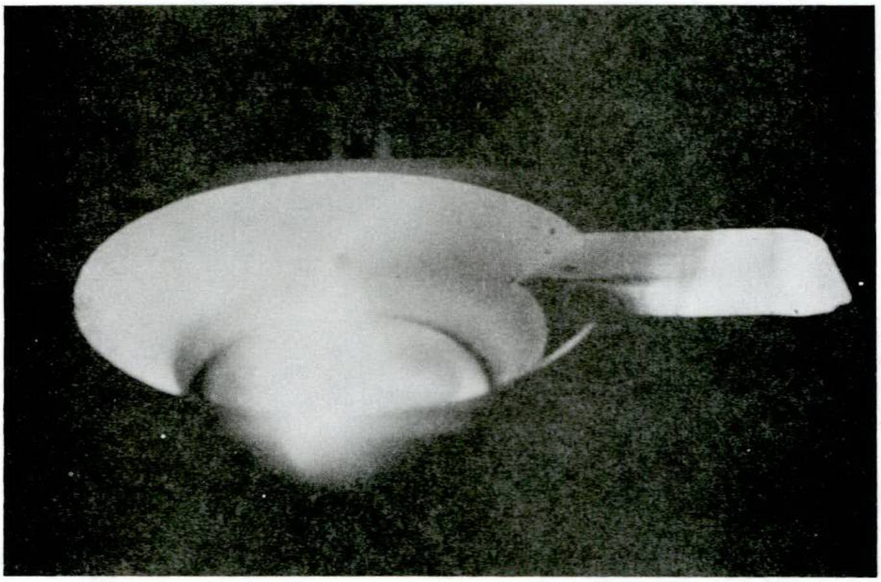
Physical Vapor Deposition, published by Temescal a Division of BOCG, Inc., Berkeley, CA 1976.



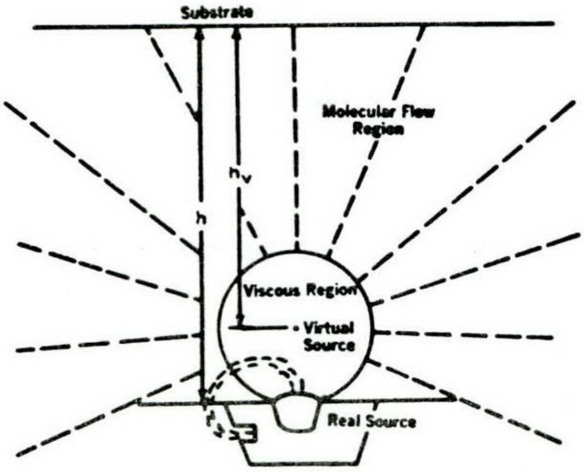
Size obtained from shunt bar chart. Mounting hardware not required to secure the shunt bar. The permanent magnet supplies the clamping force.

SHUNT SIZE MATERIAL-COLD ROLLED STEEL	OPERATING VOLTAGE	
	WITHOUT POLE EXTENSIONS	WITH POLE EXTENSIONS
NO SHUNT REQUIRED	10 kV	10 kV
6 mm SQ. BAR 86 mm LG.	7-8 kV	8-9 kV
10 mm SQ. BAR 86 mm LG.	5-6 kV	6-7 kV
1.3 mm SQ. BAR 86 mm LG.	4 kV	5 kV
1.6 mm SQ. BAR 86 mm LG.		4 kV

