UV-NIL with optimal droplets

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ABSTRACT

A homogeneous residual layer thickness in nanoimprint lithography (NIL) is a serious problem in step and flash (UV-)NIL. Improvement of thickness homogeneity could be expected from optimized size of droplets at resist dispensing in case of UV-NIL. The optimization in droplet size must exclude the stamp geometry involving areas in which the resist has to flow laterally over large distances so stamp geometry should be considered at optimization. The paper is devoted to development and critical analysis of an optimizing algorithm, which take into account only filling factor (geometry) of a stamp and does not consider the following resist flow.

In current realization of the approach a specially developed algorithm transfers stamp geometry defined in standard GDSII (or ACAD) format into rectangular (square) cells and calculates the filling factors taking into consideration stamp depth and desirable residual resist thickness. Then depending of the jet model continuous or discreet volume is calculated and saved for further use by control system of a UV-NIL machine.

Keywords: UV NIL, step and flash NIL, optimization, droplet dispensing

1 INTRODUCTION

A homogeneous residual layer thickness in nanoimprint lithography (NIL) is a serious problem in both thermal NIL and in step and flash (UV-)NIL. Improvement of thickness homogeneity could be expected from optimized size of droplets at resist dispensing in case of UV-NIL. The optimization in droplet size must exclude the stamp geometry involving areas in which the resist has to flow laterally over large distances so stamp geometry should be considered at optimization. Also the optimization should consider process of resist wetting and spreading at imprint analyzing resist viscous flow. The paper is devoted to development of an optimizing algorithm, which take into account *only* filling factor (geometry) of a stamp and does not consider the following resist flow.

2 OPTIMAZING APPROACH

In current realization of the approach a specially developed algorithm transfers stamp geometry defined in standard GDSII (or ACAD) format into rectangular (square) cells (Figure 1) and calculates the filling factors taking into consideration stamp depth and desirable residual

resist thickness (Figure 2). Then depending of the jet model continuous or discreet volume is calculated and saved for further use by control system of a UV-NIL machine

Several alternatives could be adopted as jet work model. Two extreme models of jet dispensing are of main interest here (Figure 3):

-a "continuous" model when the jet is able to provide a drop with infinitesimal accuracy and

-"discreet" model when final drop consists of several droplets of some minimal volume.

Other jet models like "threshold" model or "nonlinear in time" model can be easy incorporated in the approach
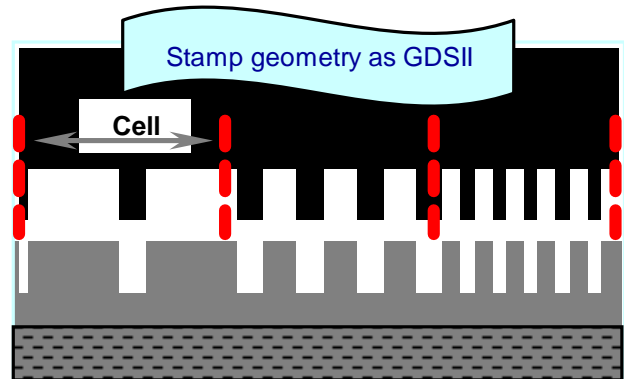

Figure 1 Schematic presentation of stamp defined in GDSII format with different density divided into square cells
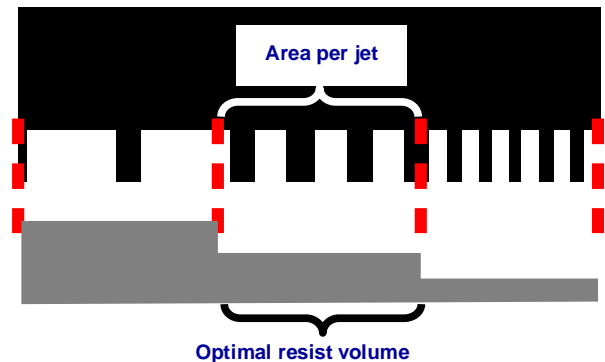

Figure 2 Calculation of ideal resist volume considering stamp depth and residual resist thickness.

