In situ gas purification and vacuum control in sealed cavities

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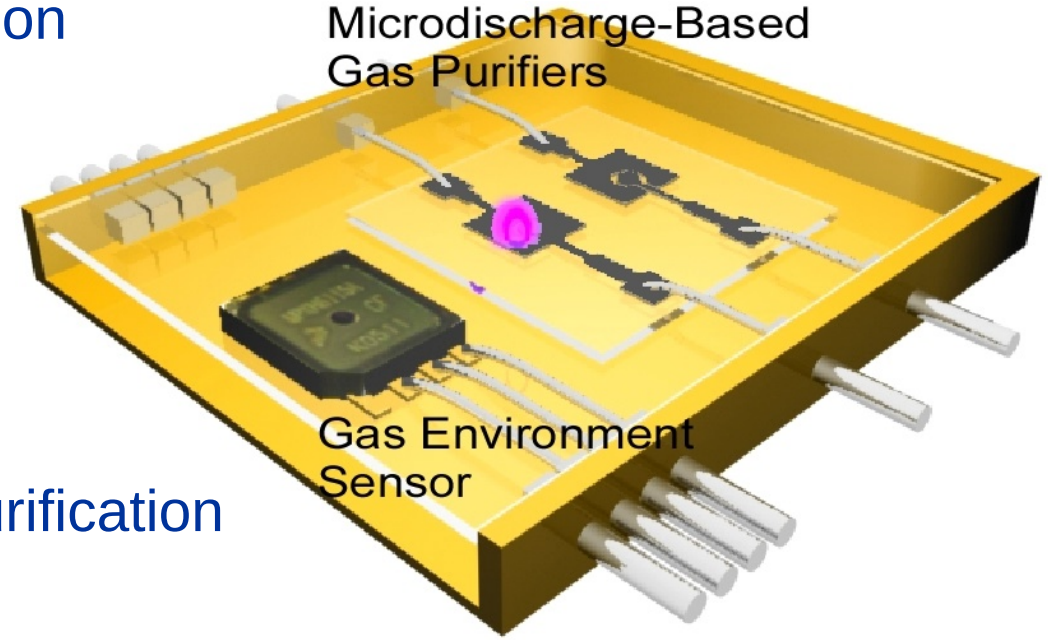
Presentation Outline

- Microscale packaging in the Michigan WIMS ERC
- Reasons for gas purification in microscale packages
- Operation
- Benefits
- Inert and Organic Gas Purification Results
- Pressure Control
- Conclusions



Microdischarge-Based Gas Purifiers in Sealed Microscale Package

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UM Engineering Research Center on Wireless Integrated MicroSystems (WIMS)

- Founded in 2000 by Prof. Kensall Wise at the University of Michigan by consolidating existing activities and building new partnerships
- Domestic alliances with 9 US universities
- International alliances with U. Freiburg & Kyoto U.

Sixth-Year Statistics

- 134 Projects
- 201 Graduate Students
- 174 Undergraduate Students
- 38 Core Faculty
- 18 Industrial Partners
- 155 Sixth-Year Publications
- 20 Sixth-Year Patents Awarded

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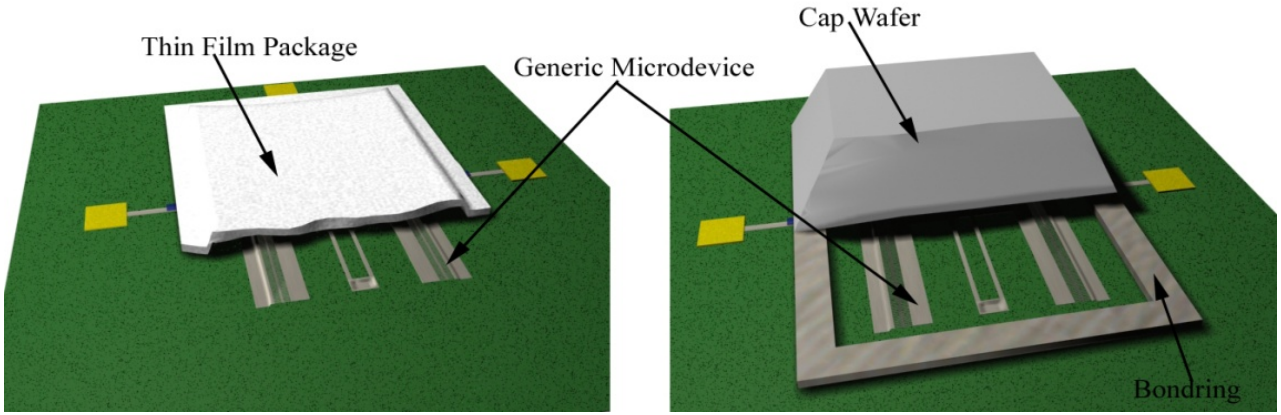
Wafer-Level Vacuum Packaging