1. Diagram of an electron beam source.

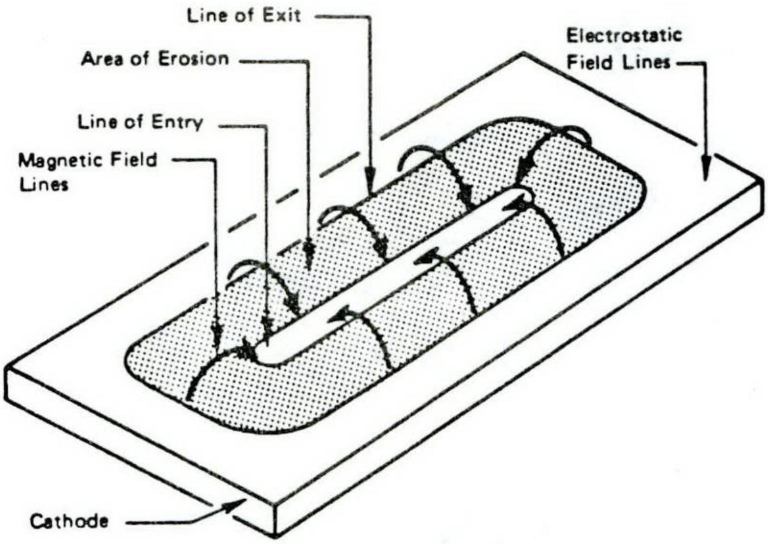


2. Electron beam evaporation source.

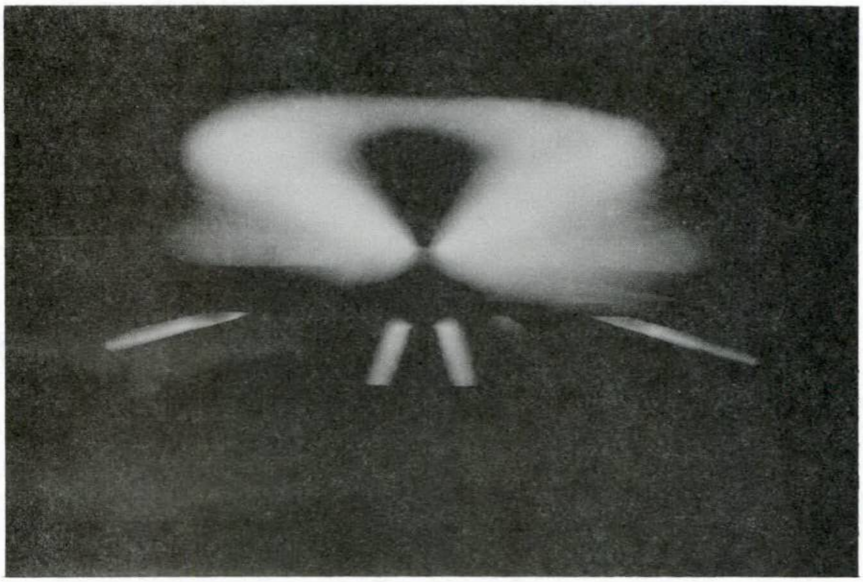


Schematic Diagram Showing Regions of Viscous Flow and Molecular Flow around EB Heated Crucible

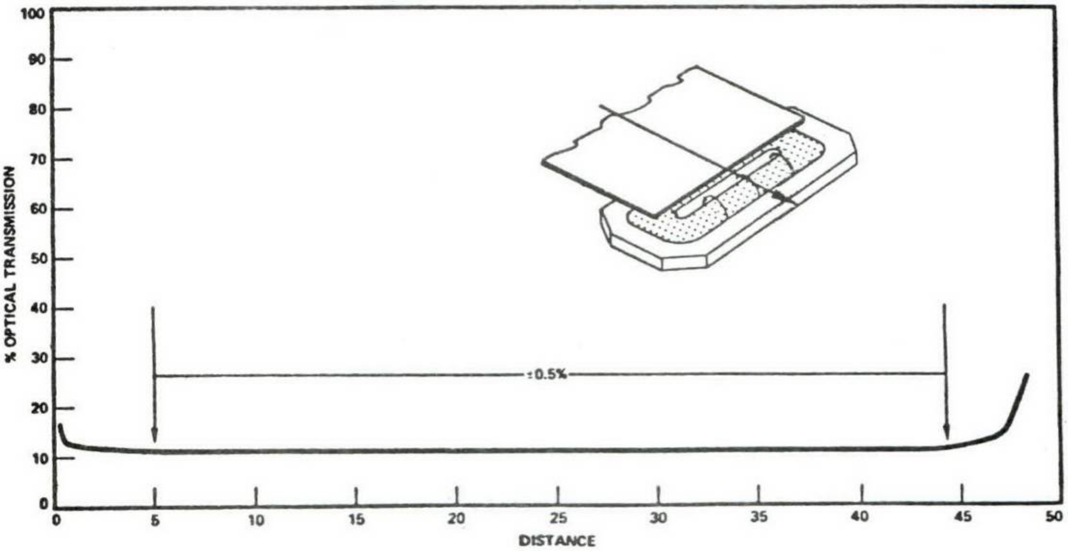
3. Distribution from an electron beam evaporation source.



