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Assessing the Feasibility of Utilising Convolutional Neural Networks for the Detection of Cracks in Solar Cells

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1. Introduction

- Solar cell crack detection plays a vital role in the photovoltaic (PV) industry.
- Automated defect detection is becoming increasingly necessary due to the growing production quantities of PV modules and limited application of manual/visual inspection.
- Convolutional neural networks (CNNs) have emerged as a powerful tool for crack detection, offering several advantages over traditional methods [1].

2. Framework

- As shown in Figure 1, the deployment of a CNN network for solar cell inspection begins by capturing an EL image of the solar cell.
- The CNN network is trained to recognize patterns and features in the image that indicate the presence of cracks or fractures.

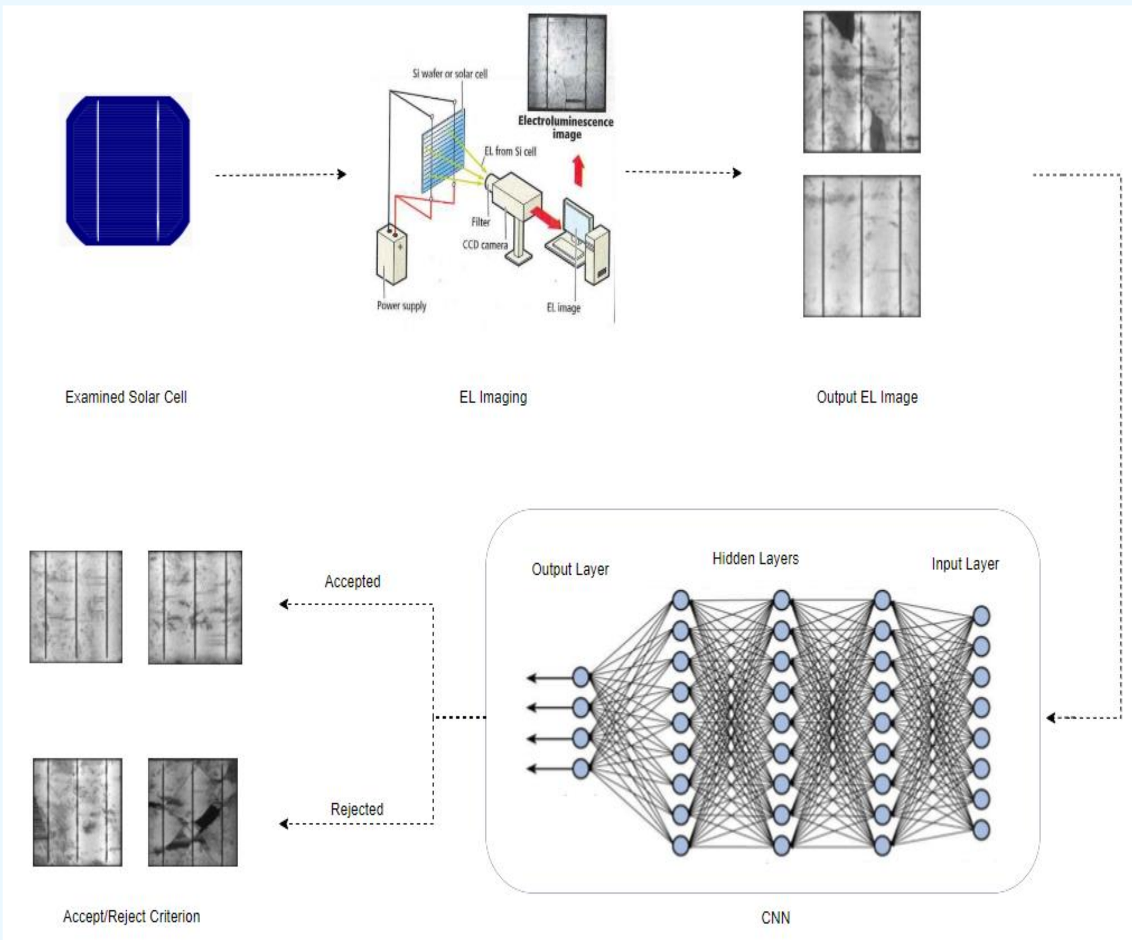

Figure 1. *Incorporating the CNN network into decision making for the identification of solar cell cracks in an industrial setting application.*

