

The magic goes out of stamper electroforming

Stamper electroforming has lost much of the magic and mystery that used to surround this seemingly crude, chemical process. However, *George Cole* discovers that there is still room for the artisan to meet the differing needs of the various disc requirements



The new Digital matrix SA4m four cell electroplating system

SINCE THE ARRIVAL OF THE COMPACT DISC, new formats have come along and created new challenges for those working in the stamper electroforming sector. Stamper production has always faced a trade-off when it comes to the ideal physical specifications, as Chris Jayne, process engineer for Digital Matrix, Europe explains: "The defining line between ductility and hardness of the finished stamper is a little blurred. A stamper that can flex to the rapidly changing environment of the mould cavity is essential. This equals ductility! At the same time, longevity of the stamper is required to prevent multiple changes in mass production facilities. This equals hardness!"

Ian Locke head of design at Sibert, adds: "A harder stamper will last longer on the mould and is especially important for high volume runs. A harder stamper will normally also produce a better punched stamper ID and OD and have less deformation after punching and back finishing. Nickel has a certain memory that will allow the stamper to return to the original flat state, even if it is deflected very slightly during the punching process. However, it is more difficult to work with a softer stamper." He adds that the overall stamper hardness is controlled by the electroforming process with regard to program and solution, "We do not dictate a specific stamper hardness value, but prefer to work with customers and the relevant electroforming OEM's in order to ensure that the punching equipment works correctly within reasonable and recommended limits."

So were these pressures intensified with the launch of formats like DVD? And does the size of the run affect operations? Jayne thinks not: "The length of the disc production run is irrelevant. The difference between CD stampers and DVD stampers is purely the amount of information recorded. The physical properties are identical in that they must be flat within 2% total thickness variation [TTV], of the overall 295 micron thickness, and that they are free of imperfections on both the information side, and the polished rear side that sits against the mirror surface finished mould."

Jayne also thinks that the hardness of the stampers is irrelevant, in that a standard nickel sulfamate solution will only give hardness in the range of 170 to 240 Hv, which is dependant on the age of the solution. "If a higher hardness figure is required, (generally for recordable formats)," he adds, "then chemical additions will have to be made on a regular basis. These chemical additions will require monitoring and replacing on a shift by shift basis, as they are a consumable within the solution make-up, and diminish in quantity as they are grown into the stampers."

Stefan Knipper, product manager, microtechnologies at Technotrans, notes that large orders are split onto several machines to increase throughput and so there's not a big difference between shorter or longer runs when it comes to its effect on the stamper. Pascal Andre, Plasmon's technical manager, says: "DVD electroforming market has only seen small changes in the last years. As the run sizes are smaller the pressure on delivering the stampers to production has

increased. But the basic principles in electroforming have not changed and will not change." The parameters and the effects of parameter changes in electroforming are well known, he adds, noting that it's very hard to keep control over the process if you have to change the settings per order. Andre thinks that the potential cost/time savings by tuning the stamper per order would probably be counter-productive as the costs of tuning the process are much higher than the potential saving.

IT IS FAIR TO SAY THAT IN THE EARLY DAYS of the optical disc formats, electroforming was something of a 'black art', with educated guesswork, trial-and-error and operator experience playing a major role in the finished product. But is that still the case today or has science completely taken over the process? Knipper thinks that: "The processes are very much standardised, although there are some still some variables. These days, the stripping of photoresist is automatic, so you don't need the know-how to run the machines to do a good job. Back in the early 90s it was more of a black art. When I worked at Sonopress, there would be operators wearing rubber coats running in and out of the department, but those days are over!"

Jayne says that he meets many people during installations who are experts in their own right. "It doesn't matter what training that we give before we leave them to run the equipment alone, because when we return for a courtesy or a maintenance visit, we often find that they have developed their own way of carrying out certain operations."

After all, these operators are the ones who are using the equipment 24/7, he says. "So as long as they are not brewing beer in the systems, and as long as the end product is to their satisfaction, who are we to tell them it is wrong? So from that point of view, the science is there but the black art is still lurking in the background." But Andre believes that science has now taken over: "Maybe you will still find somebody who claims electroforming is a black art but it has never been – the process parameters have been known from day one. The tuning of the process for new formats (like with HD DVD) follow sound principles as a result of pre-defined tests and trials. There is no magic in production."

