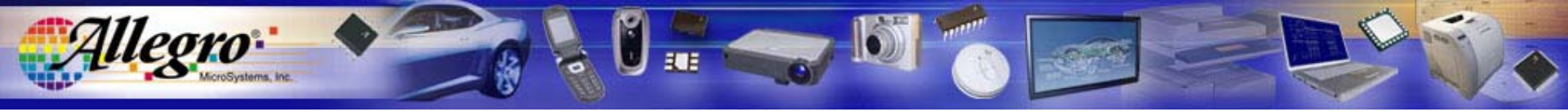
Allegro® MicroSystems, Inc.

High-Performance Power ICs and Hall-Effect Sensors

Alternative Cleaning Problems and Solutions

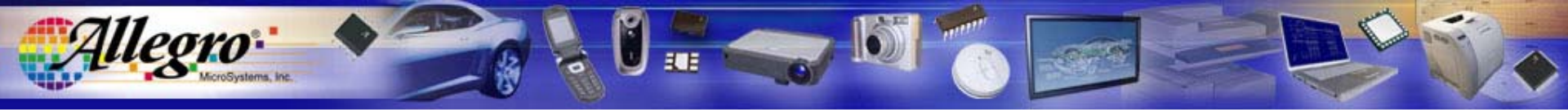
B. Smith 11/3/2010



Allegro MicroSystems, Inc. is a leader in developing, manufacturing and marketing high-performance power and Hall-effect sensor integrated circuits. Allegro's innovative solutions serve high-growth applications within the automotive, communications, computer/office automation, consumer and industrial markets. Allegro is headquartered in Worcester, Massachusetts (USA) with design and applications centers located in North and South America, Asia, and Europe.

Further information about Allegro can be found at

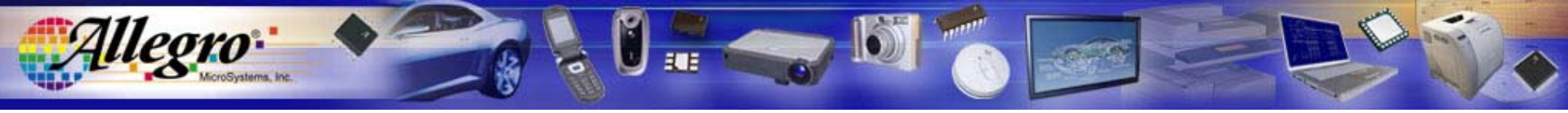
www allegromicro.com.



Allegro's TUR Project History

Since 1994, Allegro has investigated 143 TUR and Resource Conservation projects

- One half (72) of these projects have been implemented, 11 are still open, and the balance were not implemented.
- Total annualized savings to date is $1.1M for TUR and $1.2M for Resource Conservation.
- The projects involved Semiconductor and High Purity Water Manufacturing.



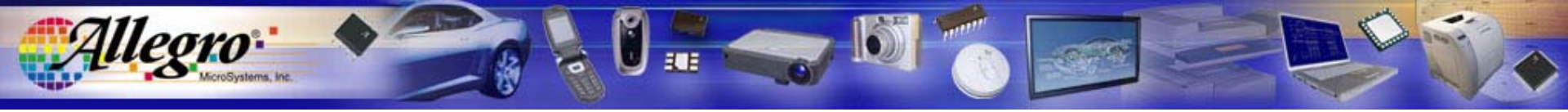
Examples of Allegro's TUR Projects
Cup Cleaning

- Evaluated use of Cup Baking Oven—to remove dried polyimide and photoresist coating by baking. Would use less xylene, destroy by thermal oxidizer any VOC vapors, and require use of a larger oven, class A rated for hazardous materials.
- Savings: xylene price $5,300/year
  Hazardous waste disposal and drum cost $1,600/year
  Toxics Use Fee- State of MA $1,100/year 5,600lb xylene
  Total Savings $8, 000/year
- Project Cost: Blue M CSP400A-C-7HP oven $6,088
  Exhaust $10,103
  Electrical $ 250