- Wafer-level
- Low temperature



Packaging Using Thin Films

- Metals:
  1. Low-temperature, thin-low-profile
  2. More flexible process
  3. WIMS explored and reported on this approach in the past

*** K. Najafi**

Packaging Using Bonding/Capping

Anodic Si-Glass: Reliable, biocompatible, needs flat surfaces, optically transparent

Eutectic Si-Au: Low-temperature, flows over feedthroughs, biocompatible

Solder: Low-temperature, flows over feedthroughs, minimal disturbance to device wafer, wide variety of materials

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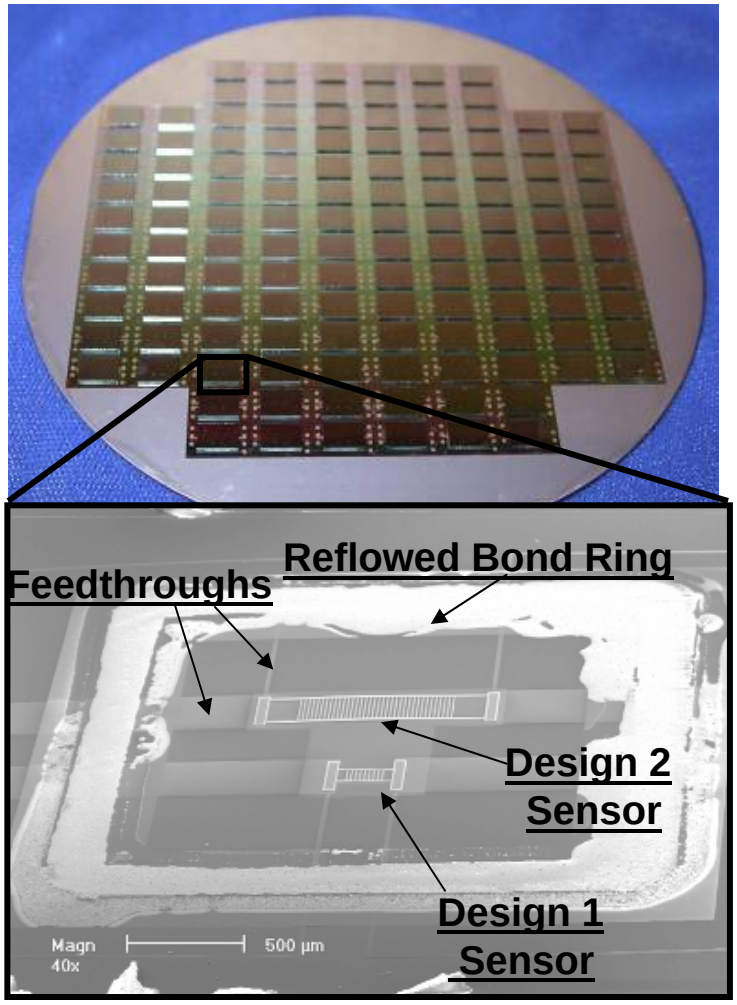
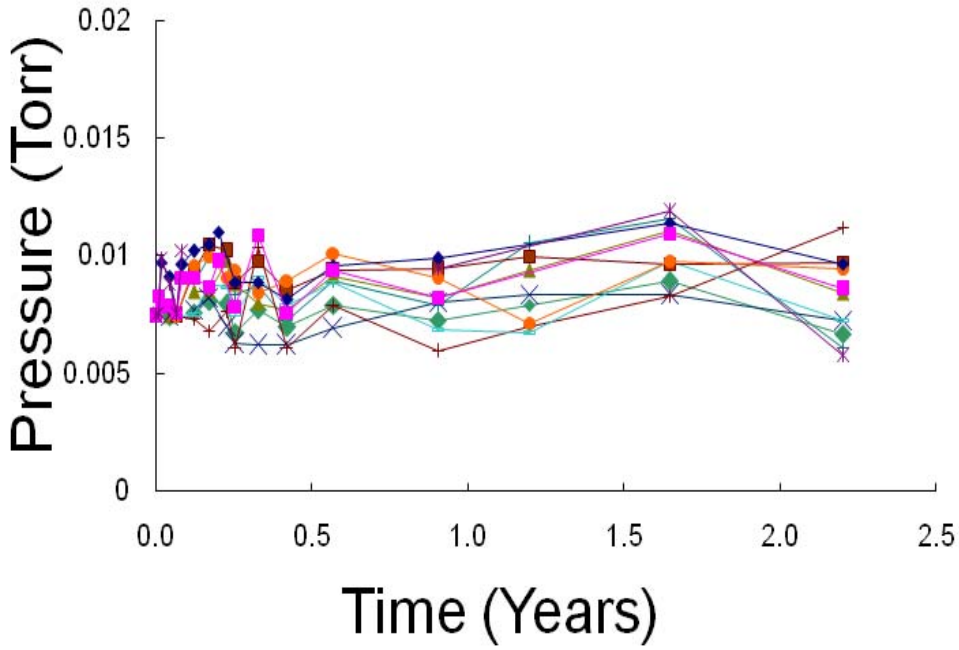
Sealed Pressure Stability



