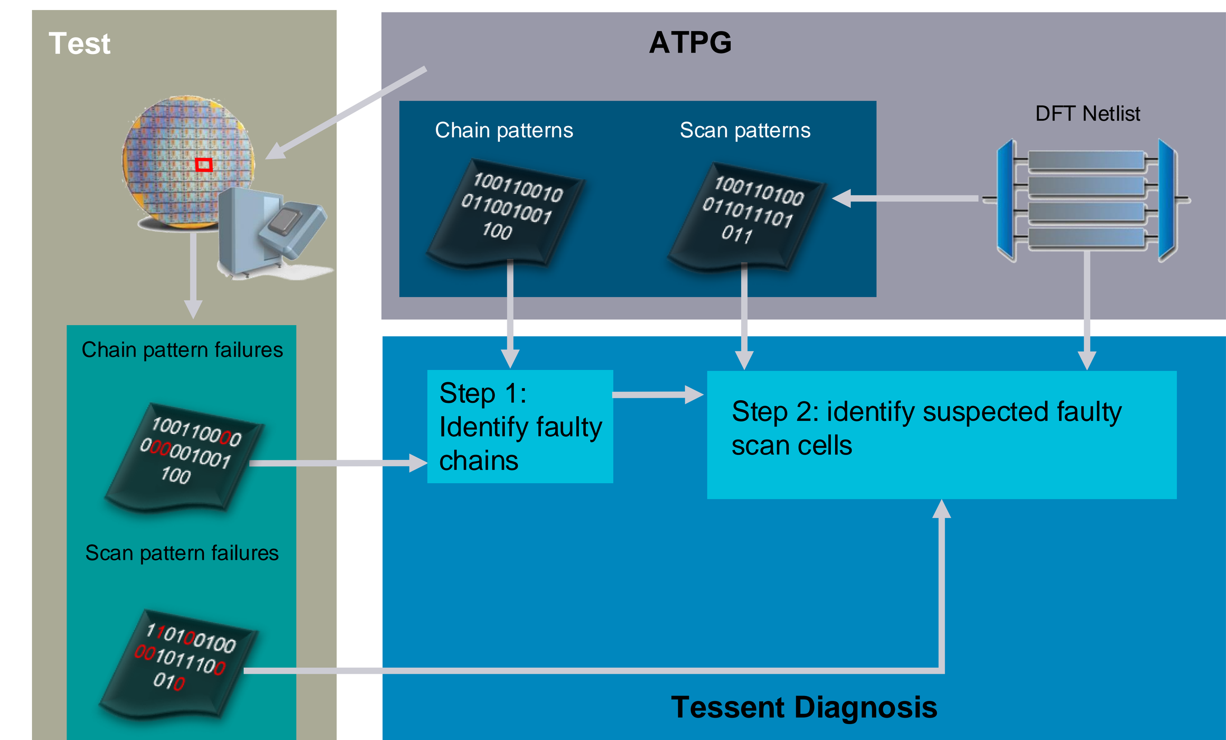
SIEMENS

ITC 2024 PO 32: Cell-aware Chain Diagnosis for Backside Power

Siemens EDA {Jayant D'Souza, Preston McWithey, Szczepan Urban}

Background

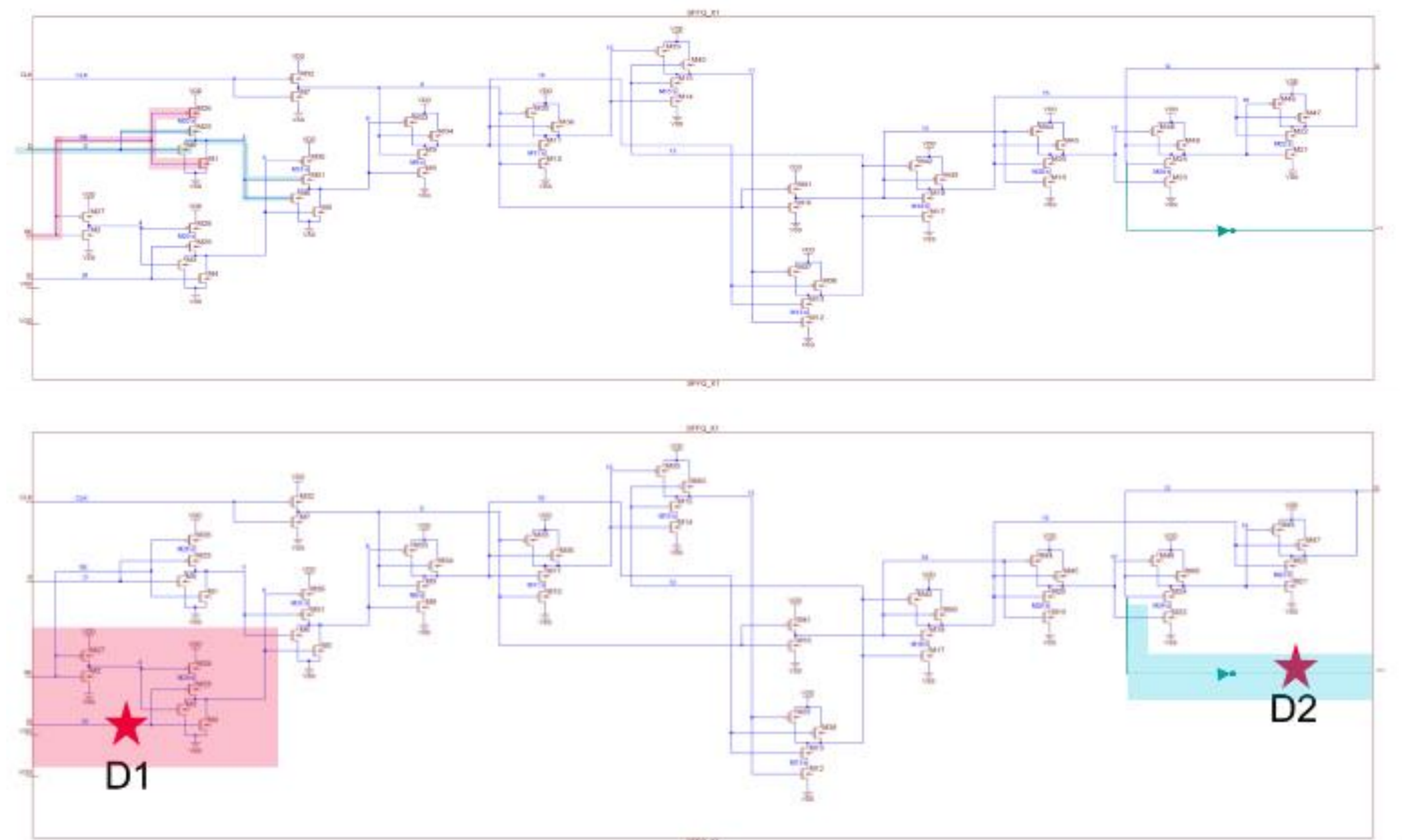
Manufacturing defects can occur throughout the product lifecycle. During the early yield ramp phase, identifying these defects and eliminating them quickly are critical for product profitability. Scan chain diagnosis has long been used to identify these defects. When defects occur in the scan chains of the design, it prevents testing of the logic of that design. However, defects on the scan chain also provide extremely valuable data to improve defectivity on a process node. The advent of new technologies, like backside power, in advanced process nodes have made fault isolation extremely challenging, further impeding the path to successful physical failure analysis. A new software-based technology provides accurate localization to enable efficient failure analysis defects internal to a cell. Scan chains are the backbone of the digital test infrastructure, and diagnosing defects on these chains is paramount as they can also indicate systematic defects in a process or product. During early yield and product ramp, defects found in the scan chains form the largest proportion of the defect population. Chain diagnosis requires the use of both chain test patterns and scan test patterns. The flow to performing scan diagnosis is as shown. The result of scan chain diagnosis is a set of logical and physical locations with possible defect types that localize the possible defect area on the failing die. Advanced nodes and features like backside power delivery have made fault isolation extremely challenging. In this poster, we explore a new diagnosis technology to accurately identify defects in advanced nodes, and dramatically reduce suspect area for PFA.



