Proceedings of the 29th Annual TECHNICAL CONFERENCE

SVC

SOCIETY OF VACUUM COATERS

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SOCIETY OF VACUUM COATERS
EXECUTIVE COMMITTEE MAY 1, 1986

Views expressed herein are solely those of the authors. The papers have not been edited. They have been published exactly as received from the speakers at the 29th Annual Technical Conference of the Society of Vacuum Coaters.

President's Message

The 29th Annual Technical Conference of the Society of Vacuum Coaters (SVC) continued our tradition of successful meetings. Last year's count of 29 papers presented rose to 43 in 1986. This year's total attendance exceeded last year's total. And the broader range of companies that sponsored the Reception/Exhibition—29 in 1985, but 37 in 1986—represented more fully the diversity and scope of the vacuum coating industry and of our Society.

The concurrent technical sessions were expanded to include new areas such as Compact Disc Technology and Industrial Coating Technology. The popular SVC Process Seminar, now in a restructured format more conducive to questions and answers, proved once again to be a highlight of the Conference. And three Short Courses sponsored by the American Vacuum Society continued a fruitful affiliation that we plan to continue in years to come.

I would like to thank SVC's supplier members who sponsored the Reception/Exhibition. You will find a list of these companies between the technical papers and the advertisements in the proceedings. These companies are contributing crucial support to your professional society, and we hope that you will patronize them whenever your needs call for the products or services they provide.

We owe a special thanks to the SVC Executive Committee whose members worked long and hard to bring you a complete and worthwhile program. Without their support, our conference would not have been nearly as successful.

And on behalf of the Executive Committee of the Society of Vacuum Coaters, I would like to thank you for your continued support of the programs and activities of the Society. We look forward to seeing you in Boston, Massachusetts for the Thirtieth Annual Technical Conference, April 27-May 1.

Neil M. Poley
President

Preface

As stated last year, it is the continuing objective of this Committee to present programs of technical papers which are of significant educational and informational value to the membership of the Society of Vacuum Coaters. Our goal is to meet your needs and, to do so, we need your input.

Many of you who attended the 29th Annual Technical Conference completed the conference evaluation forms, for which we thank you. To those of you who may have additional comments and particularly to those of you unable to attend this conference, please let us hear from you. Let us know if you would like to serve on a technical advisory committee, present a paper, or offer ideas for future papers. We welcome your thoughts.

You will find published herein the manuscripts of the papers presented at the Conference.

We would like to extend a special note of thanks to the suppliers who sponsored and participated in the reception/exhibition, and to the many members and speakers who helped to make the 29th Annual Technical Conference one of our best yet.

Our remarks would not be complete without acknowledging our Immediate Past President, Doug Chambers, and President Neil M. Poley, for ongoing devotion and leadership to the Society and to the profession.

Respectfully,
The Executive Committee

The text for the following papers presented at the 29th Annual Technical Conference were not available for inclusion in the Proceedings:

Microstructure and Related Properties of Thin and Thick Film Coatings
Karl Guenther
University of Alabama

Paralyne Conformal Coatings for Optical Applications
Roger Olson
Nova Tran

Single Pumpdown Multiple Layer Coating Systems
Dr. Ron Thomas
Polar Materials

Accelerating Solvent Removal by Use of Infrared in Conjunction with Three-Dimensional UV Curing
Curt Leach
Heraeus-Amersil

Proper Disposal of Hazardous Waste
Tom Keyse
Rollins

Ion Beam Plating with Electron Beam Hollow Cathodes Discharges
Hans Richter
Richter Precision
Koji Moriyama
Ulvac

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Contents (continued)

Concurrent Trends in Optical Disc Technology

R. Morrison, Mining & Manufacturing

Optical recording media can be classified into three categories: pre-recorded (read-only), write-once, and erasable.

Pre-recorded media includes those products for which all of the information or data is incorporated on the disk at the time of manufacture and cannot be altered by the user. The best known example is the compact audio disk, but also included are videodiscs and CD-ROM or read-only computer memory.

The second category, write-once, consists of media on which information is written by the end user, but once written, cannot be altered. It thus becomes a permanent record which can be stored for long periods of time and can be re-read at will.

The third category, erasable, is also written by the end user, but can be erased and rewritten, much like a magnetic disk.

The most important characteristic of all optical media is high-density, low cost storage capacity. A typical capacity is 500 Mbytes on a 5 1/4" disk, or about 800 times the storage capacity of a magnetic floppy disk of the same size.

GENERAL PROCESS SEQUENCE

The fabrication sequence for optical disks of all types can be described in the following generalized process steps:

Data (signal) preparation and formatting
Master fabrication
Stamper (tool) fabrication
Disk fabrication (molding, replication)
Thin film coating

Substrate disk diameters range from 3 1/2 to 16 inches with the great majority in the range from 4 3/4 to 12 inches. Substrate materials include aluminum, glass and plastic, with

PMMA and polycarbonate constituting the principal usage. The physical properties of these plastic materials have a major impact on processing technology and will be discussed further.

