# Finessed Robotic Pick & Place Technique Reduces Contamination

"OffsetDropOff" Reduces Common Wafer Scraping by 50%

*by Donald Christian – RobotScope Systems*

Summary: Separating a robot's pick and place points using a software-computed OffsetDropOff vector yields multiple benefits: contamination reduction, improved delivery precision and throughput, and simpler, more repeatable robot installation and service.

The traditional robotic "pick and place" operation is so simple that there would seem to be little room for improvement. But a new OffsetDropOff technique has been shown to reduce chronic workpiece scraping by 50%, avoiding particulation while improving delivery accuracy and simplifying robot setup. OffsetDropOff improves handling especially for carrier-borne items such as wafers or glass plates in cassettes, and can be implemented on any pick-and-place robot.

## *Picking & Placing at the Same Point Causes Excessive Scraping*

Many automated factories transport individual workpieces in material carriers – in modern semiconductor factories, wafers are carried in clean FOUPs (Front Opening Unified Pods). After processing, each wafer is replaced and the container door is closed. The closing door presses all 25 wafers fully back into their slots and re-seats them at their Home positions. This sliding action scrapes the wafers against the container ribs, causing friction and creating particles. Freed particles rain down onto the wafers below, damaging their delicate lithography.

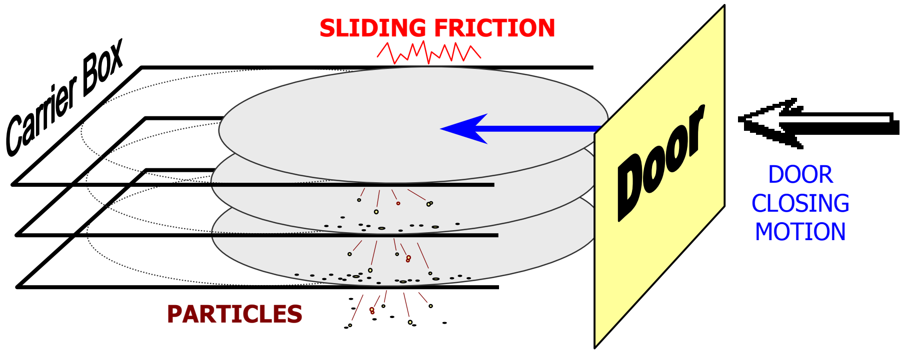


Fig.1 –Wafers Slide Home and Particles Rain

A typical scuff of 6 to 12mm under a 25-high wafer stack creates a little storm of particles, repeated with each door closing. Fortunately, the shower stays mostly inside the container. Unfortunately, that's where the wafers are. Scrape distance is set by several factors, primarily by the skill of the person who installs the robot, and it's usually not controlled. Some equipment manufacturers actually recommend a scrape length of 8mm or longer in their installation manuals!

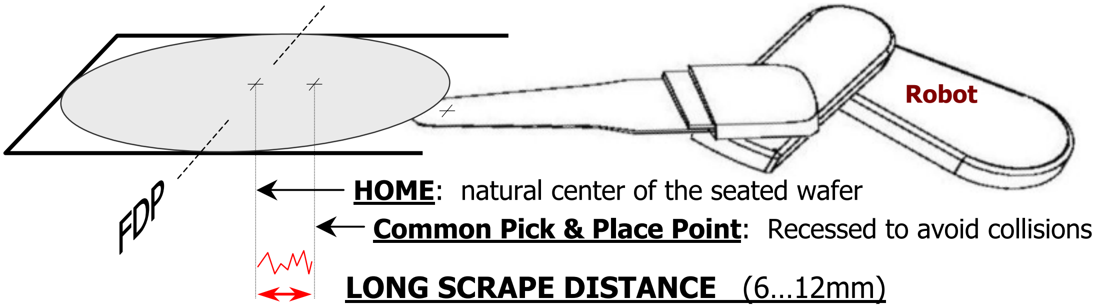


Fig. 2 - Common Pick / Place Point Cannot be marked at HOME Position

Most modern robotic handlers (EFEMs or Equipment-Front End Modules) pick and place workpieces at exactly the same point in space. This is not optimal. It's simpler for the software but it necessarily trades off accuracy, picking up slightly off-center and then dropping off unnecessarily distant from the Home target. In practice, both positions are usually imperfect and this makes for sloppy handling. The pick-place point must be sufficiently far from Home to avoid back- and side-wall collisions, so the recession distance and direction between pick- and place-points are critical.

