Long-term storage: Die or assembly?

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To store, or not to store

- ✓ Commercial decision
  - ✓ Insurance policy
  - ✓ Cost of “insurance”
  - ✓ Storage strategy
- ✓ Conscious decision
  - ✓ Storage by design or storage by accident?
- ✓ Is it a unique or custom product ?
  - ✓ Analyse risks of non-availability
  - ✓ Do I own any of the IPR ?

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Initial Considerations

- ✓ The “device” is to be supplied in predictable quantities over the next 25 years.
- ✓ The “device” will be deemed “fit-for-purpose” at any stage during it’s 25 year “shelf life”.
- ✓ Question … does the “device” have to meet future and unknown legislation ?

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What to store

- ✓ Level of “importance” of each item
  - ✓ Again … look at level of customization
- ✓ Do I have to store it ?
  - ✓ or will my feed & supply chain do it for me
  - ✓ Level of trust / reliance
- ✓ What state is my item in?
  - ✓ Can I store it ?
  - ✓ Will it store ?
    - ✓ Shelf life, known issues, legislation ?
  - ✓ Anything special ?
    - ✓ Handling & storage training ?

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Storing as Assembled product …
the criteria

- ✓ The “device” is going to be stored for up to 25 years.
- ✓ The “device” must be “process-able” after storage
  - ✓ Lead finish
  - ✓ Final lead preparation
  - ✓ Package integrity
  - ✓ Caution : newer “processing” methods and standards
- ✓ The “device” (once processed) will be expected to work as if it were a new device.
- ✓ The inherent reliability or specification of the “device” shall not be compromised.
  - ✓ Warrantees … expressed or implied

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Storing as Die / Wafer product …

the criteria

- ✓ The die or wafer is going to be stored for up to 25 years.
- ✓ The die must be “process-able” after storage
  - ✓ To manufacture a suitable “device”
- ✓ The “device” (once assembled) will be expected to work as if it were a new device.
- ✓ The inherent reliability or specification of the “device” shall not be compromised.
  - ✓ Again, warrantees, expressed or implied

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Date codes, batch numbers, traceability

- ✓ Only TESTED product should be stored.
  - ✓ Only GOOD product … remember!
- ✓ Storage security
  - ✓ Are the devices physically secure
  - ✓ Is a paper “ring-fence” good enough?
  - ✓ Is barbed wire seen as OTT (you know your colleagues).
- ✓ Multi-site storage ... is this an issue ?

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Where to store

- ✓ On-site or off-site
  - ✓ Access by whom ?
- ✓ Single site storage location
  - ✓ Lowest cost
  - ✓ Possible limited size
  - ✓ Insurance “risk”
  - ✓ Minimal logistics, single “stores” department
- ✓ Multi-site storage location
  - ✓ Improved insurance risk
  - ✓ Increased logistics and personnel

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How to store ?
Storage conditions

- ✓ Storage standards
  - ✓ Die / Wafer IEC62258-3
  - ✓ Def Stan series
    - ✓ 00-60, 61-21, (05-61 for explosives)
- ✓ Monitoring and periodic datalogging of
  - ✓ Humidity
  - ✓ Temperature
  - ✓ Gas purity (where used)
  - ✓ Sampling of inventory and inventory movement.

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How many to store ?

- ✓ Survival rate
- ✓ Cost vs. Survival
  - ✓ “cotton wool” vs. “engineers drawer”
- ✓ Yield calculation
- ✓ Prediction of demand
  - ✓ Quantity per unit time
  - ✓ Quantity per product
  - ✓ Type of demand (linear, sporadic, lumped)
- ✓ Product / project share

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What to store

Assembled Product.

- ✓ Pro
  - ✓ Known quantity and quality for storage
  - ✓ “Ready for action”!!!
- ✓ Con
  - ✓ Cost of “manufacture”
  - ✓ Risk of wasted effort
  - ✓ Can I “sell” product in any/all events?
  - ✓ Physical storage generally larger
    - ✓ Increased “types” of components inside leads to complicated storage issues.

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What to store

If I store the component product.

