# Photolithography Hotspot Detection Based on Deep Learning LHD Model

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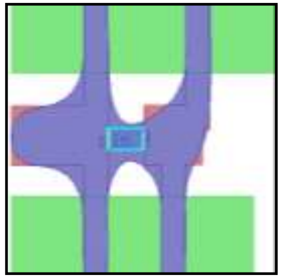
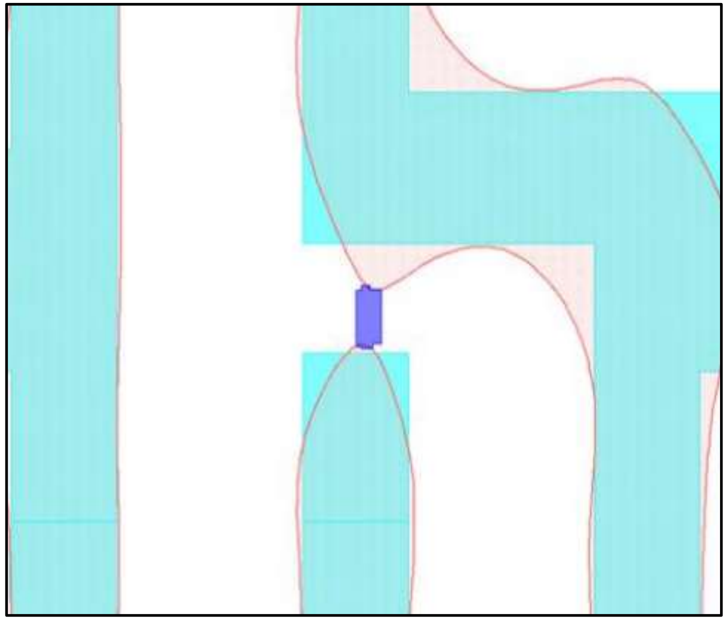
# Introduction

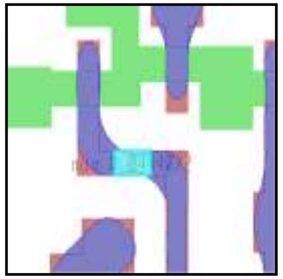
**In order to circumvent potential circuit risks, deep learning based hotspot detection methods have emerged.**

Bridge

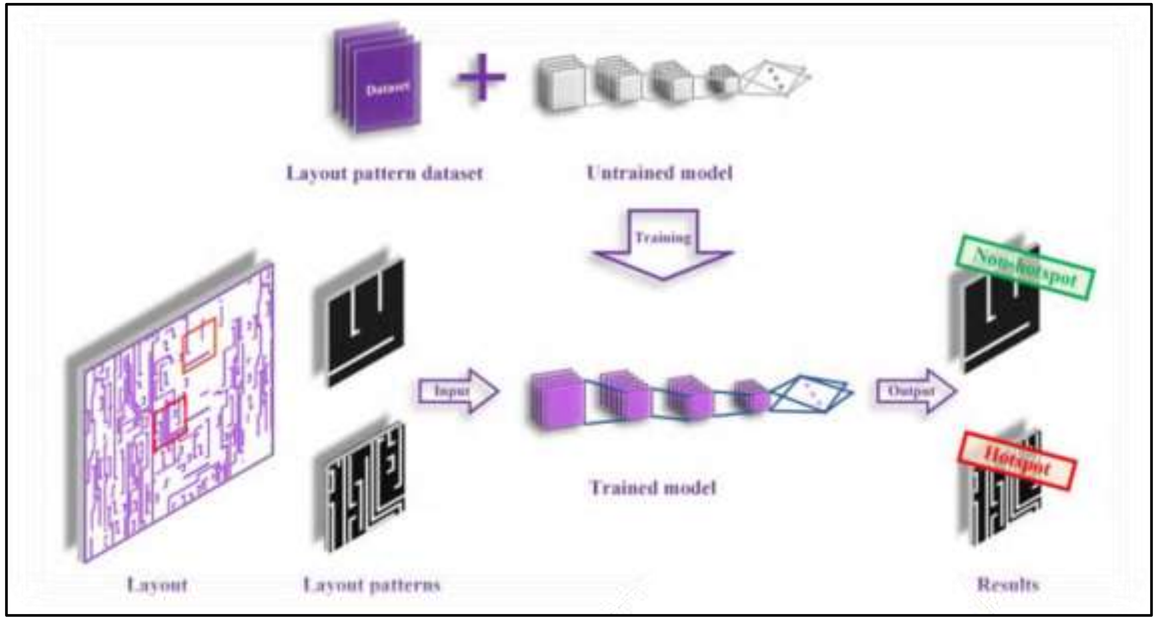




Hotspot



Pinch




[1]

