“A Glance in the Rear View Mirror at the Evolution of Vacuum Roll Coating.”

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Agenda for Presentation

- Introduction
- Early History—Mid 1930's-1940's
- The Emerging Years--1950's- mid1960s
- The Next Steps 1960's-The Present
- Conclusions
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Introduction

- Roll to Roll (R2R) vacuum roll coating has come a long way, as we know it today, since its start in the early 1930's.
- Advances were driven by improvements, discoveries and developments made in such areas as:
  - Machine design.
  - Substrate material improvements.
  - Deposition materials and techniques.
  - Process Improvements including monitoring, close loop control and data acquisition.
  - New applications and market demands.
- Other dynamics included:
  - Lower prices, in most cases.
  - Flexibility of end products.
  - Performance of bulk properties at tremendous weight savings.
  - The ability to create materials with properties that are not easily duplicated, or in some cases impossible to do in the bulk state.

Introduction cont.

- In 2005 the current size of the R2R market was estimated to be in excess of $4 billion, although this number includes a lot of products where value steps were added to the vacuum deposited layer to enhance their overall performance. So, even with that consideration the R2R vacuum coating industry is substantial.
- Much of the information collected for this report is anecdotal and has no official reference.
- A more detailed account of the R2R history can be found in the Vacuum Roll Coating chapter contained in an SVC book titled, “50 Years of Vacuum Coating Technology and the Growth of the SVC.”

Early History

- R2R vacuum roll coating, as we now know it, started in the mid 1930's.
  - Credit for original developments is usually given to a Hungarian scientist, Paul Alexander.
    - Commissioned 2 coaters built by Konrad Kurz of Germany, one sent to Germany and one sent to Cecil Whiley of the UK.
    - He later moved to Belgium and then Princeton U. in the USA.
    - Started Alexander Vacuum Coatings, later bought by Continental Cans
- First commercial product made by Whiley was gold leaf to replace manually hammered product.
  - Could make in 1 day (~400 sq. M) that took a week of manually hammering to produce.
  - One popular use was to make monograms for men's hat bands.

Early History cont:

- Impact of WW II on R2R Vacuum Coating.
  - Development of radar jamming chaff for airplanes based on Al/glassine due to better dispersion and lower weight than AL foil.
  - Development by Bosch of capacitors made by R2R vacuum deposited Al, resulting in significant weight savings for airplanes over standard foil based capacitors.
  - During this time the US Government declared all German Patents filed in the US null and void.
    - Taking advantage of this ruling companies such as Hy-Syl (later became Madico and then bought by Lintec), National Research and Continental Cans got their start in vacuum R2R coating.

Early History cont:

- One initial major use for R2R vacuum coating was to convert paper stock to make labels.
  - Problem was that the relatively rough surface of the paper resulted in a diffuse reflection, not the “bright” specular reflection that the end user wanted.
  - Problem solved by over coating the paper with a lacquer.
  - This process of coating with lacquer, along with those used in the decorative hardware business led to the famous descriptive expression coined by the late Michael Hansen, that “SVC was the suck and spray society”, since many of the original members of that society came from the decretive and lacquer businesses.

The Emerging Years: 1950's to the 1960's

- Characterizing The early 1950's.
  - Coaters were very simple with primitive substrate transport systems with maximum coating speeds of 3-4 M/min.
  - Diffusion pumps were based on Hg or glycerin oils, which took hours to pump down and had difficulty handling the high out gassing of natural based substrates used, such as paper, glassine and CTA.
  - Thermal evaporation boats were made of carbon that would last only 1-2 hours due to corrosive nature of the melted Al.
  - Al wire feed systems were crude and the Al wire purity was suspect at best.
  - Due to all of the above, production cycles were of the order of only several hours resulting in a run of ~ 1500 lineal ft/cycle.

The Emerging Years cont.