Simple single-point software forces the installer to manually tweak each station to avoid collisions and scrapes. This exposes system performance to the influence of patience, skill, eyesight, mood, and luck. A careful installation engineer will try to minimize scrape offset when he sets up the robot. But if he marks it too close to Home, some wafers will bang the rear wall of the container. This design tolerance problem is often blamed on "poor quality setup/teaching". So his usual compromise is to set the scrape distance longer but safe: typically 6mm to 12mm or more. An excessively long scrape is unlikely to be noticed - and any contamination or yield loss it creates will probably be masked by normal process delays and by yield noise from other sources.

### *Offset Drop-Off (ODO) – A Cleaner Way*

Wafer scraping during door closing cannot be eliminated, but it can be minimized. ODO software physically separates the pick-point from the place-point. Wafers are picked up precisely at their nominal Home position on the FDP (Facial Datum Plane). This well-defined location is the essential reference coordinate for each load port, and is easy to identify during robot teaching. Wafers are always at this Home position because the closer or door holds them there while seated.

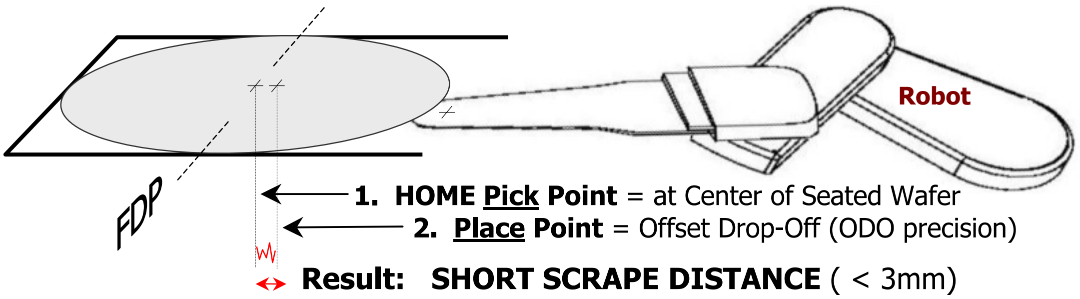


Fig. 3 –Offset Drop-Off Minimizes Scraping

The place-coordinate is computed relative to Home; it's offset is precisely measured to avoid back-wall collisions. In our lab tests, no more than 3 mm offset was required, even across a wide variety of FOUPs, wafers, and load ports. When we restricted the test to multiple specimens of a single model container, 2 mm offset was sufficient. This is a significant improvement from 6…12 mm.

Benefits from the OffsetDropOff technique include:

1) Reduced scuff friction. In our tests, a 50% scuff reduction was easily achievable.
2) Faster process throughput. Picked wafers arrive naturally centered, so the prealigner makes fewer corrective spins. The time-savings can be traded off for even higher placement accuracy (3) by tightening the prealigner's corrective threshold limit.
3) More accurate or repeatable wafer placement onto the process chuck. A tighter prealigner tolerance guarantees that wafers are centered more precisely on the process stage.
4) Tighter machine control. More predictable wafer handling performance across wafers, robots, and machines. Less variance, more matched operation (more copy-exact discipline).
5) Simpler and faster robot installation and setup. Manual estimation and teaching of offset vectors is eliminated. Teaching proceeds faster and is more consistent and accurate. Robot installation is less affected by skill, patience, and luck.

6) More serviceable. Adjustment procedures are simplified and more automated. When the pick point must be adjusted, the software automatically mirrors changes to the place point.
7) With this greater finesse in the control software, an opportunity is opened for further technical advancements in other material handling areas.
8) Longer container life. Less wear and tear on containers. Fewer container rewash events are required (R2, R9). Note that the sliding friction can also generate a static electric charge that attracts particles directly onto the wafers.

The OffsetDropOff technique takes "scrape management" out of the installation process and into in design of the robot software, where it can be better controlled. The scrape vector becomes a simple parameter that can be analyzed and optimized using formal design rules. Robot setup becomes less of an art and more a precision technology.

Some fair questions that ODO raises for robot vendors and users are:

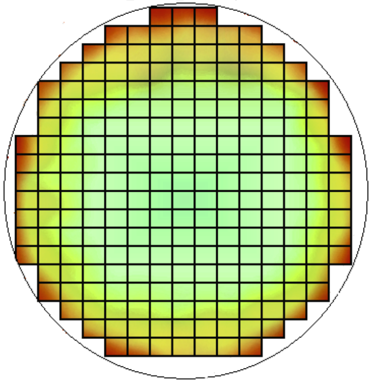
- How far are your wafers or workpieces scraping right now?
- How far would they be scraping if the robots were running optimally?
- Is scraping the same on all machines, or better or worse on some?
- Does scrape-distance drifting over time?
- How does one readjust a station's scrape to bring it back within tolerance?