Deep learning method

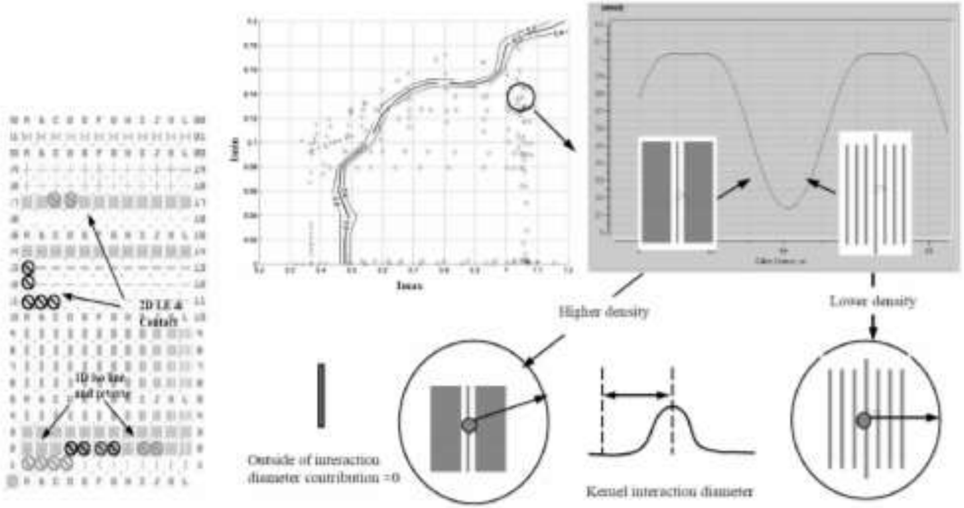
**The advantages of deep learning hotspot detection methods include short modeling cycle , good convergence, high accuracy and lightweight structure.**

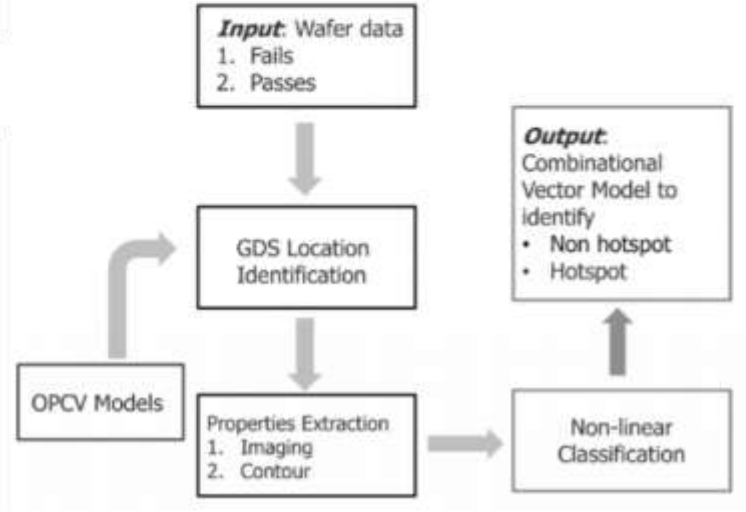
[1]廖陆峰,李思坤,王向朝.基于预训练VGG11模型的光刻坏点检测方法[J].光学学报, 2023, 43(3):10.DOI:10.3788/AOS221429.

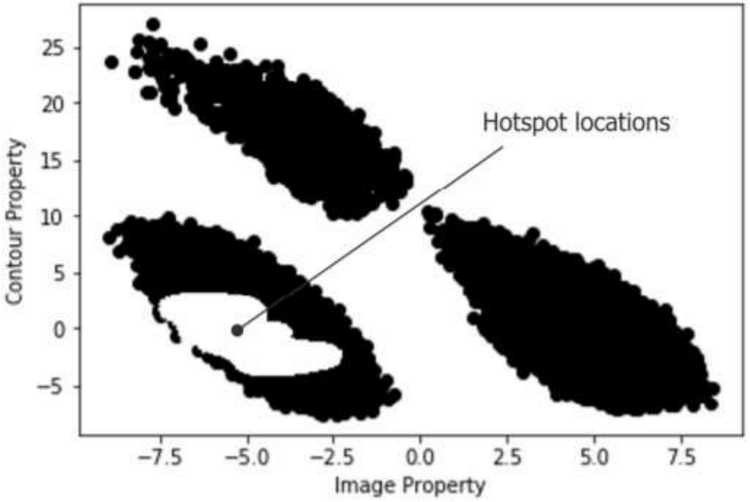
# Current Research Status at Home and Abroad

◆ Wei, Alexander , et al. "Combinational Optical Rule Check on Hotspot Detection." SPIE Advanced Lithography Conference 2018.