3. EL Imaging

- EL imaging is a technique used to visualize the electrical activity within a solar cell [2], as shown in Figure 2(a).
- In this work, the EL image resolution employed ranges from 1000x1000 pixels to 2500x2500 pixels.
- In Figure 2(b), five healthy (non-defective) solar cells are displayed, while defective solar cells are shown in Figure 2(c).

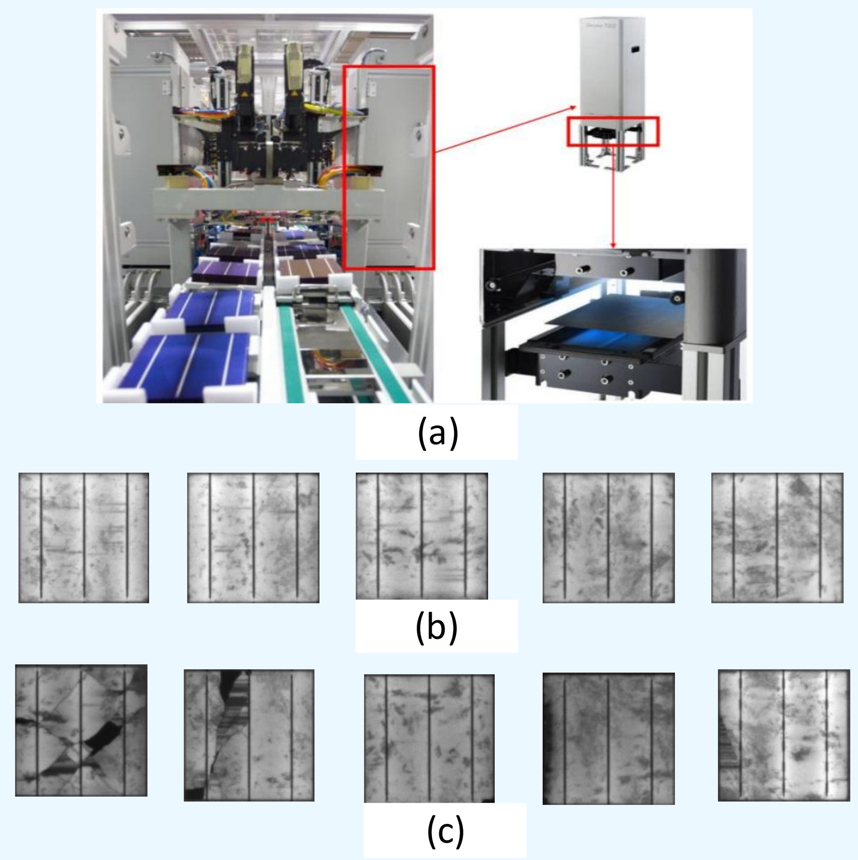

Figure 2. *(a) Solar cell production line with in-house EL detection equipment, (b) Example of solar cells without any cracks "healthy samples", (c) Example of solar cells with cracks "cracked samples".*

4. Developed CNN Architecture

- To begin developing a CNN architecture for crack detection, we began by creating a training network from scratch.
- Three convolutional layers containing 32 filters with an initial input size of 227x227x3 pixels is connected through a double max pooling to a normalization layer and a ReLU layer, as shown in Figure 3.