- ✓ Pro
  - ✓ Small form factor for storage
  - ✓ “Resellable” or viable asset
  - ✓ Component already “assessed”
  - ✓ Easily handled & packaged … “*understood by all*”
    - ✓ Bagged, tagged, tubed and boxed.
  - ✓ Simple storage on-site
  - ✓ Deliverable on a “one-by-one” basis, if needed.
- ✓ Con
  - ✓ Inflexible – cannot accommodate package or product change
  - ✓ Storage effects on lead finish and package needs consideration
    - ✓ Lead oxidization
    - ✓ Moisture ingress
  - ✓ Possibly more delicate, higher risk of damage
    - ✓ Inert atmosphere storage
  - ✓ Requires some final assembly
    - ✓ Manufacturing equipment & “know-how”
    - ✓ Test and measurement equipment
  - ✓ Easily “borrowed” for other projects !

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What to store

If I store die and/or wafer product.

- ✓ Pro
  - ✓ Smallest form factor for storage, also often the cheapest.
  - ✓ “Resellable” or viable asset, possibly
  - ✓ Flexible – can accommodate package or product change
  - ✓ Not easily “commandeered” for other projects !
- ✓ Con
  - ✓ Component only partially “assessed” … KGD
  - ✓ Extra work, to know quality/quantity of device.
  - ✓ Delicate, highest risk of damage
  - ✓ Dedicated storage, generally at specialist site by specialists !!!!
    - ✓ Inert gas storage, special cabinets,
    - ✓ Refer to IEC 62258 Part 3
  - ✓ Requires assembly
    - ✓ Assembly equipment and “know-how”
    - ✓ Test and measurement equipment
    - ✓ Assembly Personnel
  - ✓ Only really viable on a batch basis, not “one-by-one”.
  - ✓ Not all “components” may have been stored (packages, lids etc.,)

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How to store ?

- ✓ Types of storage
- ✓ Robustness of item
  - ✓ Analyse how to destroy the item
  - ✓ Emplace preventative methods
- ✓ Suitable packing and protection materials
  - ✓ Specialist suppliers of materials (HiTech)
- ✓ Access to stored items

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Notes

- ✓ DON'T KEEP DOING AN INVENTORY CHECK!
  - ✓ Stop "disturbing" the stored product, trust your paperwork …
- ✓ Easy to provide conductive paths between "pins" of Assembly and Device for ESD protection
  - ✓ Not so easy for die/wafer !!!
- ✓ Easy to physically handle larger parts … whether you should or not
  - ✓ Die/wafer ALWAYS require specialist handling

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When to store

- ✓ Can I obtain the items to store ?
  - ✓ Cost vs. timing
  - ✓ Project / item lifetime
  - ✓ Whereabouts in item life-cycle are we ?
- ✓ Timing of setting up storage facility
  - ✓ Packing, handling & bagging equipment
  - ✓ Actual storage are allocation
  - ✓ Dry N_2 or inert gas supply
- ✓ Life-time under storage ?
  - ✓ Known shelf-life
  - ✓ Stock rotation
  - ✓ Call off rate

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Accompanying Paperwork ?

- ✓ Documentation needed
  - ✓ Data sheets, Specifications
  - ✓ Test results, Wafer maps Electronic media
    - ✓ Long-term reliability
      - ✓ Oxide shedding on magnetic media
      - ✓ CD's & CDR's unreadable
    - ✓ File Format issues
- ✓ What storage medium ?
  - ✓ At least Paper has a reasonable track record !

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Preparing die/wafer for storage

- ✓ Again, only TESTED product should be stored!!
- ✓ If wafer is to be stored, then the wafer should
  - ✓ either be inked,
  - ✓ or stored with the wafer map in future-readable form !!!
- ✓ If die product is to be stored, then separated singulated known-good-die only should stored.

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Mounting Properties of Tape

- ✓Chemical Properties
- ✓Tack / adhesion level
- ✓Movement
- ✓Migration
- ✓UV exposure (for UV release tape)

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Die Storage Containers

- ✓Wafer Vial
- ✓Wafer Cassette
- ✓Sawn wafer on film & frame
- ✓Tape and Reel
- ✓Waffle Pack
- ✓Gel Pack®

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Historical Storage

- We have been storing die/wafers for over 15 years, with few problems, but :
  - This is OLD technology !
    - 10u to 7u SLM/DLM, poly if you're lucky !
  - It was BUILT and DESIGNED to last
    - Generally military-type or military sponsored.
  - The technology was COARSE, RUGGED and ROBUST
    - Bipolar, PMOS, NMOS or MG CMOS
    - ESD specifications easily met (most of the time)

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How to damage die product ...