$$Class(x) = c1*kernel(x-x1)+c2*kernel(x-x2)+... ,$$



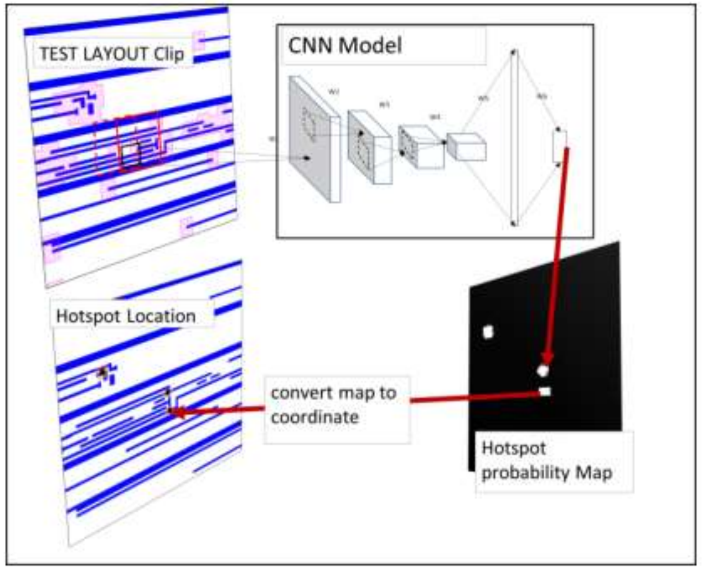



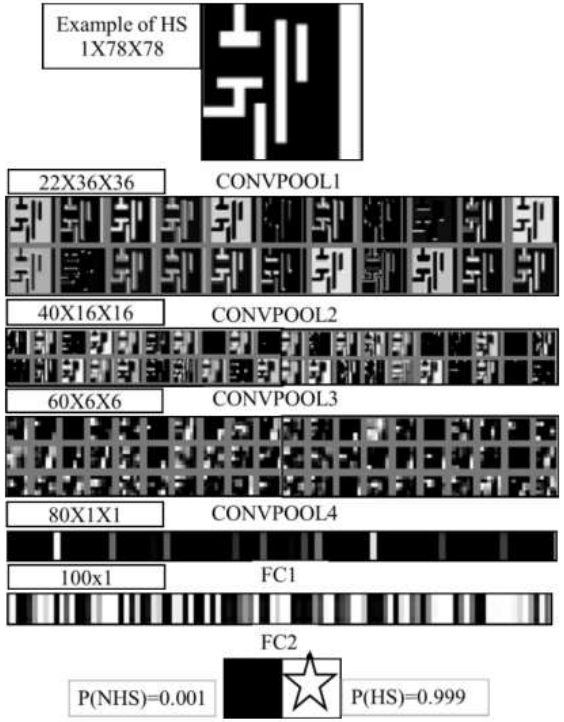




- ➢ Contour detection hotspots by **photolithography model** simulation
- ➢ The accuracy of the predictions was **75% to 80%**, which needs to be improved.

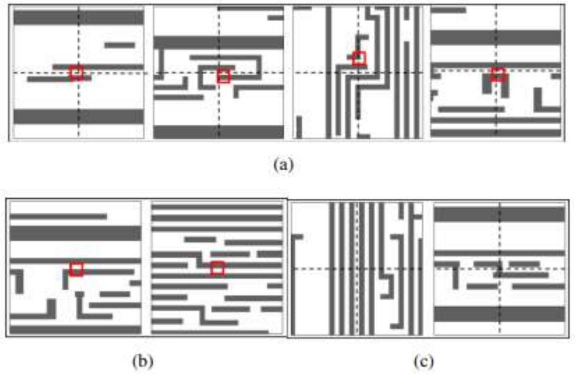
# Current Research Status at Home and Abroad

◆ Shin M , Lee J H . CNN Based Lithography Hotspot Detection[J]. International Journal of Fuzzy Logic and Intelligent Systems, 2016, 16(3):208-215.




| Test layout | Methods | Recall | Precision |
|---|---|---|---|
| Benchmark1 | B. Yu [4] | 0.810 | 0.202 |
| | Y.-T. Yu [5] | 0.947 | 0.125 |
| | Ours | **0.951** | **0.306** |
| Benchmark2 | B. Yu [4] | 0.811 | 0.039 |
| | Y.-T. Yu [5] | 0.982 | 0.040 |
| | Ours | **0.995** | **0.190** |
| Benchmark3 | B. Yu [4] | 0.909 | 0.089 |
| | Y.-T. Yu [5] | 0.919 | 0.109 |
| | Ours | **0.985** | **0.138** |
| Benchmark4 | B. Yu [4] | 0.870 | 0.054 |
| | Y.-T. Yu [5] | 0.859 | 0.043 |
| | Ours | **0.989** | **0.078** |
| Benchmark5 | B. Yu [4] | 0.805 | 0.047 |
| | Y.-T. Yu [5] | 0.929 | 0.031 |
| | Ours | **0.976** | **0.068** |
| Average | B. Yu [4] | 0.841 | 0.086 |
| | Y.-T. Yu [5] | 0.927 | 0.070 |
| | Ours | **0.979** | **0.156** |




➢ Merits: Machine learning based hotspot detection techniques are used to transform the problem of hotspot detection for plat maps into a problem of **categorizing whether a graph is a hotspot or not**, making **better results** in ICCAD 2012 dataset.