Factory automation developers in other industries have implemented pick and place techniques similar to ODO. Some applications have been driven to higher performance by very fragile workpieces such as glass windshields and large flat panel displays. Sloppy robots can easily damage these large, brittle devices. Semiconductor wafers are physically more durable but are quite sensitive to micro-contamination.

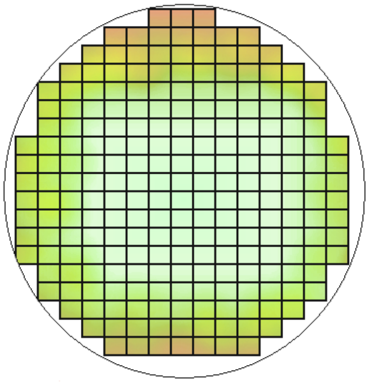
## *Questions and Answers*

**Q:** Does door-close friction really create significant numbers of particles?
**A:** Particulation is always a factor but its severity varies with each process. Many fabs have found it necessary use special washing machines to re-clean the inside of each container between lot cycles, and vision systems to watch for container wear and tear. FOUP manufacturers carefully design their products not to create particles during transport, but they are not perfect. There are only a few ways that particles can get into FOUPs so when particles are noticed, door close friction must be a prime suspect.

**Q:** How much yield improvement can I expect with POV software?
**A:** Most wafers exhibit poorer yield around their edges than in their center. Low-yield die positions near the periphery are candidates for rescue.



Typical yield erosion at wafer edges



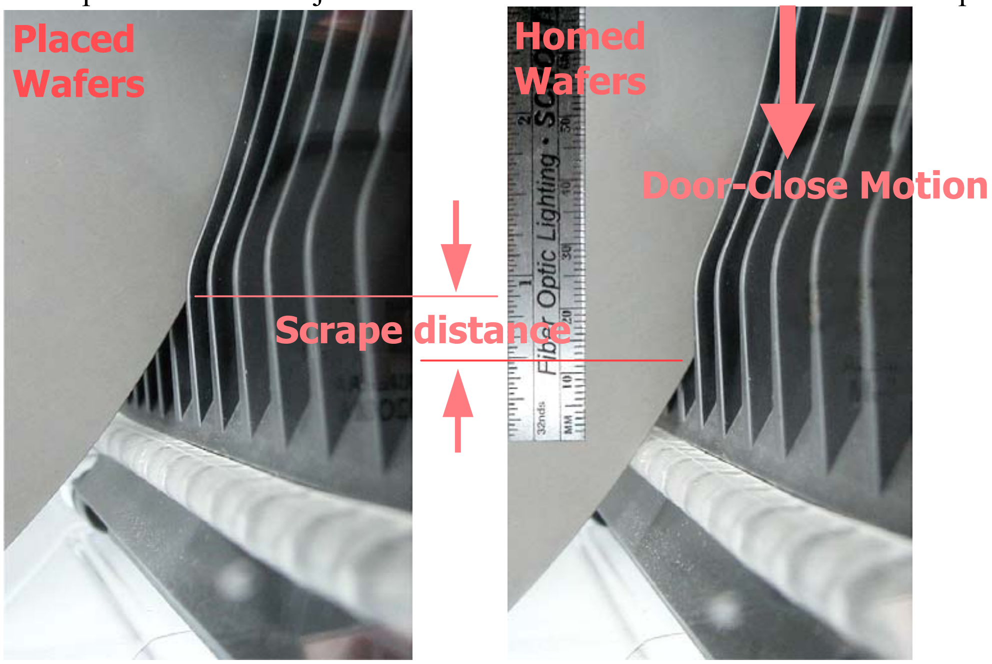
Reduced scuff attenuates the "bowl" pattern

The net yield improvement from ODO in other applications will depend on several factors. Door closing friction may not be the only source of edge decay. Other considerations include: FOUP design and material, robot tracking, wafer geometry, material, and coating, and precision of the robot installation. For example, a limping robot may scrape the wafers' sides during pick and place. Wafer edges are often where yield is nibbled away first. Edges also have thinner coatings, wilder temperature swings, and greater mechanical stresses - making flaking more likely.