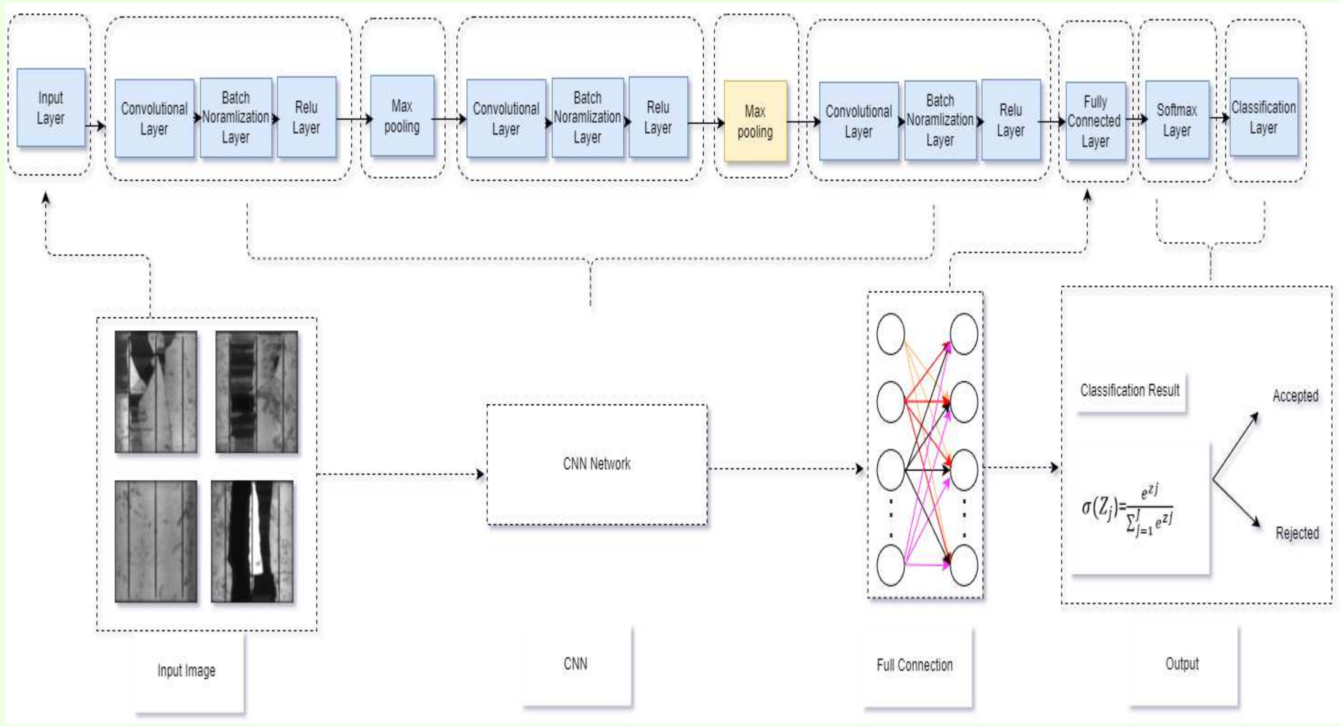

Figure 3. *Developed CNN architecture.*

5. CNN Network Accuracy

- According to the accuracy graph in Figure 4(a), the developed CNN architecture achieved an accuracy of 96.7%.
- Based on the developed CNN Architecture, as shown in Figure 4(b), it appears that initially, the loss of the model was a fraction higher, but progressively reduced towards zero, showing a high degree of learning.