Total Cost $16,441

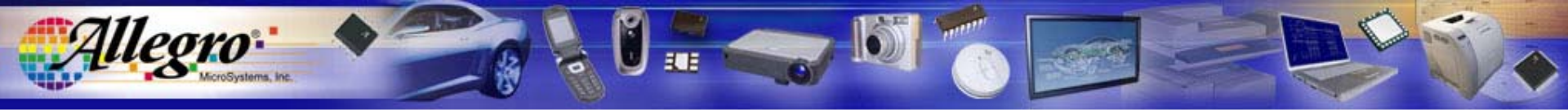
Payback: $16,441/$8,000=2.1 years

---but the 4" wafer process would go away in 1 year…



Eliminate Use of TCE, TCA, and Trichlotrifluoroethane

- Cleaning of pump oils from vacuum pumps was changed from TCE and 1,1,1-TCA to a terpene (Limonene) called Citrasafe from Inland Technology.
- Other vacuum pumps using a different oil had the use of their cleaner use decrease to almost zero by careful fine filtering of the used pump oil.
- Large vapor degreasing tank with 1,1,1 TCA (1300 gal/yr) for removal of lapping wax was eliminated entirely by use of a wafer backgrinding machine. This was done before the Montreal Protocol.
- Cleaning of circuit boards with trichlorotrifluoroethane was changed to the use of citrasafe in an ultrasonic tank.

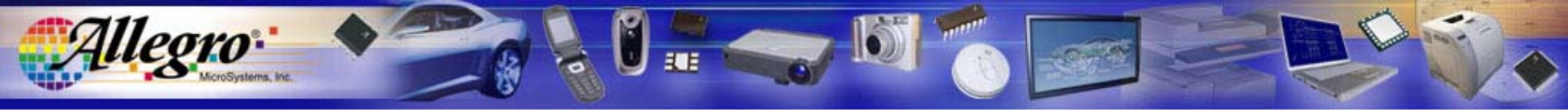


Eliminate Use of IPA for Wafer Cleaning

- Although not a TUR chemical, disposal of IPA in the wastewater drain was acceptable but not desirable.
- IPA removes silicon dust on the wafers.
- By purchasing cantilever-type loading diffusion furnaces (as part of setting up the 6” wafer process) which do not create silicon dust and using the RCA cleaning process (replaces 5% of previous IPA cleans), uase of IPA for wafer cleaning was eliminated entirely.
- Savings: 30,000lbs/year and $95,000.

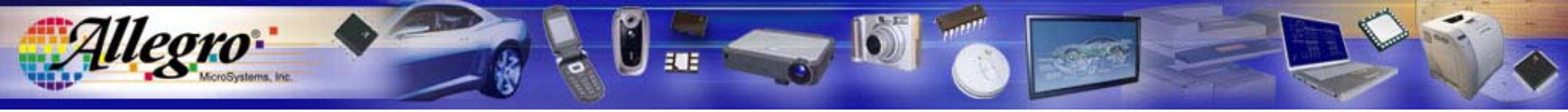
Wafer Carrier Cleaning

- Wafer boxes, process wafer carriers, single wafer carriers and wafer shipping jars and boxes were being cleaned with an IPA spray gun in a cleanroom hood.
- Plastic is hydrophobic and is very absorbent of organics such as oils. Wafer carriers eventually build up a heavy layer within its pores and on the surface of oils which must be removed. Any salts from fingerprints also must be removed which IPS alone does not do.
- A surfactant detergent was found to clean the carriers well at 65C, in an ultrasonic bath. IPA use was eliminated, the surfactant is biodegradable, run at a 1:100 dilution and very cost effective. The production solution is a box spray washer (giant dishwasher). Surfactant is Vector HTC-SCA1 from Intersurface Dynamics.



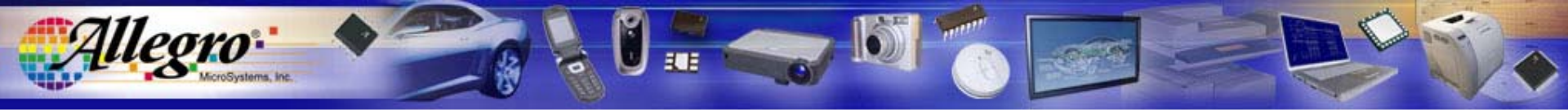
Other Cleaning Projects

- Purchased a dry ice blaster to clean tool parts. Certain tool parts were being sent to Texas for cleaning. Cost $40K, annual savings $105K, payback 5 months.
- Hot DI Water cleaning of wafers was proposed to save water and cleaning chemicals (acids) but existing equipment was not compatible with higher water temperatures. Since the cost was $500K per tool to replace plus the cost of heating the water, the project was not implemented.