- ✓ Methods of destroying die products …
  - ✓ Mechanical & Thermal
    - ✓ Breakage's and fractures
    - ✓ Visual defects, changing criteria
  - ✓ Chemical
    - ✓ Ionic contamination
  - ✓ Electrical & Radiation
    - ✓ ESD Damage
    - ✓ Prolonged UV

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Mechanical Damage

- ✓ Damage to active area of die / wafer
- ✓ Cracking or crazing of passivation
- ✓ Damage to die underside
- ✓ Damage to exposed contact areas
  - ✓ e.g. Bond Pads
- ✓ Failure at visual inspection
  - ✓ Mechanical surface contaminants
  - ✓ Compromised integrity of seal-ring
- ✓ Piezo-effect
  - ✓ Changing electrical parameters through in-built stress

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The Storage conditions : Mechanical (1)

- ✓ Die mechanical protection
  - ✓ Initial placement (accuracy of carrier geometry)
  - ✓ Whilst in storage
  - ✓ Die removal
- ✓ Vibration
  - ✓ Movement during storage
  - ✓ Inappropriate inspection
- ✓ Die / wafer orientation
  - ✓ MEMS product
  - ✓ Abrasion and adhesion of foreign matter to surfaces.
  - ✓ “dust collects on flat surfaces ….”
  - ✓ Anti-bug & bacterial protection !!!

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The Storage conditions : Mechanical (2)

- ✓ Anti-vibration // Anti-shock packing.
- ✓ Thermal Conditions : ~ 17-25ºC
  - ✓ Min & Max conditions
  - ✓ Abnormal temperature excursions
- ✓ Humidity: ~ RH 10%-40%
  - ✓ Not too low (< 10%)
    - ✓ to prevent build-up of electrostatic fields.
  - ✓ Not too high (> 40%)
    - ✓ to prevent condensation and moisture ingress.
- ✓ Use of dessicants ?
  - ✓ Mechanical abrasion of particulates
  - ✓ Long-term effects ?

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Chemical Damage

- ✓ Ionic contamination of active area
  - ✓ Induced by poor pre-storage handling
  - ✓ Contaminant mobility through Silicon
  - ✓ Direct contact of contaminants
  - ✓ Proximity of contaminants
- ✓ Intermetallic growths
  - ✓ Contact areas
  - ✓ Active areas
  - ✓ Backside contacts
- ✓ Exotic III-V material sensitivities

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The Storage conditions : Chemical (1)

- ✓ Vacuum packing
  - ✓ Encourages ingress of contaminants through packing materials
  - ✓ Addition of desiccants can cause minor particles to be present
- ✓ Positive pressure systems
  - ✓ Require good inlet filtering
  - ✓ Keeps major contaminants out
  - ✓ Abnormally high N_2 content in atmosphere
    - ✓ monitor O_2 levels for any human operation in proximity !!!
- ✓ Use of bio-degradable material
  - ✓ Issues with known deterioration

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The Storage conditions : Chemical (2)

- ✓ Airborne contaminants
  - ✓ High content of airborne Sulphur compounds in many 3rd world countries
- ✓ Storage in inert atmosphere
  - ✓ Dry Nitrogen preferred
  - ✓ Alternatives include the noble gasses : Helium, Argon, Neon etc.,
- ✓ Proximity of “active” reagent sources
- ✓ Anti-static coatings can “flake” or rub off.
- ✓ Ingress of active reagents (deterioration)
  - ✓ Sulphur from rubber bands
  - ✓ Chlorine from cardboard / paper
  - ✓ Fluorine from “Pink” antistatic foam
  - ✓ Ammonia from some papers & plastics
  - ✓ Formic & Acetic acids from some plastics & silicone sealants
  - ✓ Other chemical attacks

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Electrical Damage

- ✓ESD field damage
  - ✓PN Junction damage
  - ✓FOX-GOX breakdown / puncturing
- ✓Sensitive parameter shifting
  - ✓Change Vt from trapped Qss charge
  - ✓Change Ioff/Voff parameters
- ✓Leakage “damage”
  - ✓FLASH, EEPROM etc., exhibiting corrupt data.