THE CD CELEBRATES ITS 25TH ANNIVERSARY this year and so it's fair to ask whether there are any issues left for CD stamper forming? "CD is an established format, but the learning curve is still on-going," says Knipper. He also notes that the move from CD to DVD and other formats raises a number of issues: "Even with old equipment your stampers are usually capable of doing the new formats, although it is usually a difficult process." Although old equipment is not usually so well maintained, "... you can have a 25-year old plating machine from say, Polygram, and if the guy working the machine knows what he's doing, you can get good results." There's a clear indication that the higher the density, from CD to DVD, and DVD to the new formats or recordable discs, the more sensitive the stamper quality is," he says. "I don't think some people realise this and so you have more and more people saying 'it's the same process for CD, so why am I paying more for a Blu-ray plating system?'"

But Jayne thinks otherwise: "My short answer to that question is no, but if you ask a manufacturer or supplier of

stampers to the industry, they will disagree vehemently with me. Every replication facility has its own little quirks and standards when it comes to the appearance and the signal quality required from the replicated disc. The stamper producer or supplier must have a comprehensive overview of all of his customers' requirements, enabling him to meet these various demands." Jayne is not alone in this view as Andre explains: "It's not an issue for us. We still make an occasional CD recording but that's mainly for development work. CD-Recordable on the other hand is still a demanding market. It seems people never stop developments of new applications for these formats."

ENVIRONMENTAL ISSUES ARE A CONCERN TO MANY, so it's no surprise that electroforming industry takes green issues seriously. With its mix of chemicals, energy consumption and disposable materials, there would appear plenty of scope for reducing waste and conserving energy, but how feasible is it? Knipper thinks that electroforming is one of the "greener" parts of the optical disc production process: "All mastering systems use energy, but when you're doing 180mm or 200mm mastering that's already an energy reduction when compared with 240mm. And compared with the energy required for moulding or the sputtering processes, the energy consumption is very small. The consumption of chemicals is low. A water tank unit contains 150 litres, which is enough for nine-to-12 plating cells."

Jayne notes that: "We are finding that more and more facilities are taking their responsibilities seriously, regarding the health implications towards the operators who are using these chemicals on a daily basis. Even in the newer stamper producing regions of the world, it reflects in the increasingly safe and legal disposal of chemical waste materials."

Green issues and cost reduction programs can be combined in an easy and good way in electroforming, says Andre. For example, the chemicals and nickel used can be removed from the water using a simple and efficient processes. "We have been recycling all water since many years now," he adds, "thanks to the aid we received from the local government, the return on investment on the project was within three years and now it's a cost saving." The same goes for the clean-room area, where they try to re-use the energy/heat. "The green policy is part of our total quality program. We eliminated or replaced dangerous or toxic products like acetone, dichromate, hydrogen peroxide and lacquers. We believe it's our responsibility to act responsible and take care of our environment."

But while companies are successfully tackling green issues, the progress in developing common standards within the industry has been slow and painful. So are there signs at last of some movement in this area?

"The short answer to this question is 'no,'" says Jayne, "each replication facility sets its own standards for stamper requirements. As long as the replicated disc is within the laid down specifications, (the Philips Red book etcetera), then there is no need to look any further." Knipper agrees with this view: "There are certain standards but not everyone accepts them, apart from some mechanical dimensions. It's still a bit of a personal issue and companies have individual specifications. I suspect it this situation will probably get worse. Things are getting trickier in this area and you need additional equipment and different workflow, and to re-train your operators to cope with the different variables."

Andre adds wistfully: "I wish! As an independent commercial stamper service company it's sometimes a nightmare when you see all these different stamper specifications. But I must say some of it is cosmetic. The tolerances on a stamper ID, for instance, are given in a value that is smaller than the effect on the stamper ID due to the heating in the mould. It would be nice if the mould-makers could agree on the specifications, but if you have your own mastering in house, this is not an issue. Internally, customers just have one standard for most of the time."

THE STORY IS ALSO THE SAME FOR AUTOMATION. Knipper says that his team has been discussing automation for 10 years now, and developed some possible solutions. "We

made some proposals but the big players looked it and decided not to go there because it was too expensive. There are concepts available – I have several of them in my drawer!" says Knipper. However, one area has been automated. "We automated the stripping of the photoresist," he adds, "we introduced this several years ago and it is now standard in every Singulus product. Some systems can be upgraded too. This takes the responsibility away from the operator – it's very easy to do. The other processes – plating or coating – are not so operator sensitive – he just loads and unloads the machine. It's also important to have a visual inspection, because this is something that is difficult for scanners."

"There is no reason why the process could not be automated other than cost. Due to our contacts around the world we have seen automated process in electroforming at different factories. It's a matter of balancing costs and quality against the profit and reduced flexibility," says Andre. "For a long time, the separation of mother and son stampers has been a major concern. Several people have already proven this can be automated. I think the automation in electroforming the optical industry has not been a success because the costs savings are not that high." Andre also makes the point that the electroforming process is also been used as the 'human' quality control' part of the production process."