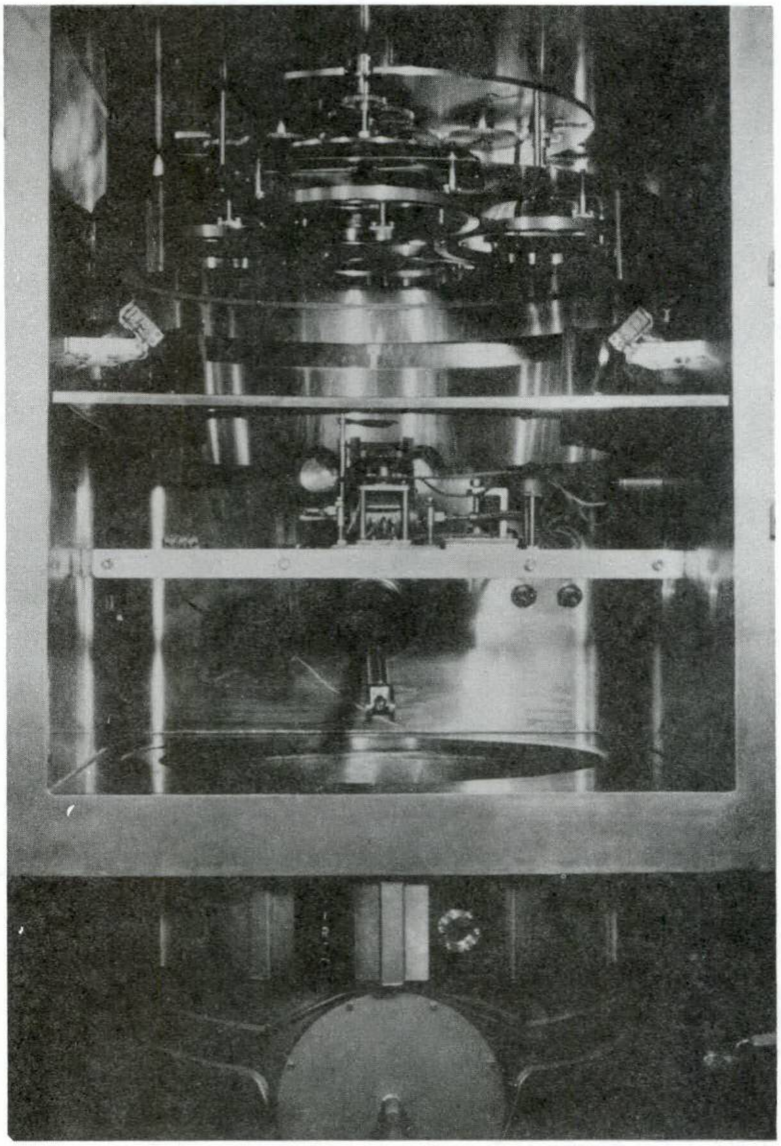
4. Planar magnetron diagram.