➢ Demerits: **No specific categorization of hotspots**, reliance on **ICCAD open source dataset.**

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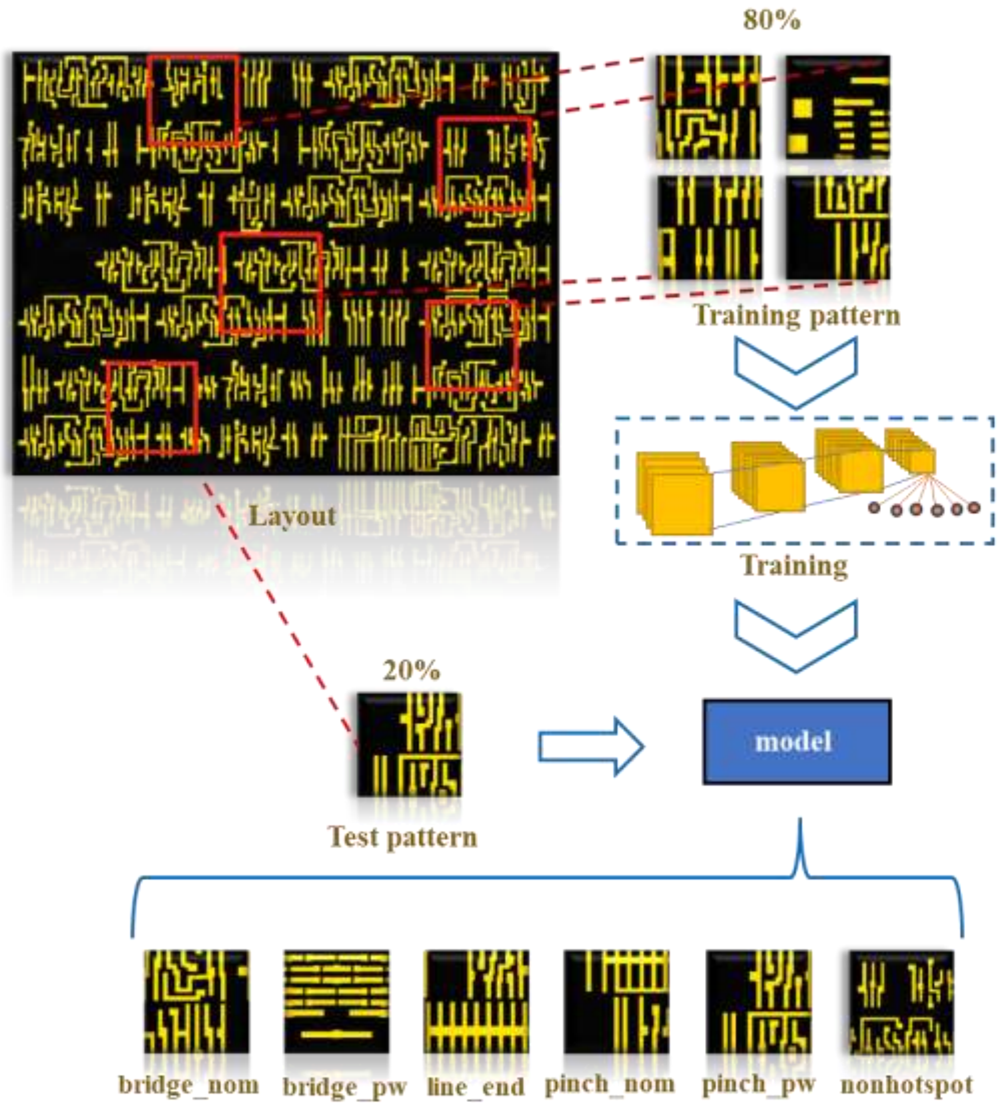
# Hotspot Detection Technology

➢The **supervised** deep learning algorithm in **pytorch** is used in the hotspot detection method of this paper. We propose a lightweight hotspot detection model, the **LHD (Lithography Hotspot Detection)** model.

➢The graphic crop of **poly target layer** is converted into image as a dataset, which is labeled as **5 classes** of hotspots and **1 class** of non-hotspots according to the simulation results, in which **80%** of the data is used as a training set, and **20%** of the data is used as a test set.

➢The hotspot detection effect is improved by **algorithm optimization and model improvement** and compared with the existing network **Convnext**.