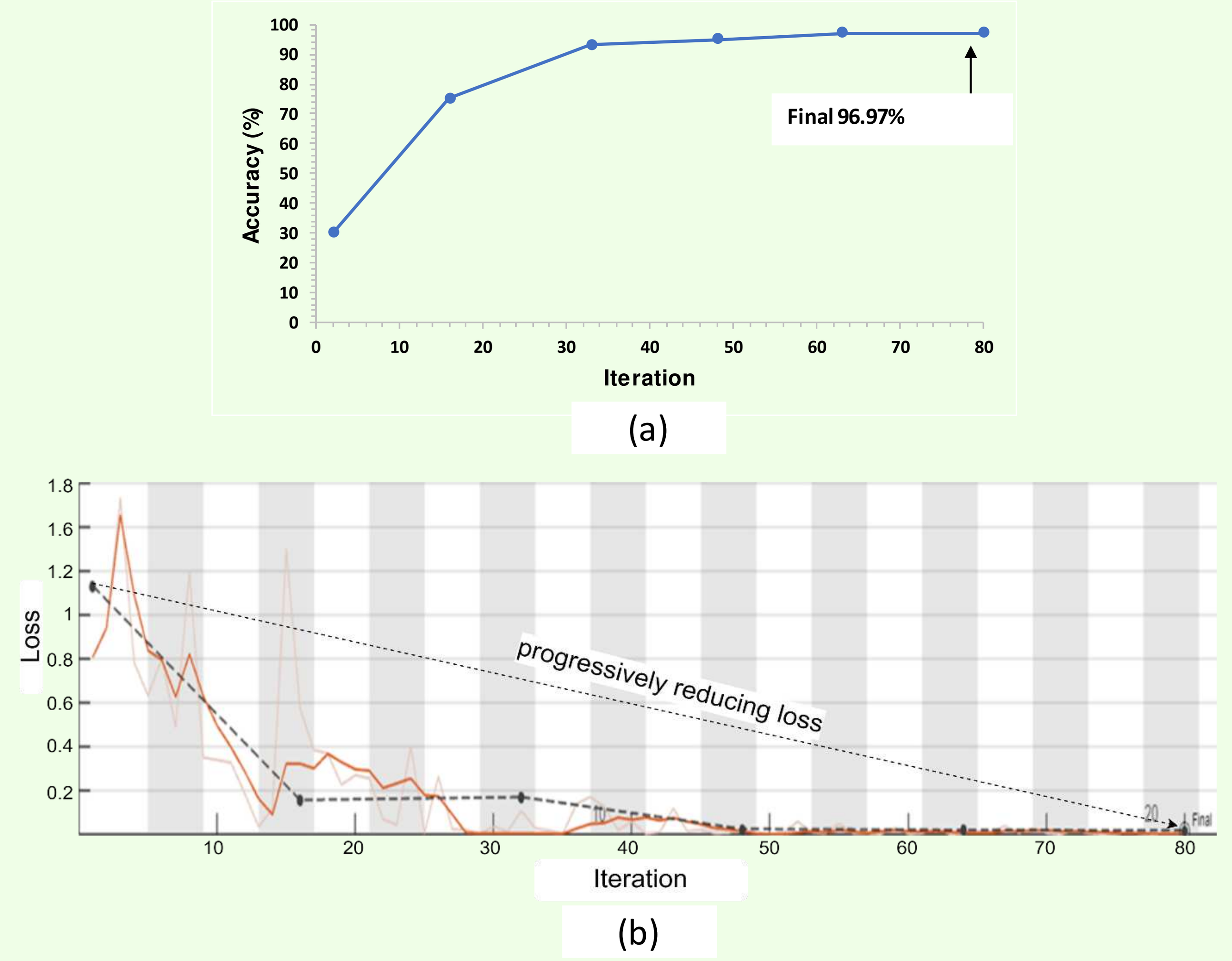

Figure 4. *(a) Developed CNN architecture learning Loss vs learning iterations (epochs)., (b) Validation accuracy of Developed CNN architectures".*

6. Results

- In Figure 5(a), health solar cells are examined, while in Figure 5(b), cracked solar cells are examined. Figure 5(c) is an examination of a solar cell with a PID, as well as Figure 5(d) is an examination of a solar cell with shading.