Cell-Aware Chain Diagnosis

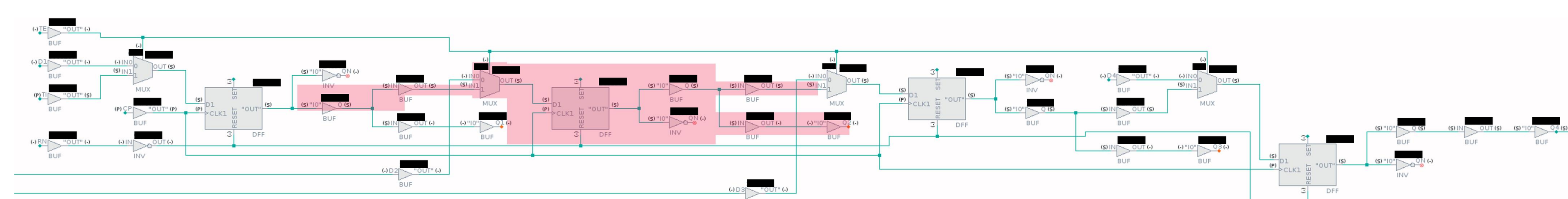
Defects in the front-end of line (FEOL) have become more prevalent at advanced nodes. Another interesting change in the design is the increased number of multibit flip flops (MBFFs). Since these cells offer reduced area, lower power, and better timing, they are preferred in physical implementation flows, with inclusion in up to 80% of the scan chains of modern designs. The sheer number of MBFFs and the increasing number of defects in the front-end layers require a new technique to analyze and ensure high diagnosis resolution. New technology comprised of enhanced switch-level simulation is used to determine different functional modes in these complex cells. As shown this simulation can help distinguish between transistors and nets inside the cell (highlighted in red and blue).

These simulations provide chain diagnosis with the ability to distinguish the shift path from the capture path. For example, assume that two defects D1 and D2 are occurring in a single bit flip flop. Typically, these kinds of defects cannot be distinguished by chain diagnosis. i.e. the entire scan cell is reported during chain diagnosis. However, after performing the enhanced switch level simulations, chain diagnosis can call out the specific defect locations, as shown in the highlighted regions. This demonstrates the effectiveness of cell-aware chain diagnosis.



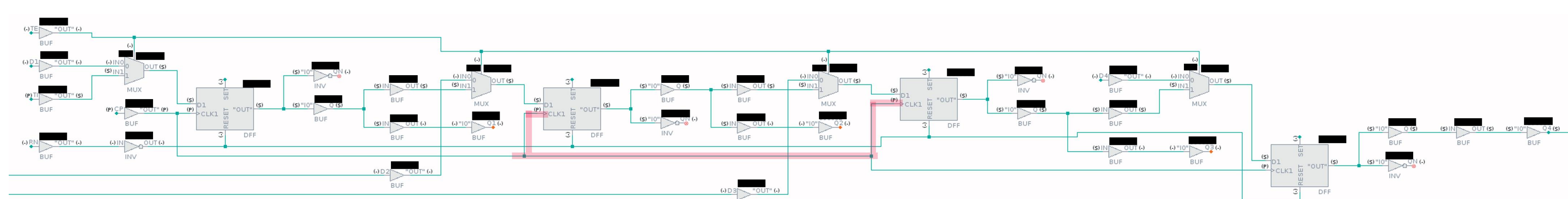
Cell Aware Diagnosis, Cell Internal Bit Isolation

With baseline chain diagnosis, if the defect occurred within an MBFF, diagnosis was only capable of narrowing down the location to a single cell inside the MBFF. However, now with switch level simulation, we can characterize the sequential cell behavior and understand the characteristics of each internal net. We can then intelligently exclude those portions of the circuitry that could not have been the cause of the defective behavior. For example, in this 4-bit flip flop we can see 4 distinct latches with muxing in-between. In the baseline chain diagnosis if a particular cell was known to be faulty, further defect isolation was impossible. However, with cell aware diagnosis, the scope of the defect is now to be narrowed down internal to the cell, the portion in red, alongside the physical coordinates and associated layout information.

