Supplementary Material

A. Discussion of Potential Societal Impact

The semiconductor industry has been continued to take action to address climate change and promote environmental sustainability. For example, over the period 2001-15, the U.S. semiconductor industry has achieved a normalized reduction of 34 percent in the total energy consumed in their operations. This significant reduction was achieved during a period when the complexity of semiconductor manufacturing increased dramatically. Many companies have shifted to renewable sources of energy or cleaner fuels to power their operations.

In addition to switching to renewables, chipmakers could also implement efficiencies in fabs to reduce their carbon footprint, including ineffective processing on the defect wafer. Our method in this paper has been applied to the real defect classification task, and we successfully reduced 3000 pcs of invalid wafer processing, including products, experimental wafers, and control wafers. In the following section, we will divide into water saving and carbon footprint to introduce potential societal impact.

Water Saving

In the semiconductor process of cleaning wafers, removing photoresist, etching, cutting, and electroplating, it produces wastewater containing chemical substances. This wastewater is not recyclable. Most of them is used for chip cleaning, photoresist removal, and etching in the IC manufacturing plants. After our proposed model had been deployment, the annual water saving was 38540 metric tons (as shown in Table I). Water use intensity (Water Consumption Per Wafer- layer) in 2021 have been decreased 6.4% from 42.1 (liter / 8-inch e wafer-layer) in 2020 to 39.4 (liter / 8-inch e wafer- layer) (as shown in Table II).

Table I. Annual water conservation analysis by defect reduction (metric tons).

Type	Purpose	Process			
		Chip Cleaning	Photoresist Removal	etching	Others
Products	Customer's wafer	8672	3661	5781	1156
Experimental Wafers	R&D	3122	1318	2081	416
Control Wafers	Equipment Monitor	5550	2343	3700	740

Table II. Annual water use intensity reduction analysis by defect reduction (liter / 8-inch e wafer-layer).

Type	Purpose	Process			
		chip cleaning	photoresist removal	etching	Others
Products	Customer's wafer	0.612	0.258	0.408	0.082
Experimental Wafers	R&D	0.220	0.093	0.147	0.029
Control Wafers	Equipment Monitor	0.392	0.165	0.261	0.052

The mixed chemical substances of wastewater are many and complex. It can be roughly divided into acid-base wastewater and fluorine-containing wastewater. Table III show the wastewater saving analysis by defect reduction.

Table III. Annual water conservation analysis with various constituents (metric tons).

Type	Purpose	Constituents		
		acid-base wastewater	fluorine-containing wastewater	Others
Products	Customer's wafer	21197	11562	5781
Experimental Wafers	R&D	10599	5781	2891
Control Wafers	Equipment Monitor	3815	2081	1041

Power and Carbon Footprint

Wafer fabrication is the most energy-consuming stage of semiconductor manufacturing. According to Hu and Chuah [1], the average power consumption per unit product (wafer) area is 1.432 kWh/cm2. We have established intelligent management systems to control power use and reduce standby power consumption. These measures saved 112 GWh of electric energy. In addition, by reducing unnecessary processing on defect wafers, we saved 6 GWh of electric energy (around 5.3% of total electric energy saving), which is equal to eliminating 3200 metric tons of carbon dioxide emissions (as shown in Table IV).

Table IV. The electric energy saving analysis (GWh).

Type	Purpose	Process			
		chip cleaning	photoresist removal	etching	Others
Products	Customer's wafer	1.4	0.6	0.9	0.2
Experimental Wafers	R&D	0.5	0.2	0.3	0.1
Control Wafers	Equipment Monitor	0.9	0.4	0.6	0.1

Table V. Carbon dioxide emissions reduction analysis (metric tons).

Type	Purpose	Process			
		chip cleaning	photoresist removal	etching	Others
Products	Customer's wafer	720	304	480	96
Experimental Wafers	R&D	259.2	109.44	172.8	34.56
Control Wafers	Equipment Monitor	460.8	194.56	307.2	61.44

B. Github Repository

https://anonymous.4open.science/r/Quantum_Deep_Learning/README.md

In this Repository, the code related to this paper is placed.

- ✓ *Self_Proliferate.py* is used to generate more feature maps (as section 3.1).
- ✓ *Self_Attention.py* is used to capturing the long-range dependencies of the feature map (as section 3.1).
- ✓ *Self_Proliferate_and_Attention.py* follow the spirit of MobileNetV2, "capture features in high dimensions and transfer information in low dimensions", to make the network more efficient. (as section 3.1).
- ✓ *quantum_circuit.py* is an example of quantum layer in the hybrid classical-quantum deep learning (as section 3.2).
- ✓ *Hybrid_CNN.py* is the hybrid classical-quantum deep learning with quantum layer and classical layer (as section 3).

References

[1] Hu and Chuah, "Power consumption of semiconductor Fabs in Taiwan area," Energy, Vol. 28, Issue 8, Pages 895-907, June 2003.