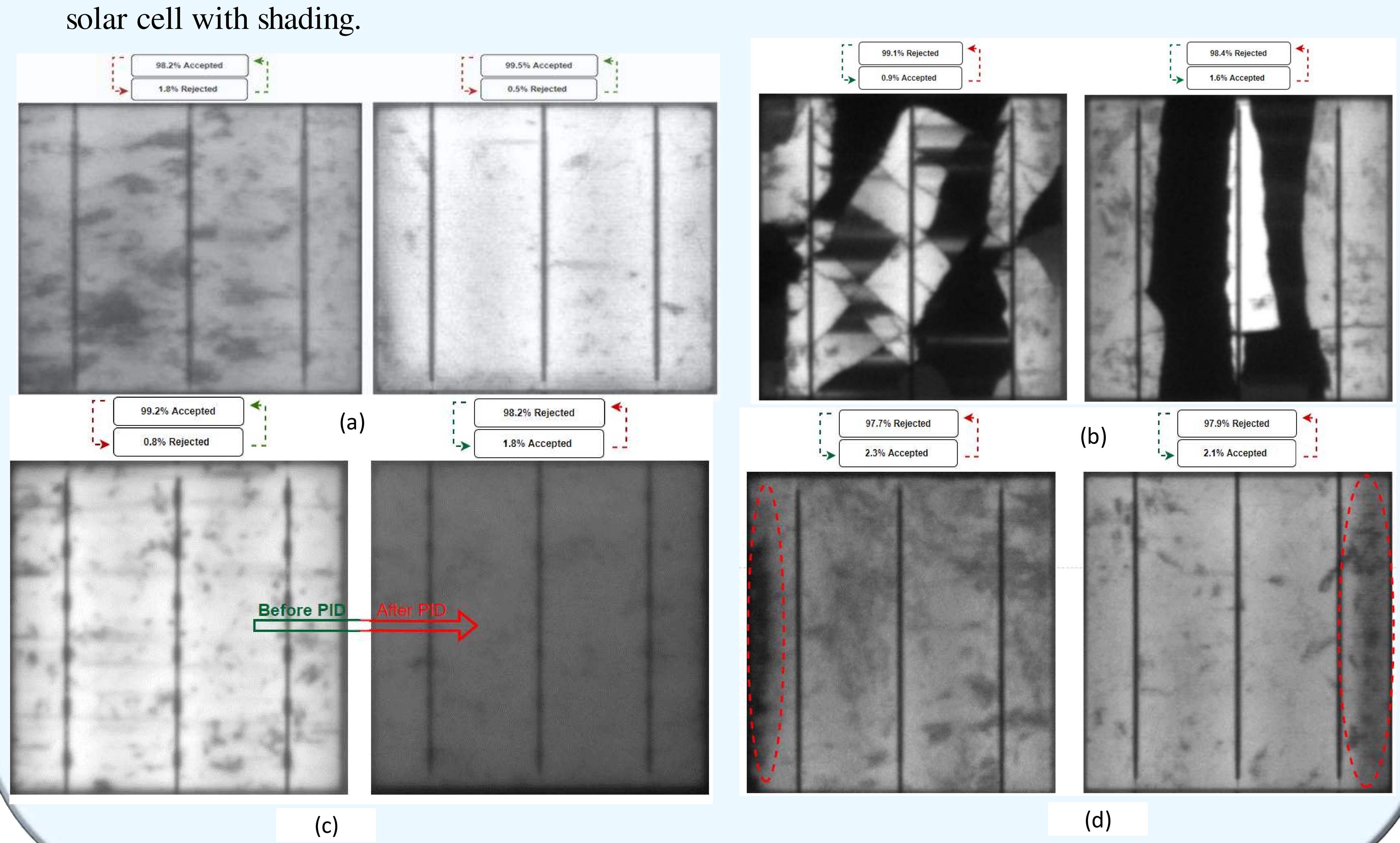

Figure 5. *(a) Healthy solar cells, (b) Cracked solar cells, (c) Solar cells with PID, (D) Solar cells with shaded area.*

7. Acknowledgment

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8. References

1. Su, B., Chen, H. and Zhou, Z., 2021. BAF-detector: An efficient CNN-based detector for photovoltaic cell defect detection. *IEEE Transactions on Industrial Electronics*, *69*(3), pp.3161-3171.
2. Hassan, S. and Dhimish, M., 2022. Review of Current State-of-the-Art Research on Photovoltaic Soiling, Anti-Reflective Coating, and Solar Roads Deployment Supported by a Pilot Experiment on a PV Road. *Energies*, *15*(24), p.9620.