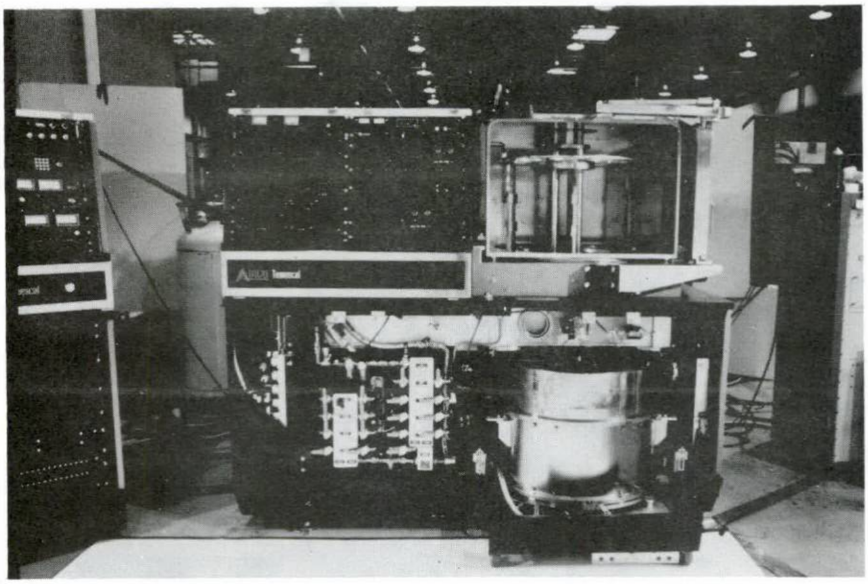
5. Planar magnetron.



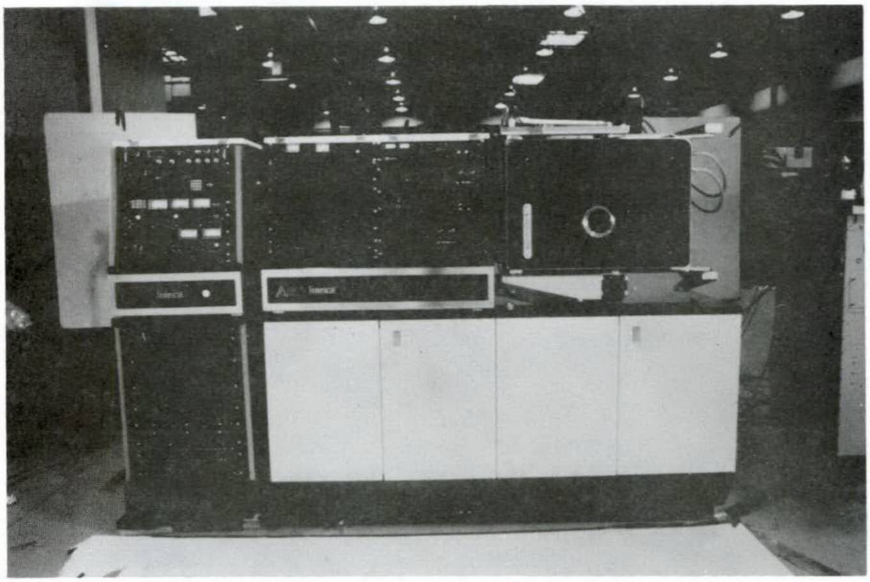
6. Distribution from a planar magnetron.



7. Small flat part coater -- box coater for applying multilayer e.b. coatings for optical purposes in batches with no load lock.

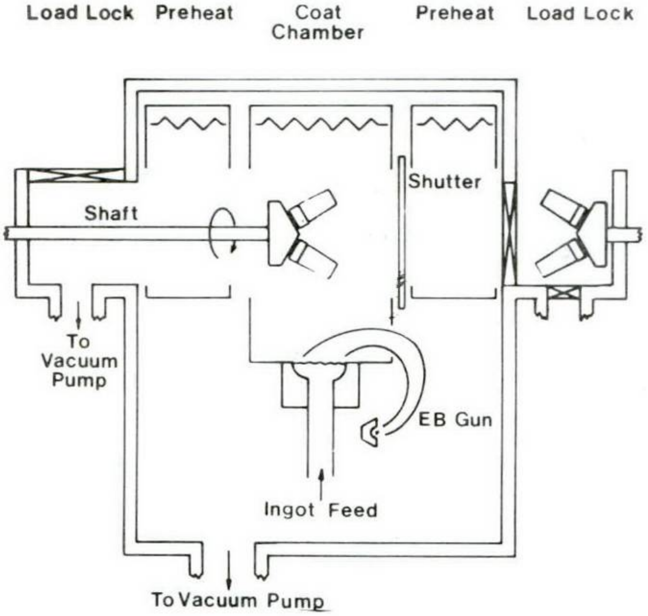


8. Small flat part coater -- microelectronic silicon wafers processing system showing load lock and sputtering source tray.