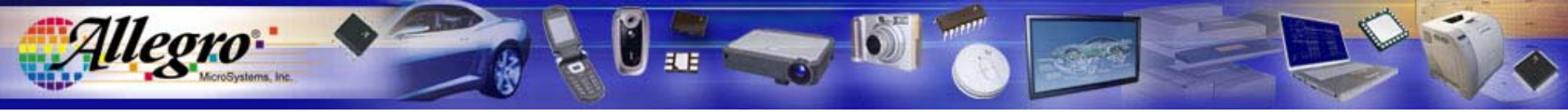
Principles of Cleaning

- The two main classes of substances to be cleaned off articles are organics such as oil, greases and waxes and inorganics such as salts.
- Organics are generally not water soluble so they require organic solvents to remove them, such as nail polish and acetone.
- Inorganics are mostly water soluble and require a water or water based chemicals to be removed, such as sodium chloride and water.
- There are substances that are the exception to these rules which may use the opposite class to remove them, such as water to remove alcohol or acetone.
- There are substances that are removed best by a combination of an organic and water, either serially or in combination, because of their nature or because they are composed of both an organic and a salt, such as fingerprints, which can be removed first with IPA for the oils and then with water for the salts, or 70% IPA and water can be used alone.



Avoiding or Reducing use of Organic Solvents

- Organic solvents are mostly toxic, flammable, do not dissolve in water or are incompatible with sewerage waste water streams (not biodegradable), produce VOC's and are expensive. Generally, reducing their use or eliminating their use is a good idea.
- One of the best ways to remove organics without solvents is to use a detergent. A detergent bridges the two classes of organic and salt because one part of its molecule is an organic and the other a salt (remember 'like dissolves like'), therefore it is water soluble and can dissolve organics such as oil and grease.
- Detergents usually have a pH which is basic but can also be acidic or neutral, and this can effect what they are capable of dissolving and how they affect the substrate (cause corrosion such as rusting or dissolution of the substrate).
- A special class of detergent is called a surfactant detergent which is used quite dilute for delicate cleaning.

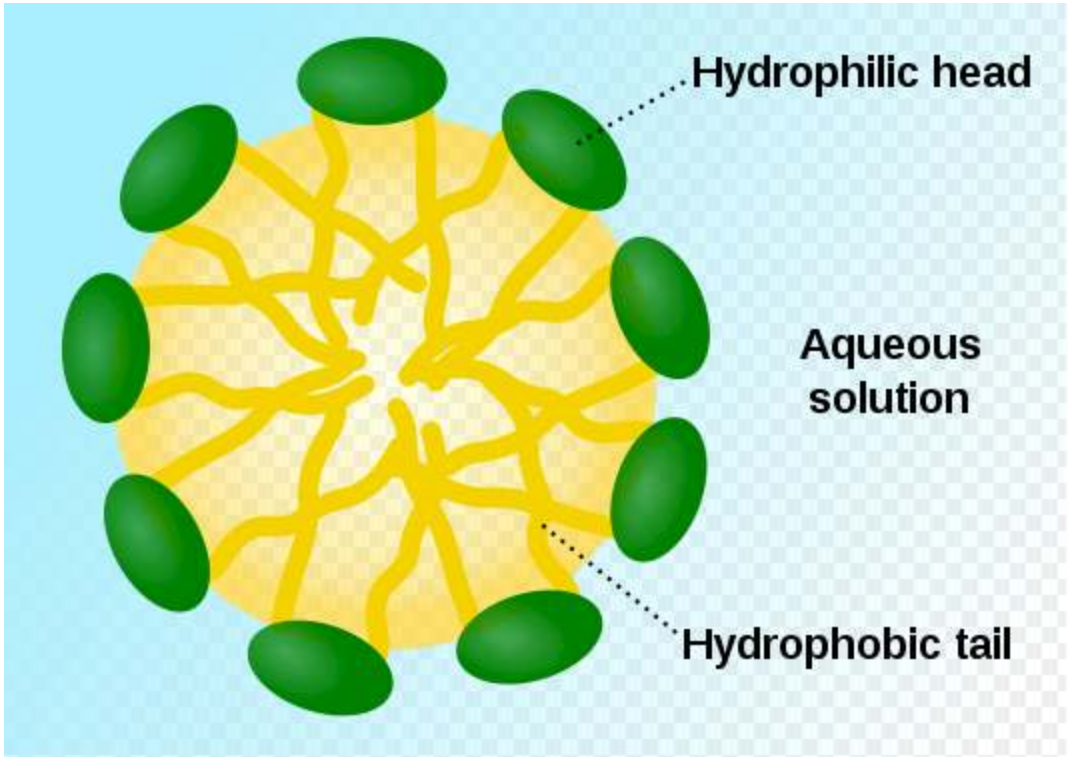


How does cleaning work?