Optical recording substrates are, in general, replicated or molded with circular or spiral tracks or grooves in which the data is recorded and which aid in tracking. The grooves have a center-to-center spacing of 1 1/2 to 2 microns and are about two hundred angstroms deep. In the case of write-once or erasable media, the grooves frequently contain some format data such as track identifications.

The rest of this discussion will be directed primarily at thin film coating materials and process technology as related to write-once and erasable media.

WRITE-ONCE

The majority of effort on write-once optical media has been directed toward four basic approaches. In all of these approaches, the heat generated by a laser beam focused to a small spot (approximately 1 micron in diameter) is used to permanently alter the reflectivity of that spot relative to the surrounding material. After writing, the presence or absence of a written spot is detected by the reflected light from a laser beam operating at a lower power level which does not cause any change in the recording material.

In the first of these four types of write-once media, a bubble is raised on the surface of a thin metal film by gas generation in a polymer film below the metal film. The distortion of the reflective metal film changes the reflection of light from that spot. In the second type, a pit is formed in the reflective layer by an ablative process. The resulting pit or hole in the reflective layer produces a non-reflective spot. The third approach capitalizes on an optically tuned anti-reflective tri- or quadrilayer structure in which the disruption of a thin but critical layer in the structure produces a large increase on reflectance. In the fourth approach, an amorphous layer is converted to a crystalline film by a non-reversible, heat induced, phase change.

The challenges of bubble-forming write-once media have included achieving consistently high contrasts between the written and unwritten areas (high carrier-to-noise-ratios) and in achieving consistently controllable transition or threshold levels for writing.

Ablative or pit-forming write-once media has typically used tellurium or tellurium based alloys in the thin film construction. Phase-change media has also in some cases used tellurium containing alloys. Tellurium based materials are used because of their low melting points and consequent ability to be vaporized or otherwise altered at low temperatures. A characteristic of tellurium based materials is their tendency to oxidize, resulting in a lack of environmental stability. Thus, much effort has gone into the development of oxidation resistant alloys and protective coatings. Also of concern is the degradation of adjacent areas of media by material which is physically scattered during creation of a pit by ablation.

Polymer dye based materials constitute an important class of ablative write-once media. The light absorbing material is a polymer dye which is applied by a non-vacuum process resulting in some inherent cost advantages.

Optically tuned write-once media demonstrates excellent threshold properties and carrier-to-noise ratios, but requires unusually tight control of thin film layer thicknesses, properties and uniformities.

Write-once (and erasable) media cannot easily take advantage of the elaborate error correction schemes which are used for pre-recorded, read-only disks. Therefore, a high premium must be placed on low uncorrected bit error rates. The specifications for these uncorrected BER's are in the 10E-5 to 10E-6 range. This in turn requires that all disk fabrication operations are performed in class 100 clean room conditions, and that mastering and replicator tool-making operations are typically performed in class 10 to class 100 clean room conditions.

Bit-error rates are also an important characteristic of media lifetime. Since the error rate may be expected to increase as a disk ages, typical specifications require that the BER at a disk's end-of-life (e.g. 10 years) either equal the original BER requirement or possibly allow a small increase. Thus, accelerated life testing and lifetime projections may depend heavily on BER changes.

ERASABLE (E-DRAW)

Magneto-optic media utilizes a trilayer or quadrilayer thin film structure consisting of dielectric (optical spacer) layers and multicomponent magnetic film layers. The magnetic films are rare earth-transition metal alloys for which both the structure and composition are critical.

Phase-change based erasable structures are commonly tellurium based alloys which again require close control of film composition and structure. As in the case of other tellurium based alloys, environmental stability and resistance to fatigue are significant problems.

THIN FILM COATING PROCESS CHARACTERISTICS

Coating processes which are used for optical media cover the full range of thin film processes, including thermal evaporation and sublimation, sputtering (RF and DC), reactive sputtering, and plasma deposition.

Write-once and erasable media structures typically consist of 3 to 5 thin film layers, consisting of reflector, dielectric (also used as chemical barrier layers), magneto-optic, bubble-forming (polymeric), and otical absorbing layers. Film thickness and uniformity requirements are $\pm$ 5% to $\pm$2% for films in the range of 100 to 1000 angstroms thick. Although the technology to accomplish this degree of control is well developed in the optical coating field, the ability is less well developed when applied to high volume production on large area, non-rigid plastic substrates.

Another strong trend in the development of write-once technology is the move toward double-sided media, i.e. disks with active recording surfaces on both sides. This can be achieved by glueing two disks back-to-back or by fabricating the disk initially as a two-sided product.