- Au-Si eutectic bonds provide long term stability, our tests exceed 2 years



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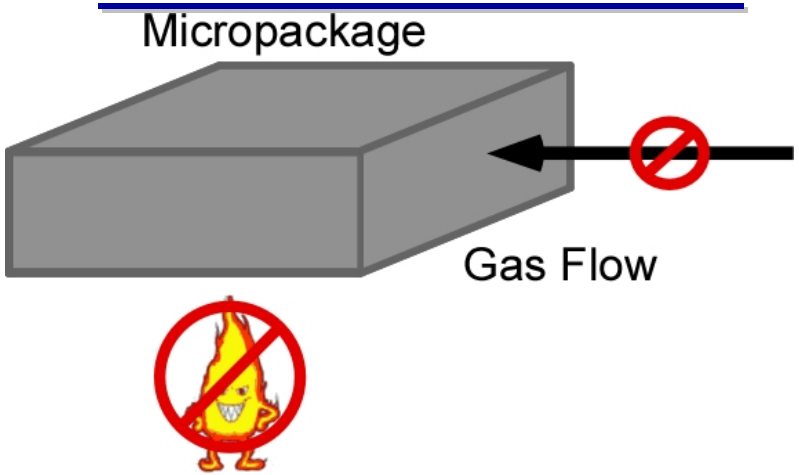
The Problem



- Parasitic leakage of contaminating gases can compromise the purity in microscale packages
- Leakage can come from surface outgassing or diffusion through cavity walls
- Small volume packages are especially susceptible
- With a 10 µTorr sealing pressure, the leakage rate is 2×10^{-8} (Liter x Torr)/(cm^2 x sec)*

- Heating packages can accelerate outgassing

*J. Mitchell, G. Lahiji, and K. Najafi, Hilton Head '06

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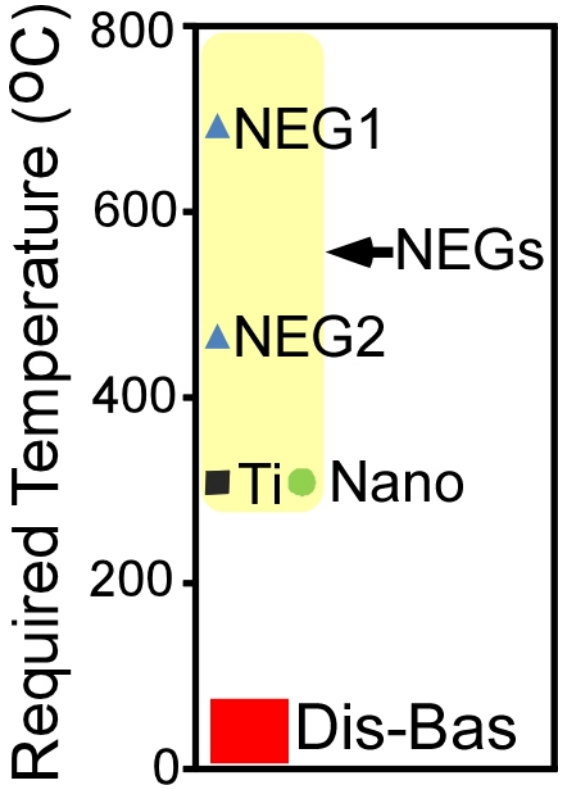
Current Solutions