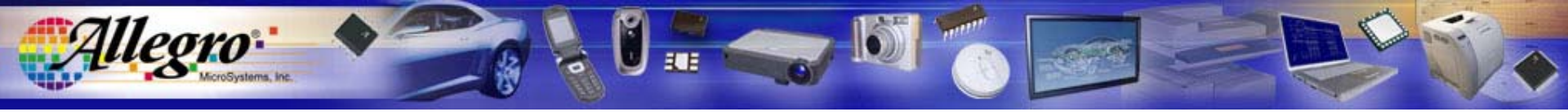
- It’s all about molecular motion, dynamic equilibrium, concentration gradients, surface tension and complexes.
- How can we increase cleaning of substrates and dissolving of substances?
- Time, Heat, Agitation, Ultrasonics.
- Change the chemical state (species), by chemical reaction, complexation or ionization.
- Change the physical state, by diffusion, osmosis, dissolution (solvation), melting, separation, dilution.
- Go from a region of high concentration to a region of low concentration.

A Surfactant Micelle

A micelle—the lipophilic tails of the surfactant molecules remain on the inside of the micelle due to unfavourable interactions. The polar "heads" of the micelle, due to favourable interactions with water, form a hydrophilic outer layer that in effect protects the hydrophobic core of the micelle. The compounds that make up a micelle are typically amphiphilic in nature, meaning that not only are micelles soluble in protic solvents such as water but also in aprotic solvents as a reverse micelle.

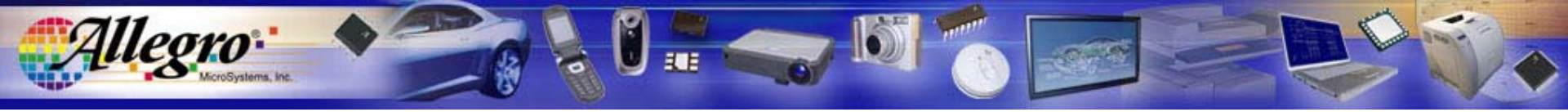


A surfactant is a “wetting agent” and thus lowers the surface tension of a surface so that cleaning agents can reach the surface and lift off contaminants.



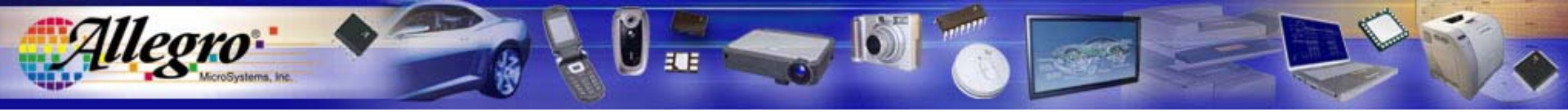
Micelles Encapsulate Oils

- Each micelle can open up and admit oil molecules and dirt particles, thereby encapsulating them like an amoeba. They act like little PacMan's gobbling up dirt and oil.
- The concentration of the surfactant detergent must be not too high or the micelles will be destroyed by each other and not too low or there will be too few to do any work.
- Increasing the temperature increases the activity of the micelles by making them open up more frequently to encapsulate more molecules. Temperatures over 65C tend to destroy the micelles and lower their ability to hold onto dirt and oil.



Ultrasonic Cleaning Tanks

- Ultrasonic waves in a tank produce cavitation bubbles at the micro level which help agitate the solution and lift off contaminants.
- If the solution contains a small amount of surfactant detergent it will reduce the surface tension and increase the cavitation rate. Dilution of the surfactant is generally around 1:100 but for some applications can be 1:20 to 1:1000.
- Further increases of molecular kinetic motion will accelerate the cleaning, therefore heating the bath will accomplish this, generally 65C max.
- Studies at Allegro and by others in the cleaning industry have shown that adding a small amount of a solvent to a surfactant detergent increases the cleaning effectiveness for organic contaminants.
- Generally, the solvent amount is about 1%. If more is added an emulsion may form, but this can still be highly effective in removal of organics. Final rinsing may require a second stage treatment in a pure surfactant detergent solution, then a water rinse.



Terpene Cleaning

- The most popular cleaning solvent is d-limonene, a terpene derived from orange peels. Available from Petroferm as Bioact EC7 or Citrasafe from Inland Technology.
- It is used by itself as a solvent directly, for greases, oils and light waxes.
- It is also added to surfactant detergents to boost their effectiveness. Such as citrasolv (in supermarkets), citranox (from Alconox), and others.
- **The effectiveness of this system is that ionics, organics (both polar and non-polar) can be dissolved in a hot (65C) ultrasonic bath with surfactant detergent and terpene mix.**
- Although not a universal solution, it is so promising that it should be tried first before giving up and using a straight solvent.