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The Storage conditions : Electrical (1)

- ✓ ES damage
  - ✓ Inappropriate packing materials
  - ✓ RH too low
  - ✓ Proximity to ES or EM field sources
- ✓ Poor initial testing
  - ✓ Stored with initial damage
    - ✓ “Walking wounded” scenario

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The Storage conditions : Electrical (2)

- ✓ Subjection to irradiation
  - ✓ Nuclear (high background)
  - ✓ EMR … local RF and microwave sources
    - ✓ Mobile Phone transmitters, microwave heaters
  - ✓ U.V. & X-Ray sensitivity
  - ✓ Photovoltaic effects on sensitive analog die.
- ✓ Effects caused by “ageing” on proximity materials
  - ✓ Polymerisation of specific plastics

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Who's involved ?

The Manufacturer

The Storage house

The Packing material supplier

The End User / Customer

Information needed from the MANUFACTURER

- ✓ Recommendations from Manufacturer as to known issues with packing materials
  - ✓ “Tacky-back” permitted for 12 months max.
- ✓ Expected lifetimes of Manufacturer supplied packing materials
  - ✓ Particularly those regarded specifically as
    - ✓ Transient packing
    - ✓ Temporary packing
- ✓ Known sensitivities of specific technologies
- ✓ Any recommended pre- and post-storage processes that may enhance the storage life.

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Information needed from the STORAGE house.

- ✓ Die & wafer traceability
- ✓ Actual age of silicon die
  - ✓ Not shown on final date code
- ✓ Silicon technology
  - ✓ Known sensitivity to external effects
  - ✓ Clearly marked packages, including static sensitivity
- ✓ Storage conditions (die history)
  - ✓ Min-Max conditions
  - ✓ Abnormal or adverse conditions that have been applied to die or wafers during storage

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Information needed from the Packaging Materials supplier.

- ✓ Are there any known mechanical, electrical or chemical degradation ?
- ✓ What known sensitivities of the supplied materials ?
  - ✓ Existing reports
  - ✓ Material details and processing
  - ✓ susceptabilities to chemical reagents, radiation, etc.,
- ✓ Recommendations on storage and lifetimes

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Information needed from
The Customer

- ✓ How long do the components need to be stored ?
  - ✓ This will affect the approach taken for storage.
- ✓ What call-off rate is expected ?
  - ✓ How often do the containers have to opened
- ✓ What periodic inspection is required ?
- ✓ Are there any pre- or post-conditioning requirements ?

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Unknown Issues (1)

- New processing materials and properties :
  - Copper metalization
    - Copper is chemically active,
      - has active oxides : Cuprite, Chalcotrichite, Tenorite etc.,
      - has active sulphides : Chalcocite, Bornite etc.,
    - Aluminium relatively passive, inert oxide
  - Bump materials
    - Novel intermetallics
    - Tin “whiskering” on new Pb-free Solder bumps ?
  - Passivation / Glassivation materials
    - Lifetime of new polyimides etc.,
  - Exotic semiconductor materials

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Unknown Issues (2)

- ✓ Die geometry shrinking
  - ✓ Increased sensitivity to ES field damage
  - ✓ Increased sensitivity to minor contamination
  - ✓ Increased sensitivity to marginal processing and in-built defects
  - ✓ Unknown “survivability” beyond the life of a PC or cell-phone
- ✓ Some product now is neither designed nor manufactured for longevity.
- ✓ Unknown issues when re-packaging / re-assembling
  - ✓ Availability of “other” items in build list.
- ✓ Consider the total operation of storage and it’s possible effect on the environment and local health / safety legislation and regulations

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Unknown Issues (MEMS)

- ✓ Storage sensitivities will be dependant upon MS type :
  - ✓ Biological
  - ✓ Chemical
    - ✓ Gas or liquid
  - ✓ Mechanical movement
    - ✓ Electrostatic
    - ✓ Thermo-cycle
    - ✓ Piezo-mechanical
  - ✓ Fluidic (pressure etc.,)
  - ✓ Mechanical sensing
    - ✓ Acceleration
    - ✓ Vibration
  - ✓ Field/extraneous sensing
    - ✓ Magnetic
    - ✓ Electrostatic
    - ✓ Radiation

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Initial conclusions

- ✓ Manufacturers consider the delivery packing to be TEMPORARY only
- ✓ Traceability needed throughout storage.
- ✓ Controlled Temperature & Humidity
  - ✓ 21ºC, ± 4ºC and 30%RH ± 10% @ 1 At (STP)
- ✓ Consider localised conditions
  - ✓ Anti-static precautions
  - ✓ Proximity of unknown or hazardous materials
  - ✓ Anti-shock & anti-vibration
  - ✓ Limit exposure to radiation where possible
  - ✓ Orientation of storage

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