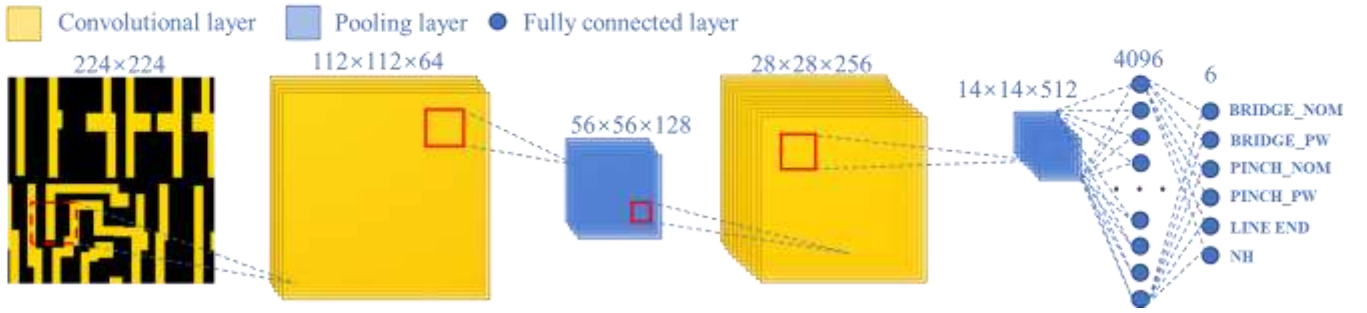

Hotspot detection technology flow

# Model Structure Design

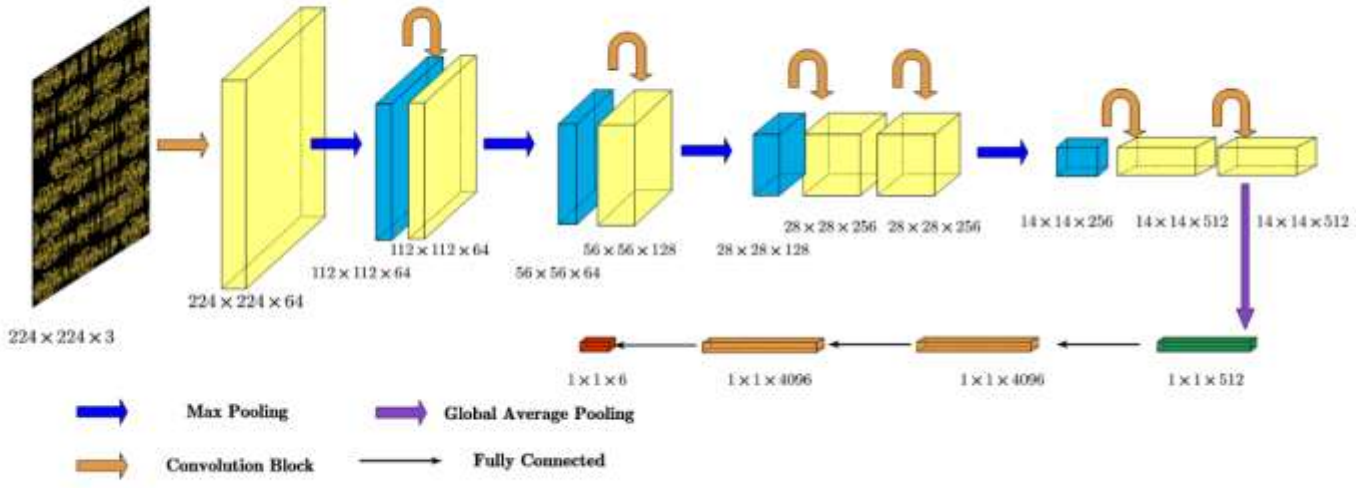
- The input to the photolithography hotspot detection model is photolithography images, each of which has a resolution of **224 × 224**, and we have used a training set to test set ratio of **8:2**.

- The convolutional neural network extracts features from an image through a series of **convolutional, pooling, and fully connected** layers and performs hotspot region prediction.

- The LHD model is composed of a **10-layer** network, which includes **seven convolutional** layers and **three fully connected** layers. Between every two layers, there is a pooling layer with a **2 × 2 pooling matrix** (maximum pooling) and a move of step size 2.