- Graph displays required operating temperatures of gas removal methods
- Nonevaporable getters:
  1) Materials are not always lithography compatible
  2) Require high operating temperatures of 300˚C

Symbol	Type	Ref
NEG1	NEG Zr-Al	[Gio89]
NEG2	NEG Zr-V-Fe	[Sae07]
Ti	Ti film	[Li07]
Nano	Nanogetter	[Spa03]
Dis-Bas	Microdischarge -Based	This work



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Gas Purification Operation

- We have developed microdischarge-based devices
- Microdischarges are created by applying pulsed DC voltage
- Utilize metal features located *in situ*
- Sequester gases including O_2, N_2, and H_2O vapor
- Sealed in microscale packages for:
  - Gas purification
  - Humidity reduction/control
  - Pressure reduction/control

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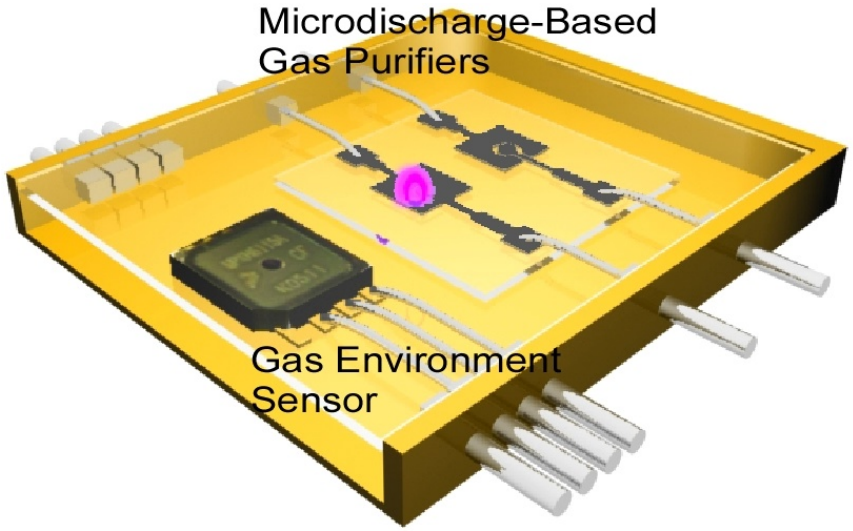
Benefits



- Tune gas environments to control the extent of purification
- Complement or replace thin-film getters
- Operate at ambient temperature
- Require no heating
- Operate over a wide range of ambient temperatures, from cryogenic to 1,000ºC
- Low power consumption on the order of 100 µJ per pulse

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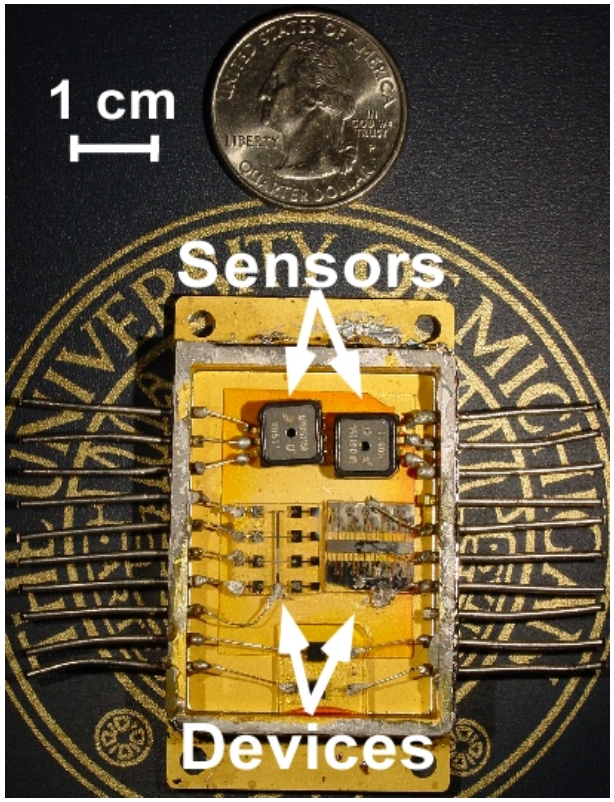
Packaging Benefits