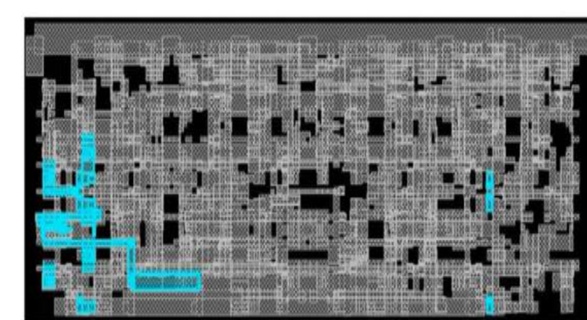


MBFF Control Signal Isolation

During diagnosis, if more than one faulty latch is identified in the same instance of a MBFF, cell aware diagnosis looks to identify a commonality shared between the failing latches. If diagnosis identifies 2 failing bits inside this 4-bit MBFF, further analysis would then be able to identify the common branch on the net marked in red as well as identify the common segments between the 2 failing bits but not all 4.

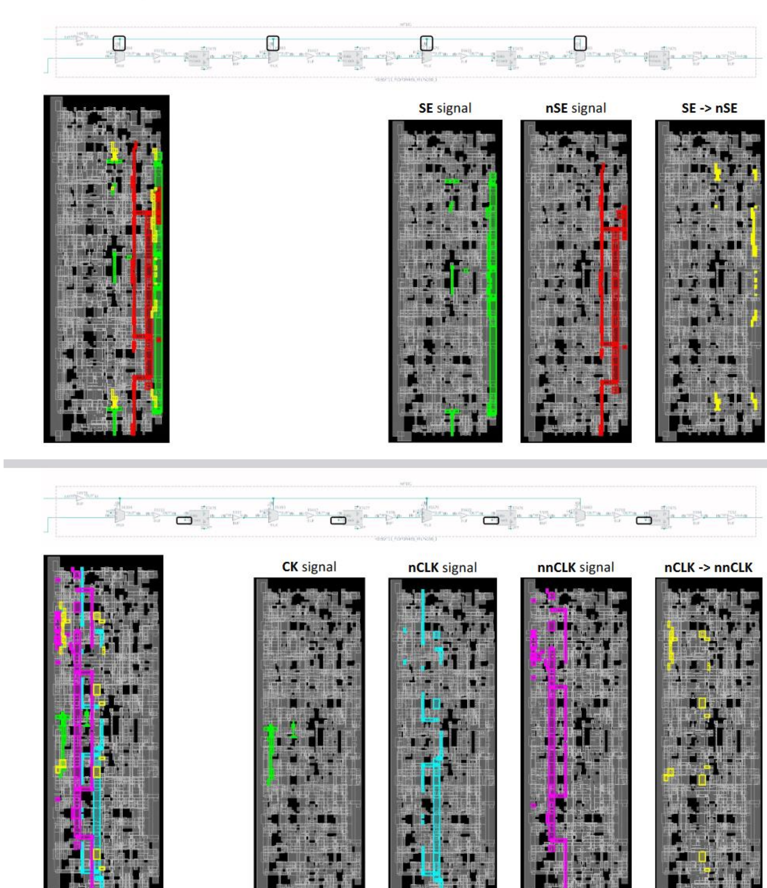


From a topology example of a 4 bit MBFF shown in the box below, an internal benchmark was able to reduce the suspect area from 2,956 possible cases down to 36 highlighted in blue.



MBFF Control Signal Isolation – Logical + Physical Call-outs

Cell-aware chain diagnosis is now able to identify all control signals for an MBFF, both from a logical and physical perspective as shown in the figure below.



Conclusions

Scan chain diagnosis has long been used to identify manufacturing defects and yield issues in early ramp. Identifying and eliminating these yield issues quickly and efficiently are required to ensure business success of a product. Root causing defect mechanisms that produce yield loss require a combination of fault isolation and failure analysis. The advent of new technologies, like backside power, in advanced process nodes have made fault isolation extremely challenging. The introduction of cell-aware chain diagnosis will help to reduce the defect suspect area dramatically. This has a direct impact on the area of the die to be analyzed during physical failure analysis. This can lead to huge savings in time, reducing the overall time to root cause a defect significantly. The introduction of this new technology will likely play a more pivotal role in failure analysis and yield analysis for advanced process nodes.