- Steady improvements were made in the 1950's and early 1960's
  - Equipment manufactures came up with designs to isolate the unwind and rewind sections from the actual coating chamber.
  - Major improvements in the drive systems increased coating speeds up to 100's of M/min. Today, coating speeds of approximately 1000 M/min. are routinely achieved in many Al thermal metallizers.
  - Pump down speeds improved to 10's of minutes with the use of halogen based hydrocarbon oils in the diffusion pumps and the addition of Stokes and/or Roots booster pumps and Polycold traps.
  - In the 1950's Metallwerke found that by coating the carbon boats with W, WB or BN life times improved. Union Carbide took the next step and made the entire boat out of BN or TB_2. With these improvements boat lifetimes increased to 1 shift.
  - PET films were introduced to the industry by ICI. OPP wasn't far behind. Their advantages were good vacuum compatible, low out gassing, and being relatively flat and smooth. OPP is a less dense polymer then PET so its sq. M yield per kilogram is higher. This makes it a cheaper film to use, even though some of its properties are not as good as PET. However it is adequate for most food packing applications.

The Emerging Years cont.

- Some equipment companies instrumental in driving these improvements in R2R vacuum coating were:
  - Leybold Hereaus L-H), General Engineering, Ulvac, Galileo, Dusenbury, Airco, Sidrabe and Van Ardenne.
- End users also add their own improvements. Some of these were:
  - Gomar, Scharr Industries, National Metallizing, Camvac, Continental Can and American Can. These companies tended not to publicize their improvements to keep them confidential.
  - Air to Air designs were also tried for flexible R2R vacuum coating.
    - Some of the companies known to the author that did this were Ulvac and Airco.
    - Problems were with substrate damage and the enormous pumping capacity needed .
    - Strip steel is still done this way.

The Next Steps: Mid 1960's to Present

- Limits of Al based vacuum coated films.
  - By the mid 1960's it started to became obvious that were some limitations associated with thermally deposited Al films.
    - While good for opaque food and industrial packaging or microwave applications, they were generally too reflective with relatively low VLT properties for emerging applications such as solar control films, touch panels, photo copiers, electrostatic printing, etc.
    - Also, thermal evaporation did not lend itself well for coating other materials. Thus, sputtering and e-beams started to be adapted to R2R coating.
- Planar magnetrons, invented by John Chapin and Airco in the 1970s and rotatables, invented in 1982 at Shatterproof, proved to be viable solutions.
    - While much slower sputtering could deposit a wide variety of materials at a reasonable coat, but not close to rates of thermally evaporated Al.
    - Sputtered films could have higher VLT, lower R, good environmental stability (dependent on material) and made with properties usually unavailable in the bulk state.
    - It should be noted that the large area glass coating companies showed the way in this adaptation.

The Next Steps: Mid 1960's to Present

- Sputtering cont.
  - Material advances made using sputter deposition:
    - ITO on flexible substrates. Sierracin Intrex is given credit for the commercial introduction of ITO/ flexible webs n 1978. They ordered the first commercial sputter based ITO coater (net 60") in 1980 from L-H.
    - Southwall developed Heat Mirror films (D/m/D) based on J.C.C. Fan's work out of MIT. They ordered the1st ever commercial coater (80") in 1978 from L-H..
    - Martin Processing, now CP Films, converted a metallizer to a sputter coater in the late 1970's to make solar control and photocopier films. They later ordered a coater from L-H in 1982.
    - In the 1980's OCLI entered R2R coating ,making a wide variety of products using both thermal and sputter based coatings.. This effort culminated in the development of their OVP security products. It is believed they use a combination of e-beam and sputtering for this product.
    - Ben Meckel of DTI built his own 80" sputter coaters in the early 1980's to make solar control films and aerospace based products.
  - Japan enters the market in the 1980's with such companies as Teijin, Toray, Nitto Denko, Oike, Toyobo and Sumitomo Bakelite. ITO is their favorite film type.
  - There are now R2R sputtering based companies in at least Korea, Taiwan and Mainland China.