- Easy to fabricate, compatible with lithographic processing
- No special packaging or handling requirements
- Typical devices have active areas <5 mm^2
- Two dimensional
- No particulates
- May remain dormant for years before operation



Devices in Commercial Package

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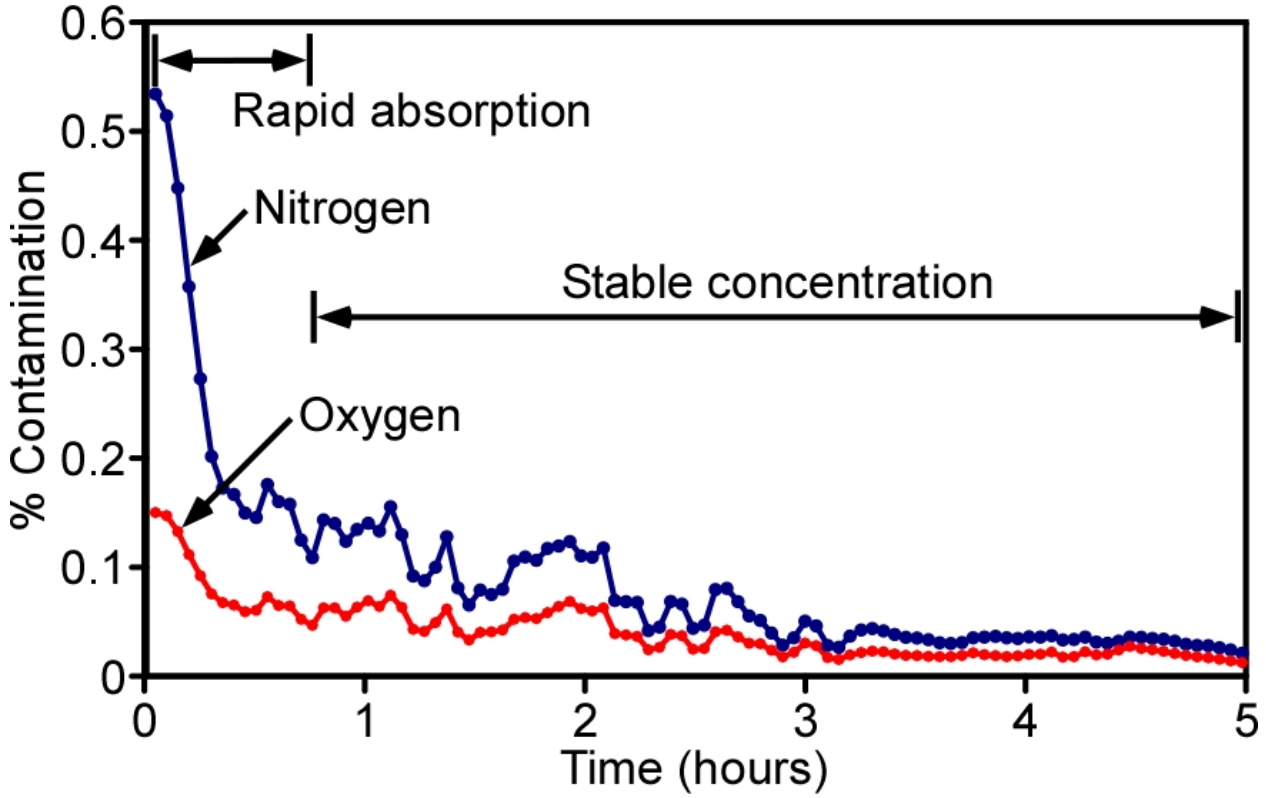
Removing Oxygen and Nitrogen