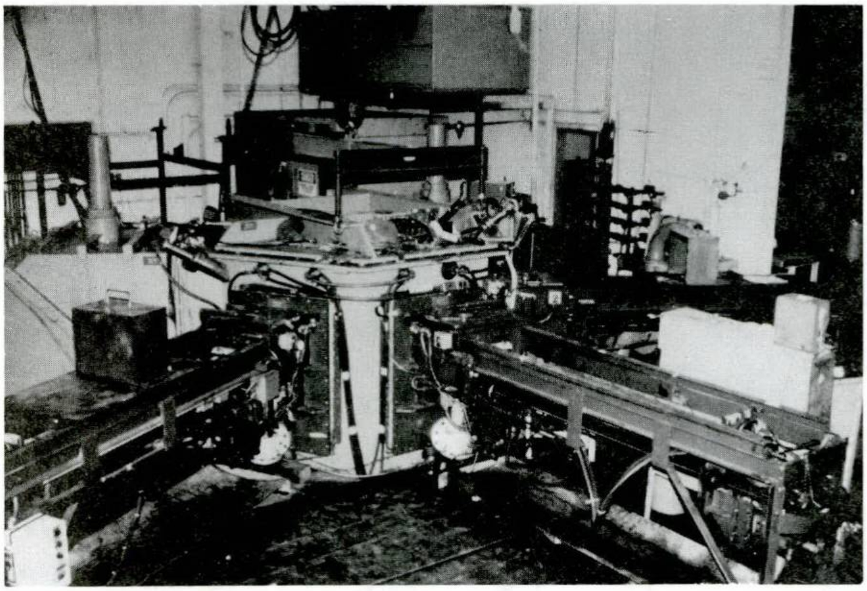


9. Small flat part coater -- microelectronic sputtering system in operating configuration.

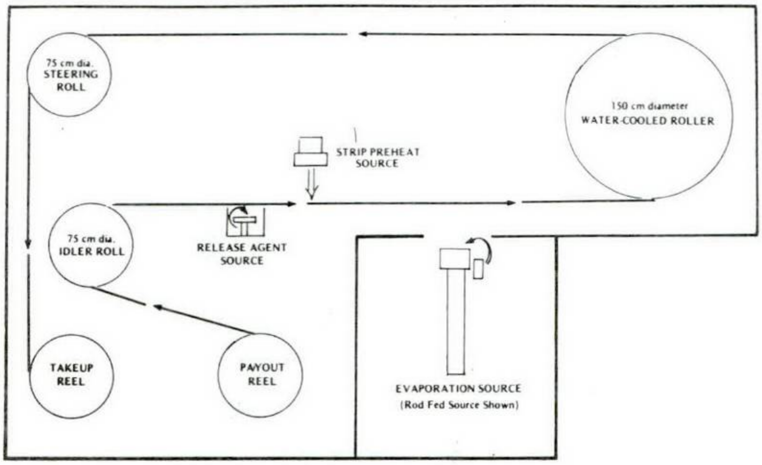
10. Small flat part coater -- microelectronic electron beam evaporation system showing silicon wafers being loaded.