**Q:** Can't I just teach two separate points (pick and place) for each station ?
**A:** Yes - done carefully, this workaround will reduce scraping. But teaching takes twice as many steps, and there are twice as many stations to manage in software. Placement accuracy is even more reliant on the installer's skill and patience, and service adjustments are more tedious. Entirely new classes of setup errors and hazards are introduced.
Software-computed ODO geometry brings all the benefits with none of these disadvantages.

**Q:** Is ODO useful with Vacuum-Grippers and Edge-Grippers ?
**A:** Yes, ODO is equally relevant with all wafer gripper technologies, all materials, and all atmospheres. The common threads are a container where wafers are seated and gravity.
At pickup, edge gripping end-effectors require higher precision than vacuum grippers. With this tighter geometric compliance, an ODO technique may be required.

**Q:** How badly is my current automation machinery scraping wafers right now?
**A:** Scraping is easy to watch through any translucent FOUP. At the end of a process cycle, view down through the top of the container just before the door closes. Watch the wafers scrape home.



Before door close

After door close

Measure the distance that the wafers scrape. Less than 3mm is good. More than 5mm indicates a problem. Wafers should also move straight back into the container, with no side-to-side motion. Lateral movement may signal problems that are more serious. Lateral centering can be measured by wafer-to-wall clearance (left-to-right comparison) immediately after drop-off.
You may find it useful to make a visible benchmark in or near the FOUP.

**Q:** Is Offset-Drop-Off relevant with no-door cassettes (200mm or smaller or SMIF pods)?
**A:** Yes, perhaps even more important. Wafers must be seated in containers before they can be safely transported between process steps. With most open-containers, seating is done with a "cassette tilter", often using gravity. During seating, the wafers still scrape home and then hit the rear wall – perhaps even bounce. Friction and impact is worse at longer scrape distances. Back-wall collision impact may cause more damage than scraping.
Note that most SMIF box designs reseat and scrape wafers mechanically, just like FOUP doors.

**Q:** If I use high-precision alignment tooling for setup, isn't that good enough?
**A:** Tooling addresses only static alignment. ODO software addresses dynamic behavior (choreography). The two are complimentary and synergistic. Recent improvements in alignment tooling have been shown to reduce subjectivity and improve the setup accuracy of taught stations.

**Q:** What about those new alignment tools ?
**A:** Some marvelous new robot teach- and calibration- tools have been introduced recently, including instrumented wafers and active carrier stations (see refs). These techniques are highly compatible with ODO software. Combining the static accuracy of good tooling with OffsetDropOff's clean choreography, high levels of process control, hygiene, and reliability should all be achievable.

**Q:** Can I use ODO at non-carrier stations (like chucks and stages)?
**A:** ODO software is beneficial at stations that have a backstop or hard edge boundary to avoid.

**Q:** My wafer sorter has no prealigner. What difference does ODO make?
**A:** Handling wafers without a prealigner increases the risk of collisions with container walls. ODO reduces this risk through improved handling accuracy. Over a large number of wafers, this translates to a reliability improvement. Scrape-induced contamination is still an issue too.

**Q:** Does OffsetDropOff affect reliability ?
**A:** ODO's effect on handler reliability is positive. Every system has a tolerance budget that is tested by "normal" operating variances. These variances include the size, material, and texture of incoming containers and wafers, wear and tear on the equipment, vacuum level, and other factors. ODO provides tighter handling accuracy, making more of the tolerance budget available for these "normal" external variances. Over a large number of wafers, this translates to improved reliability.

**Q:** Can wafer scraping be eliminated entirely ?
**A:** Some wafer friction will likely always be present, but it can be minimized further. "Scrape budget" is limited by robot precision and mechanical tolerances stack-up. When the vectors add up unfavorably, wafers and containers can collide. Tolerances arise from factors such as installation and manufacturing variances in robots, load ports and FIMS, FOUP containers, and even wafers. FOUPs become worn and warped over a long service life. In factories where variances are tightly controlled, scraping is minimized but tradeoffs do apply.
Some improvements in wafer contact geometries and materials look promising, and further improvements are possible.

**Q:** Where does OffsetDropOff software fit in the bigger picture ?

**A:** OffsetDropOff is one of several fine-control software techniques used to refine robotic handling and minimize contamination. It can be applied in any automated factory where workpiece carriers like FOUPs or cassettes are used. Its value is complimentary with other anti-contamination software and hardware techniques. OffsetDropOff software should be considered a standard "best practice" for good robot hygiene and control.

The goals of gentler handling, higher throughput, and improved sanitation will remain landmarks for future engineering tradeoff and design. Further advancements in automation reliability and hygiene are on the horizon.

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