Automation of stamper production equipment has been an on-going issue for many years, says Jayne, "A few companies have made forays into this field, but the intervention of the operator is still considered the most efficient way to produce the high quality end product. We are after all dealing with an electro-chemical process that changes with each 90-minute product. Also, from the perspective of an equipment manufacturer, the customer is always looking for the cheapest option, and automation does not come

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cheap!" Knipper doesn't see much progress in the area of automation because: "Except for the new formats, the level of investment will not be high enough to make automation effective. The exception is the new formats – BD and HD DVD – but I don't think these products will be as big as CD or DVD, so the level of investment might not be so great."

The production of recordable media introduces new challenges to the electroforming process. Recordable media is much more of a mass produced item. Pre-recorded media is produced in quantities of hundreds in the minimum, to hundreds of thousands in the maximum. "Recordable media is produced in the hundreds of millions. The recordable media producer literally wants to mount a stamper into a mould and be able to leave it running for days on end producing good product," says Jayne. "The difference, of course, on the information side of the stamper, is that with the pre-recorded disc, there are pit structures that carry the digitally encoded information, whereas the recordable stamper has a continuous spiral."

Andre agrees that there are major differences between the prerecorded and recordable industry. In the recordable/rewritable sector, the production lines have to run without stopping, and the same time the QC reaction time is relatively long. "If we supplied a stamper that failed in replication, it would probably take the replicator at least 30 minutes before he discovered there was an issue. Add up the costs of stamper loss, line set-up time, lost consumables, and I do not think the line would run profitably for at least a week. In recordable stamper production, quality, reproducibility and stamper lifetime are the key items."

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FINISHING, WHICH INCLUDES HOLE PUNCHING and polishing, also introduces new issues, especially for the new high density disc formats like Blu-ray Disc and HD DVD. "These will lead to changes and adjustments in the specifications for stampers, especially the centre hole size and the durability of the materials," says Knipper, "rear-side polishing will become more critical. The small signal difference between the mirror surface and the pit signal will be influenced by the roughness of the rear side. Any roughness will be passed through the material."

Jayne likens the installation of a new system with a new wine. "The longer a solution runs, (some solutions have been running for 10 years plus!) the more it becomes reliable in producing like-for-like product. The polishing problems can be related to the settings recommended for finishing the rear side of the stamper. These settings will change with the maturity of the solution," he says. Jayne also points out that the growth of the nickel crystals is constantly changing, giving a rougher or smoother, harder or softer pre-polished finish. This scenario also applies to the accurate punching of a centre hole in the stamper. The accuracy of the hole will determine the eccentricity of the finished disc in the player. As the nickel changes its crystalline state, it also affects the hardness of the finished stamper, which in turn affects the accuracy of the centre hole. Elongated, oversized and undersized centre holes are just a few of the faults that are encountered during punching.

Andre thinks that overall, the equipment available on the market is doing a good job when it comes to finishing. Good maintenance helps, he adds: "Like in any part of production, you have to keep record of what you're doing, checking the process parameters on continuous basis to keep control on quality and costs."

Measuring and controlling all mechanical parameters is very important (stress, edge of the ID punch hole, thickness and thickness variation). It will provide vital information for the process stability."

THE ARRIVAL OF BLU-RAY DISC AND HD DVD has inevitably brought new challenges for the electroforming companies. With even tighter tolerances, the room for error or thickness variation is much smaller, as Locke explains: "This is very critical as even a small variation in stamper temperature can affect the moulding process. Additionally, if the stamper thickness has a high variation, this will be reproduced in the polycarbonate disc and during use will create a mis-balance. These issues are obviously amplified when manufacturing multi-layer formats requiring two moulded polycarbonate discs, such as DVD. Too much polycarbonate total thickness variation may even prevent the optical disc from loading or playing. An uneven stamper thickness can also result in a stressed polycarbonate disc."

Knipper has identified another issue: "The major challenge for the high density formats is that we're talking about a much smaller bonding gap between the two parts of the different layers of the disc. If a disc has a 20-micron bonding gap and you produce a 10-micron topographic in the material substrate, the stamper tolerance gap is now between 10-30 microns and that has implications for the signal deviation." Jayne adds: "The challenges are essentially the same as for the DVD discs, which took years to appear as an accepted worldwide agreed format. For us in the stamper producing industry, we will always strive to produce the flattest, roundest, most user friendly stamper for the replication industry to produce the highest quality discs possible, whatever the format."

Image on OTO Sept page 20

In last month's *One to One*, the caption on the lead image on page 20 omitted the fact that the picture was of the inside Sibert's SPS Punching Machine with Sibert's HD type option – apologies to Sibert.



Sibert's top line SPS Punching System