Final results as a matrix of volume per elementary area is transferred to a system controlling jet dispensing (Figure 4).
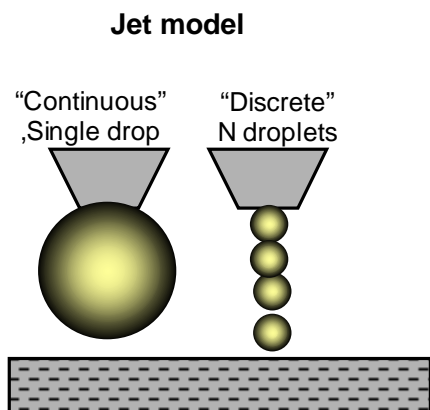
Jet model

"Continuous",Single drop   "Discrete" N droplets

Figure 3 Two extrime jet dispensing model "continuous" and "discrete".
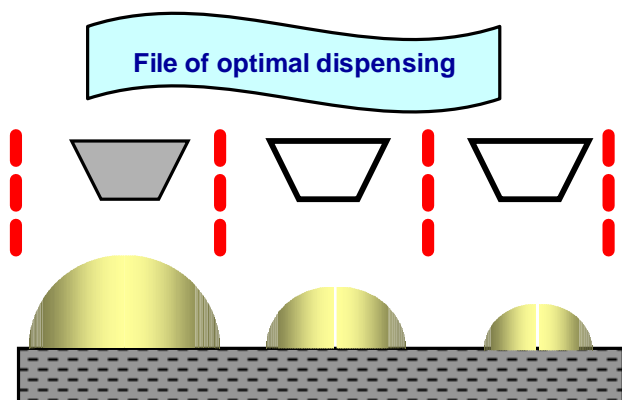

File of optimal dispensing

Figure 4 ".Final data presenting resist volume shoud be deposite by jet in the center of elementary area calculated from GDSII file.

2.1 Continuous model

The first simulation was performed with a test structure, which contains areas with variety of filling factors. The calculations were performed in "continuous" jet model. Schematic 3D presentation is shown on Figure 6.

Figure 5 shows geometry of a binary stamp as downloaded from GDSII format where black area corresponds to protrusions in <u>imprinted</u> structure. Figure 6 illustrates work of the algorithm where 24x24 cells covering the whole test structure are filled with different drops with volumes corresponding to calculated filling factor. Cell filling factor is schematically illustrated in bottom of Figure 6 in form of 3D presentation as drops spreading on a substrate. In reality dispensed resist has a shape of spherical segment diameter of which is dependent on wetting angle.
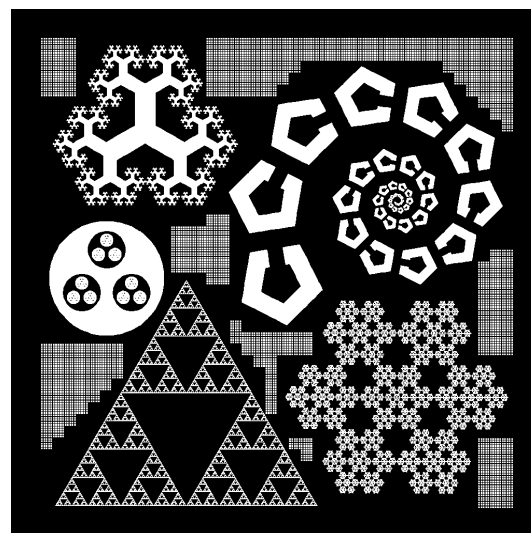

Figure 5 Original binary stamp in GDSII format, black area corresponds to protrusions after imprint

