15th International Conference on Innovative Computing, Information and Control (ICICIC2021)
Online, September 15–16, 2021

Production Planning for LED Wafer Fabrication and Chip Packaging with Lagrangian Relaxation Heuristics

June-Young Bang[1] and BongJoo Jeong[2,*]

[1]Department of Industrial and Management Engineering, Sungkyul University, Gyeonggi-do 14097, Korea
[2]Department of Business Administration, Kongju National University, Chungcheongnam-do 32588, Korea
*Corresponding author: jbj@kongju.ac.kr

Introduction

In this paper, we propose Lagrangian relaxation heuristics to obtain near optimal production plan for LED wafer fabrication and chip packaging. In this process, product type of wafers is determined by their die sizes, and wavelength of emitting light. The product types are binned according to the wavelength, and this binning is not stabilized and overlapped with different product types of wafer fabrication. Therefore, the production plan, determining release quantity of wafers and chips to production, should be recalculated quickly enough in the case of the binning ratio becomes greatly disturbed to meet the customers' demand.

Problem Description

We now develop a mixed integer programming model (MIP) for determining a single period production plan that minimizes the total cost while meeting the demand as possible. It determines how many wafers of each type and packages with each recipe are released for wafer fabrication and packaging stages.

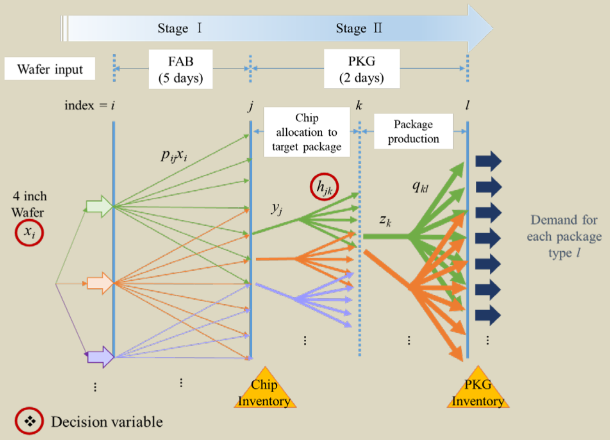

Figure 1. LED production diagram

We consider an LED production line processing 4-inch wafers. Note that up to 2000 chips can be produced from a 4-inch wafer. In this problem, we determine the input quantity of each type of wafers in a wafer fabrication (FAB) and the input quantity of each type of chips in a packaging (PKG) stage. The following assumptions are made in this research (based on situations of a real LED manufacturing system).

Mathematical Formulation

Indices and parameters

- i index for wafer types ($i = 1, \dots, n$)
- j index for chip types ($j = 1, \dots, m$)
- k index for recipe to produce target package types ($k = 1, \dots, K$)
- l index for produced package types ($l = 1, \dots, L$)
- p_{ij} production ratio of chip type j produced from wafer type i
- q_{kl} production ratio of package type l produced from chips that are input for recipe k
- D_l demand of package type l
- M_{wafer} input wafer capacity, i.e., the maximum number of wafers that can be input into FAB in each period
- C^{PI} package inventory holding cost of one unit
- C^{CI} chip inventory holding cost of one unit
- C_i^S setup cost of wafer type i
- C_i^P production cost of one unit of wafer type i
- C_l^U lost sales cost of one unit of package type l
- K_j set of recipes that use chip type j
- J_k set of chip types that can be used for recipe k

Mathematical Formulation (cont')

Now we present a mixed integer program formulation for a single period production plan of LED production.

$$\text{[P] minimize } \sum_{i=1}^{n}\left(C_i^S S_i + C_i^P x_i\right) + C^{CI}\sum_{j=1}^{m} I_j^C + C^{PI}\sum_{l=1}^{L} I_l^P + \sum_{l=1}^{L} C_l^U u_l \quad (1)$$

subject to

$$\sum_{i=1}^{n} x_i \le M_{wafer} \quad (2)$$

$$I_{j,0}^C + \sum_{i=1}^{n} p_{ij} x_i - y_j = I_j^C \quad \forall j \quad (3)$$

$$y_j = \sum_{k \in K_j} h_{jk} \quad \forall j \quad (4)$$

$$z_k = \sum_{j \in J_k} h_{jk} \quad \forall k \quad (5)$$

$$I_{l,0}^P + \sum_{k=1}^{K} q_{kl} z_k + u_l = D_l + I_l^P \quad \forall l \quad (6)$$

$$x_i \le M_{wafer} B_i \quad \forall i \quad (7)$$

$$x_i \ge B_i \quad \forall i \quad (8)$$

$$S_i \ge B_i - B_{i,0} \quad \forall i \quad (9)$$

$$0 \le u_l \le D_l \quad \forall l \quad (10)$$

$$B_i, S_i \in \{0,1\} \quad \forall i \quad (11)$$

$$x_i, y_j, h_{jk}, I_j^C \ge 0 \text{ and integer} \quad \forall i,j,k \quad (12)$$

$$z_k, u_l, I_l^P \ge 0 \quad \forall k,l \quad (13)$$

Lagrangian Relaxation Approach for Planning Decision

Procedure 1. (Solving original problem [P])

Step 0. Set u = 0, b = 0 and X = 0.

Step 1. If u > U or b > B, stop; otherwise, go to step 2.

Step 2. Find the optimal solution of [SP1(FAB)] and [SP2(PKG)], and increase the number of u (i.e., $u \leftarrow u + 1$). If the optimal solution of [SP1(FAB)] and [SP2(PKG)] is feasible to [P], the obtained solution is optimal. Terminate the procedure. Otherwise, go to the next step.

Step 3. Find a lower bound, LB, from the solution found in step 2, and update the best lower bound and set $b \leftarrow 0$ if the newly found lower bound is less than current best lower bound. Otherwise, set $b \leftarrow b + 1$ and update Lagrangian multipliers by the subgradient optimization method.

Step 4. Find a feasible solution for [P]. If ratio of difference UB and LB, (UB–LB)/LB is less than ε, terminate. Otherwise, go the step 1.

Computation Experiment Results

TABLE 1. Performance (percentage gap) of the algorithm

Number of wafer types	DR	PG† (%)		
		MIN	AVG	MAX
n = 15	0.8	4.17	6.06	8.74
	1.0	2.64	5.76	9.68
	1.2	3.60	5.31	8.95
Sum/Average			5.71	
n = 20	0.8	4.16	5.50	7.70
	1.0	3.59	5.72	8.74
	1.2	3.31	5.95	8.65
Sum/Average			5.72	

† Percentage gap of the heuristic solution from solutions obtained by CPLEX within 10 h of CPU time.

The average percentage gap of the total cost of the Lagrangian relaxation heuristics algorithm from optimal solution is obtained by CPLEX than 5%.

Conclusion

We proposed Lagrangian relaxation heuristics to obtain near optimal production plan for LED wafer fabrication and chip packaging. Results of computational tests showed that the near optimal production plan can be obtained within a half hour, while the optimal solution can be obtained around 2 hours CPU time. The percentage gap between optimal and Largrangian heuristics is less than 5% for the single period problem. For the further works, we consider the multi-period production planning problem for the two-stage production of LED with random yield to obtain long term production and inventory control plan.