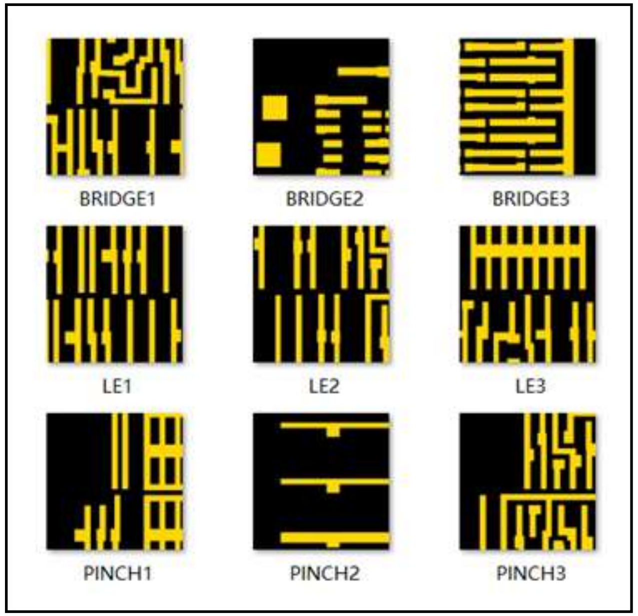



Convolutional neural network schematic framework

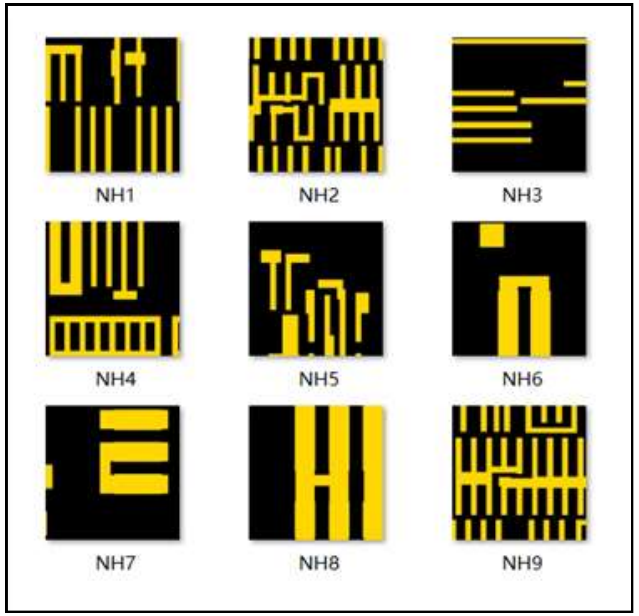



Structure of the LHD model

# Dataset Input




(a)




(b)

Dataset Presentation: (a)Hotspot (b)Non hotspot

| Dataset | Class | Number |
|---|---|---|
| 6 | BRIDGE_NOM | 63 |
| | BRIDGE_PW | 16 |
| | PINCH_NOM | 201 |
| | PINCH_PW | 200 |
| | LINE END | 200 |
| | NH | 2384 |

Data distribution

➢The dataset contains **680 hotspot maps** and **2384 non-hotspot maps**, of which the hotspot set includes the following five categories: **BRIDGE_NOM, BRIDGE_PW, LINE END, NH, PINCH_NOM, and PINCH_PW**, and the quantity ratio is as shown in the table on the right, which is exactly in accordance with the proportion of hotspot distribution of the actual plat map in order to reflect the real situation.

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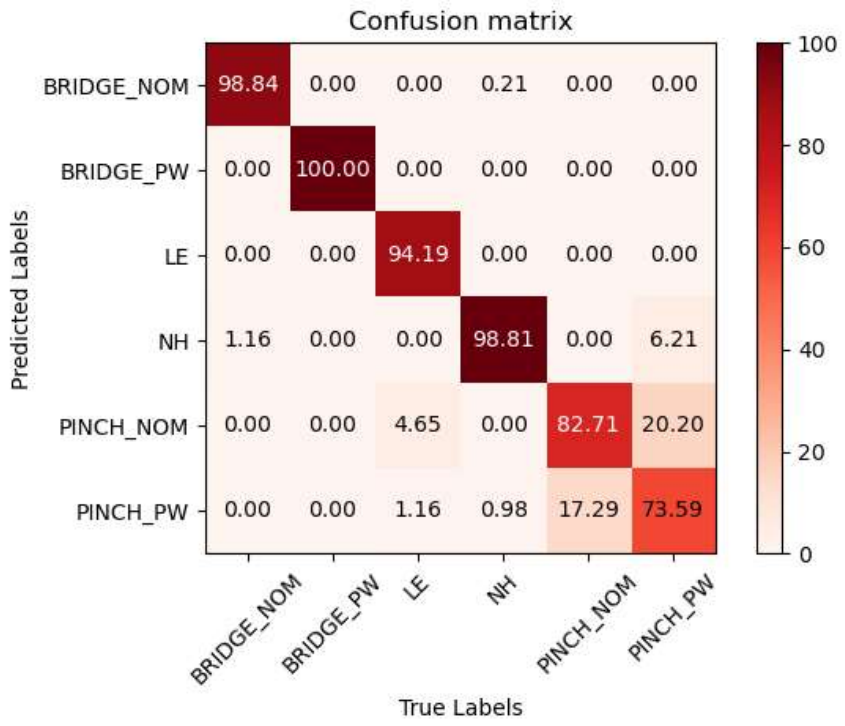
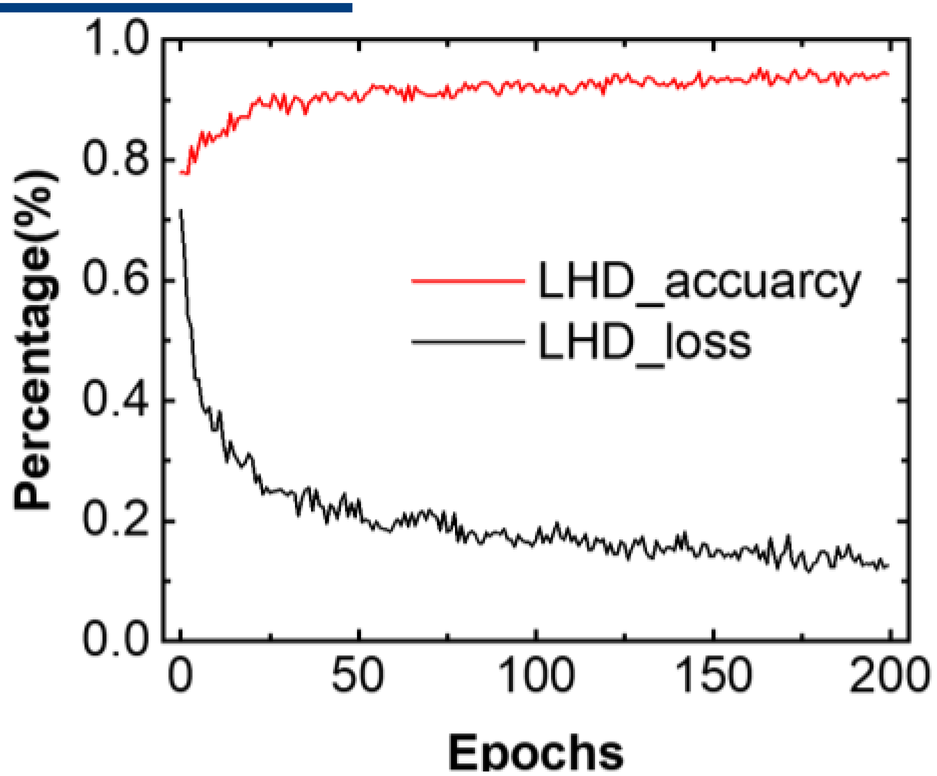
# Accuracy Performance