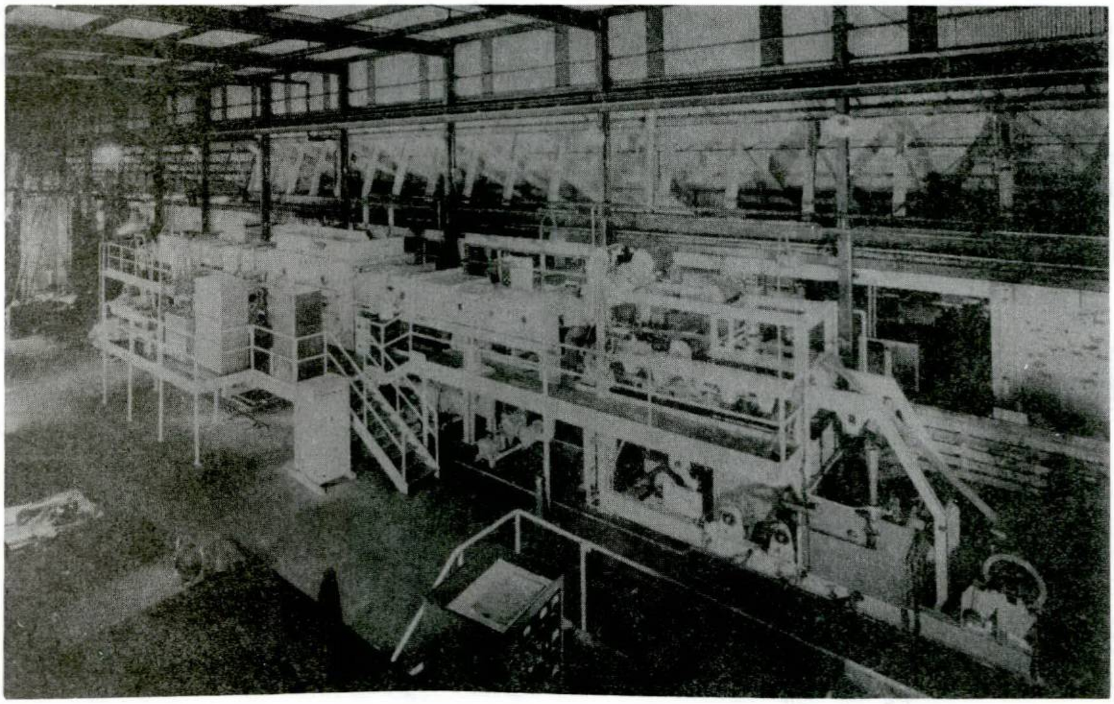
11. Complex shape part coater -- Diagram of a two lock system to electron beam evaporate alloys onto turbine blades.



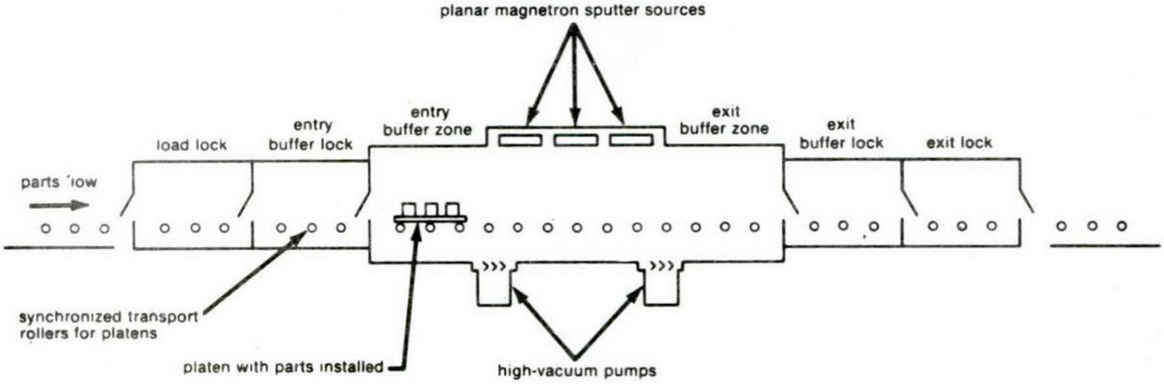
12. Complex shape part coater -- photo of e.b. turbine coater.