Optimal droplets as balls
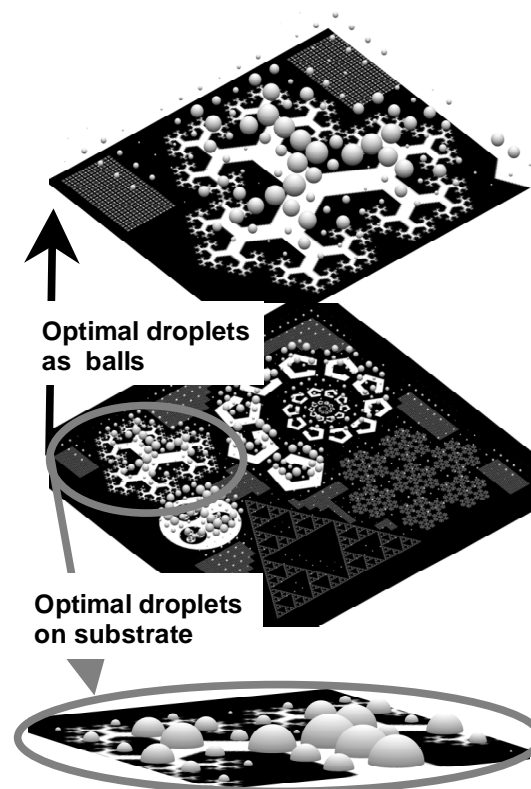
Optimal droplets on substrate

Figure 6 Schematic 3D presentation of optimal resist volume should be dispensed in an each cell (within square area marked in Fig.2). Each droplet comprises a spherical segment corresponding to wetting angle about 90^0. Diameter is calculated in "continuous" model

2.2 Qualitative analysis

Let us make a quantitative analysis of dispensing. Consider a drop of some minimal size V_{min} and find residual resist thickness h if the drop is pressed with an absolutely flat stamp to fill an elementary area of size A. A is equal to $d*d$ where d is distance between jets in line. Then

$$h = \frac{V_{min}}{A}$$

Estimation for typical values A=0.5mm*0.5mm V_{min}=60pl, gives h=240nm. This value is too high to perform optimization of drop value because typical expected value of residual thickness is 25-30nm and expected stamp depth is 150nm

One of solutions of the problem is to increase distance between jets in jet-line, for example one can use not all jets in line but only a half of them. This increases d in two times and results to residual thickness 60nm, acceptable but still larger than desirable value.

Another solution (and maybe the best) is to decrease minimal drop value. It is known that there is ink-jet with V_{min}=3pl [1].

2.3 Discrete model

To simulate variation of jet distance, influence of other like residual thickness and stamp depth a practical test stamp submitted by Dr. Holger Schmidt (Lehrstuhl fuer Elektronische Bauelemente Universitaet Erlangen-Nuernberg) in GDSII was used (see Figure 7). Black areas represent places where residual thickness should high so the stamp represents
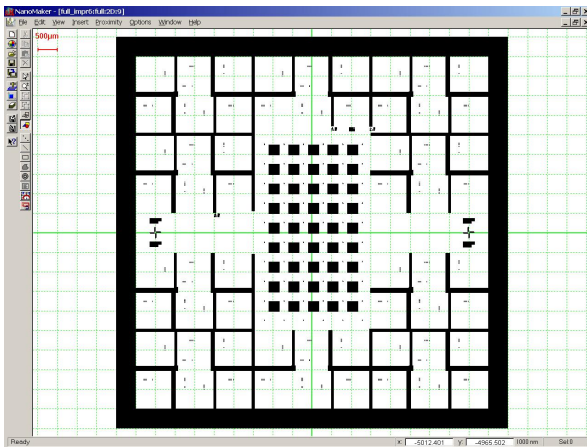

Figure 7 "Erlangen" practical test structure.

Firstly optimal dispensing was calculated for the following parameter set (H_residual=20nm; Stamp_depth=**150**; V_drop=60pl; d=1mm) and result is shown in Figure 8. Analysis of optimal volumes shows that the optimal volume of most cells smaller than 60pl. Then stamp depth was increased to value 250nm and optimization in discrete model was performed (Figure 9).