Accuracy confusion matrix

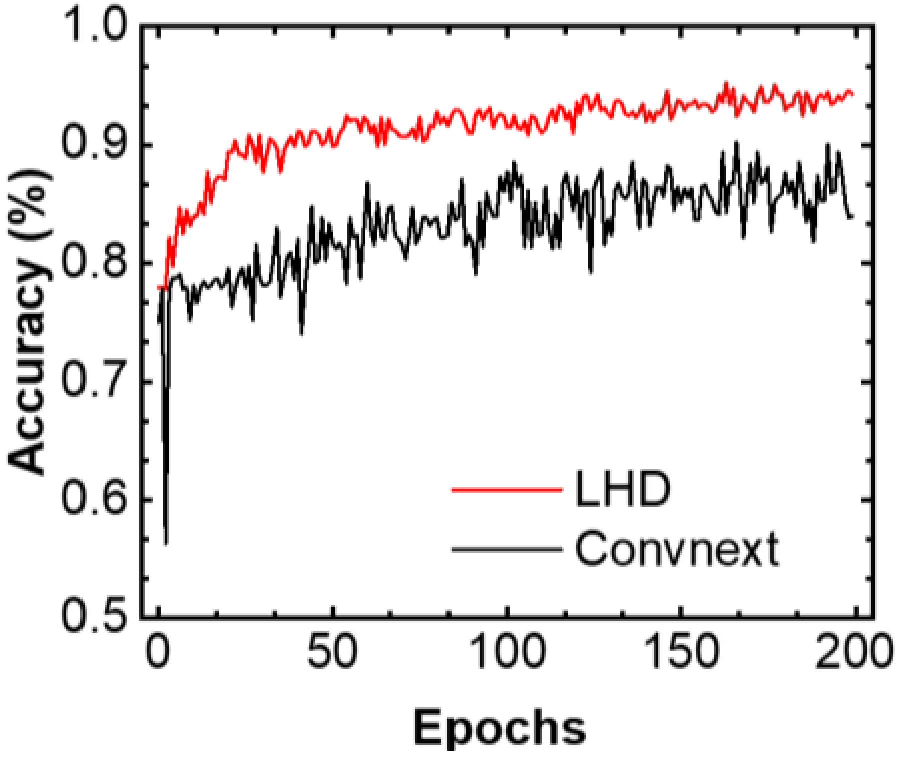



Accuracy loss and function curve

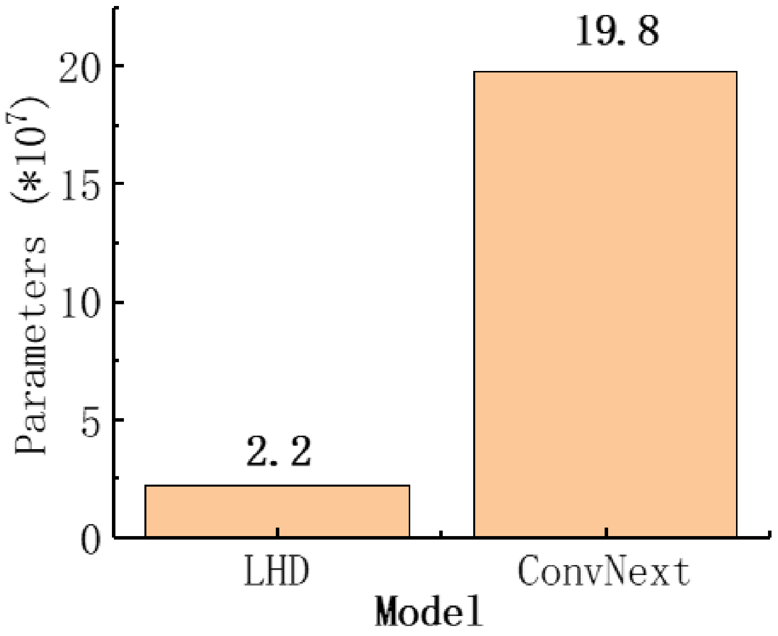
➢ From the diagonal elements of the confusion matrix it can be concluded that the LHD model achieves **more than 90% accuracy** in BRIDGE_NOM, BRIDGE_PW, LINE END, and NH types, and slightly lower accuracy in PINCH_NOM and PINCH_PW types, which are given only minor differences in conditions, but can also achieve **more than 70% accuracy**.

➢ The accuracy and evaluation loss of LHD converge after about **100 epochs** with **good convergence**, and the accuracy of the model can reach **95.25%** after convergence.

# Model Performance Comparison




Model accuracy comparison

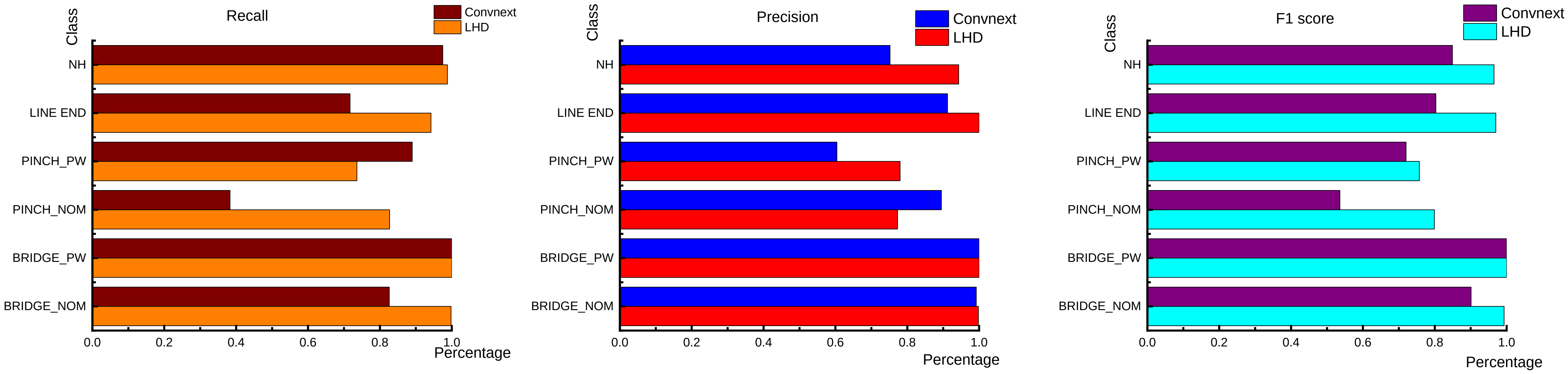



Model parameters comparison

- Convnext network is used in hotspot detection scenario the accuracy starts to converge only after **133 epochs** and the accuracy of convergence is **90.18%**. LHD network has an accuracy of up to **95.25%**, which is **5.07% higher** than that of Convnext and it **converges faster**, which reflects a better performance.

- The number of parameters for the LHD model and the Convnext model are **22131014** and **197734120**, respectively, and the LHD model is **88.8% lighter** compared to the Convnext.

# Evaluation Function Comparison




Evaluation function comparison

- No matter which evaluation function, the function values achieved by LHD are higher than Convnext, the check accuracy rate can be **17.6% higher** on PINCH_PW type, the check full rate can even be **44.4% higher** on PINCH_NOM type, and the F1 score can be **16.7% higher** on LINE END type, which fully demonstrates that LHD proposed in this paper can achieve better detection results while **realizing model lightweight** and at the same time can **achieve better detection effect**.

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# Conclusions

- This paper introduces a lightweight hotspot detection model, the **LHD (Lithography Hotspot Detection) model**, based on deep learning technology.

- The trained LHD model possesses a simple structure, few parameters, and outstanding hotspot detection performance, making it achieve an accuracy of **95.25%**, surpassing the recently proposed Convnext model by **5.07%**.

- Furthermore, comprehensive comparison based on parameters such as precision and recall validated the significant advantages of this method, providing a new solution for lithography hotspot detection.

# Acknowledgments


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- **Siemens EDA Team**

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# Thank you for your listening!