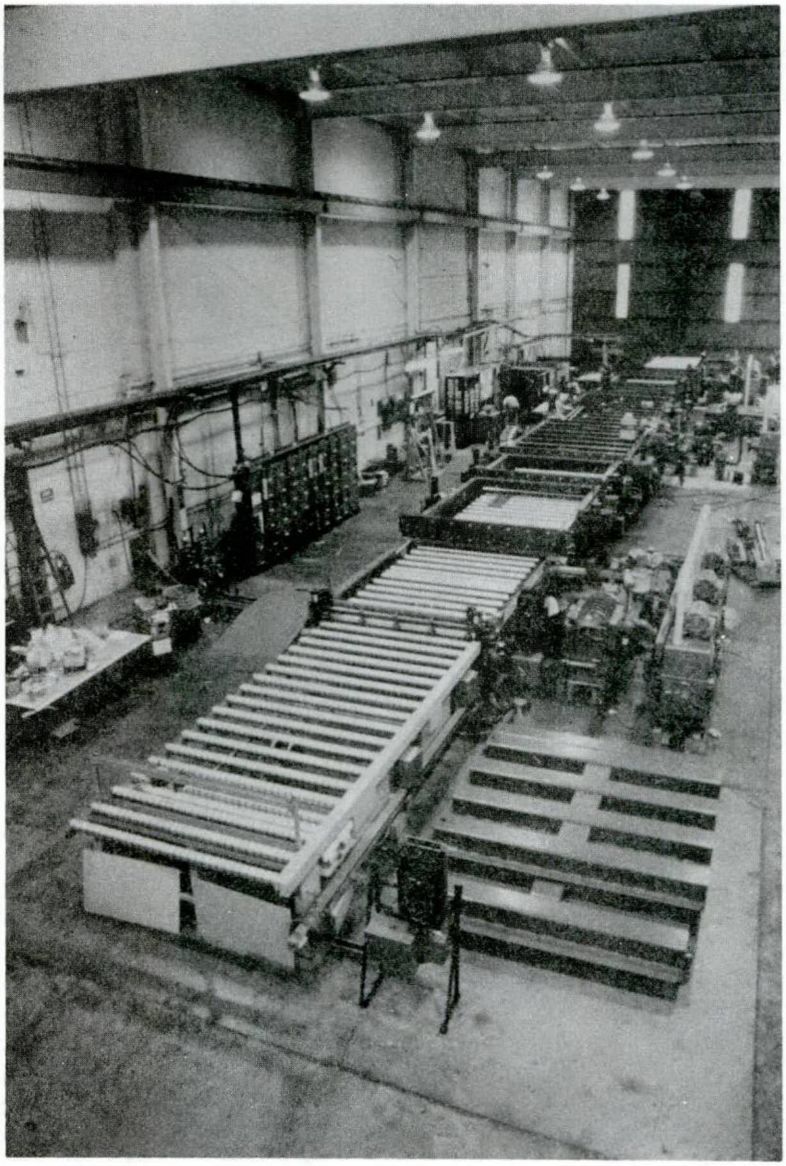
13. Continuous flexible coater -- Flexible substrate batch coating system diagram.



14. Continuous flexible coater -- Continuous strip line for vacuum processing of metals, paper, or plastic.



15. Rigid substrates -- semi-continuous in-line production glass coating system schematic.



16. Rigid substrates -- photo of in-line glass coater.

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Vacuum Coatings
Session A

Magnetron Sputtering of Metal At High Rates

David C. Hinson
Materials Research Corp.
Orangeburg, NY

MAGNETRON SPUTTERING OF METAL AT HIGH RATES

By David C. Hinson
Materials Research Corp., Orangeburg, N. Y.

The sputtering deposition of metal at high rates would allow for the replacement of plating and in certain circumstances, has become economically feasible with the advent of Magnetron Sputtering. A review of the basic principles of Magnetron Sputtering and the equipment available for depositions will be presented.

New types of metal structures which produce a more concentrated (FOCEST) deposition pattern will be discussed. Such patterns have been used to deposit copper at rates of 200μ"/minute on ceramic substrates.

A-3

Vacuum Coatings
Session A

Coatings by Conveyorized Atmospheric CVD

Nicholas M. Gralenski
Watkins-Johnson Co., Scott Valley, CA

COATINGS by CONVEYORIZED ATMOSPHERIC CVD

by
Nicholas M. Gralenski
Staff Scientist
Watkins-Johnson Company

ABSTRACT

Chemical Vapor Deposition is one of many methods which can be used to coat surfaces. It has some tradition of being "witchcraftish" but it is now much more highly developed and reduced to production practice. Much development work is underway. Films are generally in the 200 to 20,000 Angstroms range.