Write-once and erasable media can be designed as either substrate-incident or air-incident media. In the case of substrate-incident media, (which also includes CD-audio and videodiscs), the media is placed on the "back" or inside of an optically clear substrate, and the information is read through the substrate. This construction requires that the substrate material have excellent optical properties, since the read-write laser beam must be focused on the media, through the substrate. In this case, the thin film media layers must be protected with an overcoat or protective sheet, which need not be transparent. A double-sided disk is produced by bonding two such disks back-to-back.

Air-incident media consists of active thin film layers which are read and written from the thin film side of the substrate and the media is in contact only with air on the non-substrate side.

The optical properties of the substrate are no longer important and only its surface topography and chemistry are critical. This approach allows aluminum or other opaque materials to be used for substrates. The media must be physically protected from environmental and physical damage, which is accomplished by an optically clear cover bonded to the substrate, but which is not in contact in the active area.

For two-sided air-incident media, high volume production economics favor producing a single two-sided disk as opposed to two separated disks which are then joined, however, fabrication of two-sided disks imposes some significant challenges on the production processes. The thin film coating processes now must be applied to both sides while insuring that no physical contact is made to the optically active area on either side. This approach also places a premium on thin film coating yields, since in this case, the product yield becomes approximately the product of the separate yields for each of the two sides.

Since the coating process is applied to discrete parts as opposed to a continuous sheet or web, the tendency has been toward batch vacuum coating processes, using planetary tooling to achieve higher throughput. It is clear, however, that to achieve good process control and obtain high yields in large scale production, it is desirable to develop continuous processing methods. The use of continuous processes in turn favors the use of sputtering deposition processes as opposed to E-beam or thermal evaporation, particularly where alloys or dielectric films are required. In these cases, the need to maintain control of film composition and uniformity for long periods (100-300 hours) of continuous operation makes evaporation methods less attractive.

The use of plastic substrates and polymer ecapsulation materials results in constructions which are inherently non-heremetic in the usual meaning of the term. The result is that a premium is placed on the inherent chemical stability of the thin film layers themselves. Trace contaminants in the materials of construction become critical at levels similar to those of concern in the semiconductor industry, but for different reasons. Since the written feature (bit) size is only about 1 micron, any contamination which results in a 1 micron defect (pinhole, corrosion product, or chemical alteration) in any of the layers will cause a data error, and will typically become the nucleation site of further degradation which continues to grow over ever larger areas.

Polymeric substrates, chiefly PMMA and polycarbonate, are desirable because of their light weight, lack of fragility, good optical properties (required for substrate incident products) and particularly their potentially low cost. Their relatively high rate of outgassing, however, has a major process impact for write-once and erasable media. Their rate of outgassing is 2 to 3 orders of magnitude higher than clean metal or glass. The outgassing material is 95% or more water vapor. The effects of this outgassing are significant for write-once and erasable media because of their greater sensitivity to changes in film chemistry, structure or topography, compared to the single reflective layer of read-only media. The problem cannot be fully offset by greater pumping capacity because this large amount of water is emitted precisely at the surface to be coated. For example, at an outgassing rate typical of many polymeric materials after 10 minutes in vacuum at room temperature, the rate of emission of water molecules at the surface is approximately equal to the rate of arrival of aluminum atoms at a deposition rate of 20 angstroms per second. Thus, while the use of vacuum systems with large pumping capacities for water vapor may be necessary to handle substrate outgassing, caution must be exercised not to confuse indicated pressure with the actual conditions at the critical surface of the substrates.

DEPOSITION EQUIPMENT

The proliferation of disk sizes, substrate materials and media constructions has resulted in the design of highly customized coating equipment for write-once and erasable media. These machines, for either single or double sided coating, consist of a series of deposition stations which usually have some degree of isolation between stations because of the variations in the coating processes. Since particulate contamination is so critical, special attention must be given to hardware designs which minimize such contamination.

Multistation, cassette-to-cassette disk coaters of the type being developed for use for magnetic media seem to be an attractive alternative in terms of throughput and cost. The use of this kind of equipment, however, will require the solution of major process problems relating to high rate deposition of uniform layers of dielectrics, polymers and alloys. Polymer substrate outgassing is also a major problem for this approach, in which a typical cycle time may be as short as 15 seconds. On the other hand, the cost of such equipment is typically much lower than large custom systems, and in addition, such equipment tends to be more readily reconfigurable to accomodate product design changes.

SUMMARY

Current optical recording media fabrication makes extensive use of existing and well developed thin film process technology. Unique, however, are the specific material and process combinations and unusually stringent requirements for process control. Also unique is the extreme requirement for particulate cleanliness applied to large coating areas.