The Next Steps: Mid 1960's to Present

- Other Events in R2R coatings of note. Cont.
  - In the 1980's very specialized R2R sputter coatings were used to develop "stealth" coatings by several companies for use in aircraft to minimize their radar signature. The collapse of the "cold war" brought this effort to a rapid stop.
  - In 1974 the concept of the "Polycold" was introduced. This refrigerated panel helped tremendously in pumping volatile materials in the vacuum coating chamber.
  - While electron beam guns (EB) where first used by Von Ardenne for coating strip steel in the 1960's they were not adopted to coating polymer substrates until the late 1970's and early 80's, with the exception of Sierracin. By the 1980's enough improvements were made in the gun designs to allow them to be used on Al metallizers for very high speed and wide width ; production. One of the advantages of EB is that a wide variety of materials can be thermally deposited at high rates with them.

The Next Steps: Mid 1960's to Present

- Other Events in R2R vacuum coatings of note.
  - In the 1960's Sieraccin developed a R2R e-beam based roll coater for deposition of Au used as transparent heaters for car windows.
  - In the 1970's and 80's Sheldahl developed a series of aerospace and satellite coatings and flex copper films produced by R2R technologies.
  - By 1985 Coulter reported the production of CdS based solar cells deposited on SS foil made on a 12 RFI cathode R2R L-H coater.
  - During the 1980's 3M and IBM introduced several R2R coated polymer based products, with flex circuits one of the key ones.
  - Other coaters who started up in this period were VDI and Techni-Met. Both of this companies initially concentrated on metallic sputtering.
  - In the 1980's GE developed the PML process, first used to make capacitors, and later surface smoothing, surface activation and ultra high vapor barrier coatings. Sigma Tech., Vitex and others are still using it.
  - In 1992 Airco developed a PECVD process to deposit SiO_2 layers for transparent barriers for use in food packaging. General Vacuum later licensed this technology. Similar PECVD processes are doing being used now by Dow Corning and GE to develop ultra high barrier coating.
  - A number of companies developed thermally evaporated transparent vapor barrier films for use in food and industrial packaging usually using oxidizing plasmas to convert the evaporated materials to oxides ,with e-beam evaporation the technology of choice

The Next Steps: Mid 1960's to Present

- It was during the 1980's that two professional entities started focusing on R2R technologies as separate topics for their annual conferences. These were:
  - The SVC with their creation of the Web TAC, whose purpose was to promote R2R web coating and develop a dedicated session for presenting technical papers on R2R web coatings
  - The Bakish sponsored "International Conference on Vacuum Web Coatings." This activity was later incorporated into AIMCAL, where it became an integral part of their annual Fall Technical Conference program.
- The focus that these two conferences brought to R2R vacuum coatings and the myriad of opportunities to network and learn about advances in this technology proved to be a real catalyst for growth in this business.

Conclusions

- The vacuum R2R coating business has had a very complex and exciting history over the last 70 years.
- The R2R industry has advanced very rapidly over the last few decades.
- We were dealing in nano technology well before the word “nano” became so popular.
- However, we as an industry need to recognize the challenges that the development of nano particles, conductive polymers and printable electrons present. For example Sumitomo Chemical announced earlier this year a nano particle based printable solvent based material with reported properties of 90% VLT at 100-200 ohms/sq. and an extendibility of 50 times. Several companies have introduced devices that us nano particles or conductive polymer for TC coatings.
- The author believes that vacuum R2R coating and the above technologies will most likely follow parallel paths in the future, as one material cannot do everything well.
- However, we must make sure we continue to make progress and invest in the future before it is upon us.

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- Disclaimer:

This trip down memory lane was a one person effort, but with lots of input from others. However, I am sure that some high and low spots have been missed and some contributing companies and individuals have been left out. This was not done on purpose. Also some of the earlier dates were hard to pin down and might not be exact. For this I apologize. However, this is a living work and I invite any comments or corrections from all of you afterward the presentation.