Production oriented equipment design, the films and processes available, film characteristics, film uses and future trends are presented.

EXTENDED ABSTRACT

Coatings can cause a great change in the surface properties of materials. As more coatings and techniques become available a wider range of material properties can be selected for a wider range of substrates and applications.

One of the newer coating techniques is called CVD or Chemical Vapor Deposition. CVD processes can be operated below atmospheric pressure (called LPCVD for Low Pressure CVD), induced at lower temperature by ionizing the reactive gases (called Plasma Enhanced LPCVD), operated at atmospheric pressure (APCVD) and above (High Pressure CVD).

APCVD is the simplest and most reliable since there is no need for vacuum systems, plasma generators, pressure vessels or sealed interlocks. The subject of this discussion is the status of fully conveyorized continuous APCVD for a variety of films and applications.

CVD coatings are typically produced by the reaction of chemicals at a heated surface. An oven or furnace is thus a key part of the equipment makeup. Conveyor furnaces have a long history of dependable, production oriented cost effective service in many industries. In our case, a long history with conveyor furnaces for electronic applications (thick film firing, hydrogen brazing, glass sealing, reflow soldering, etc.) preceded the beginning of development of conveyorized CVD.

In 1972 the work began to add CVD to an established furnace technology. Hydrogen furnaces border on CVD since the gas is chemically active as opposed to passive oxidation protection. A furnace liner or muffle, (essentially a horizontal tube) is used to contain the firing atmosphere. A metal mesh belt carries the work through the muffle. In operation the work is simply placed on the belt, goes through the firing process automatically, comes out done on the other end. The object of adding the CVD feature

was to retain this production orientation for the making of thin films.

The furnace is not filled with chemical vapors for the production of thin films as in the case of hydrogen, since the dust and debris of chemical reaction products would soon intolerably foul the muffle. Instead, a coating chamber, about five inches long, is located near the center. The work is heated to reaction temperature, becomes coated in the chamber, cools, exits. A stable chemical "bubble" must be maintained in and only in the chamber in spite of the belt and work moving through continually.

Many of the coatings of interest are very refractory compounds. Quartz (silicon dioxide, SiO_2) is a good example. Quartz has a boiling point of about 2300°C. The prospect of evaporating quartz to a gas which can then be transported and metered to produce a high quality coating, is virtually impossible. It is an amazing character of CVD that such refractory material as quartz, not even molten below 1700°C, can be applied as a microscopically dense uniform film without any temperature exceeding 400°C.

The trick is in the chemistry. Chemicals containing the necessary ingredients, sufficiently volatile and reactive for practical operation, are selected and brought together for the film forming reaction in the coating chamber. In this way the working or handling properties of the starting materials are completely unrelated to the film material. In the case of quartz, silane, a gas at room temperature, reacts readily with oxygen at 400°C to produce a coating of pure glassy silicon dioxide, quartz.

Clearly, a very large number of these chemical combinations exist. Theoretically, any material could be produced this way. Practically, however, a large number of parameters must be resolved for each chemical combination before the process is understood and the potential realized.

Although the technique, especially for production, is relatively new, many films and processes have been developed and used in substantial quantity for digital displays, semiconductors and solar cells. Development is expanding rapidly. The oxides as a class can be expected to be the easiest since they would not be sensitive to accidental intrusion of air in an atmospheric pressure process. However, it has been demonstrated that pure metals, silicon, silicides, nitrides, etc. are within the scope of practical productive equipment design. The principles involved in atmospheric CVD; production oriented, cost effective, efficient use of materials; are paving the way to a wide variety of new and useful structures and functions.

References:

1. N. Gralenski, ISHM-Internepcon, Tokyo, Japan January 18, 1983.
2. L. W. Winkle, C. W. Nelson, Solid State Technology, October 1981.


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