Due to large drop volume optimal drops number was 1 or 2 also there are two cells where resist should be dispensed at all.
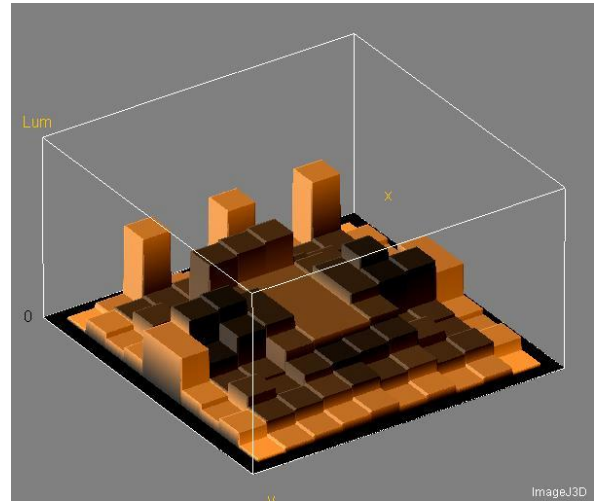

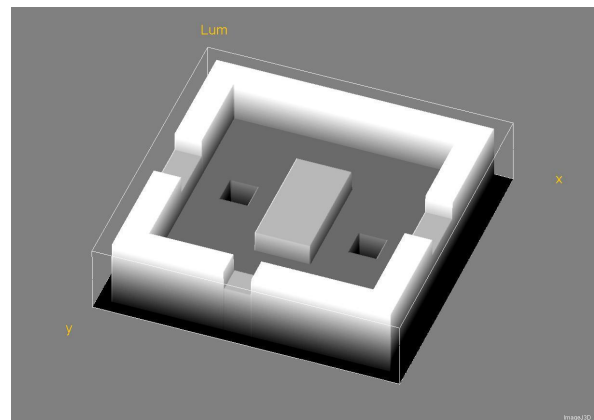Figure 8 Optimal drop volumes for continues dispensing

Figure 9 Optimal drop volume for Hstamp=250nm, disrete dispensing (V_{min}=60pl)

The next Figure 10 shows optimal drops calculated for jet pitch d equal to 2mm. It is seen that number of optimal drops belongs to range 1-5 what is better than previous case. But still there are cell with zero dispensing. Nevertheless stamp depth was decreased up to normal value used in practical imprinting.
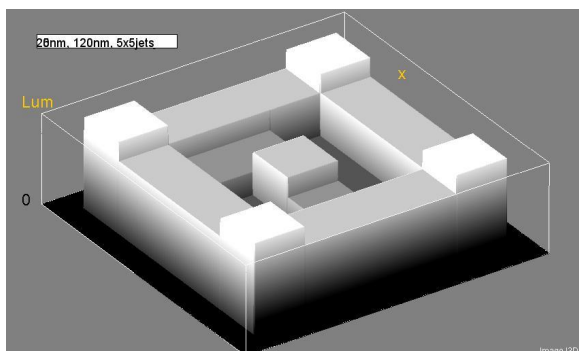
Figure 10 Optimal drop volume for Hstamp=150nm, discrete model

3 DISCUSSION AND CONCLUSION

Realization of optimal dispensing performed in the paper showed serious difficulties on this way. It turned that minimal drop volume like 60pl is too large to provide flexible volume tuning to stamp structure. This could be overcome with increasing of inter-jet distance but this leads to a situation when single jet will be more suitable and advantage of jet-line would be lost.

Another solution could be decreasing minimal drop volume.

Also important to note that the simulations performed clearly show that some model of drop spreading definitely should be considered. Only such model can help in consideration of temporal picture of drop spreading and can be a useful tool to understand whether current distance between jets is acceptable or not.

ACKNOLEDGEMENT

REFERENCES

[1] http://www.epson.com/cgi-bin/Store/consumer/consDetail.jsp?BV_UseBVCookie=yes&infoType=Specs&oid=63070381&category=Products