- In a 4 cm^3 environment of 99.25% He, and 0.75% air
- 50x reduction in N_2 and 16x reduction in O_2
- Preliminary demonstrations achieved 90 ppm and 70 ppm respectively

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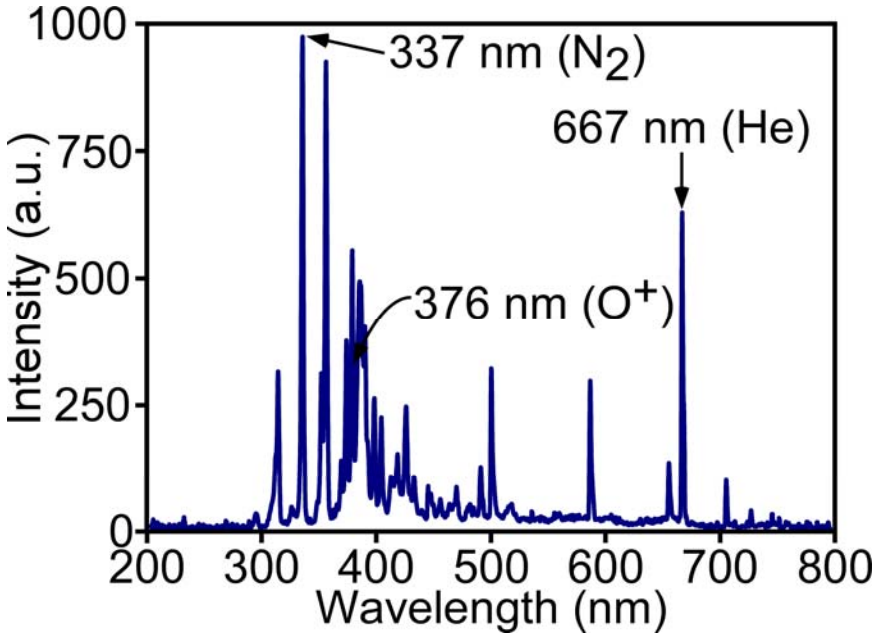
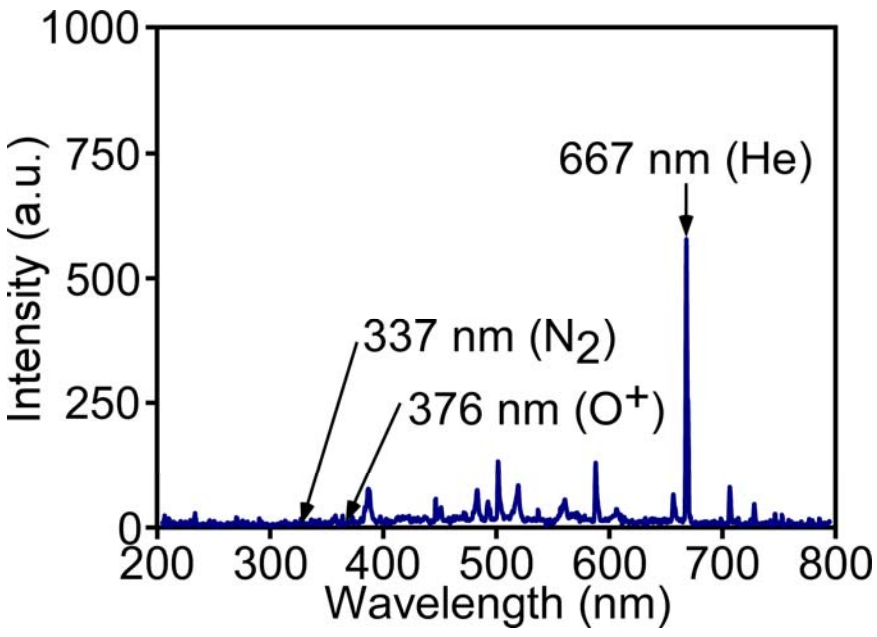
Inert Gas Purification



Before Purification



After Purification

- Spectra before and after purification, showing removal of oxygen and nitrogen contamination in helium environment
- Final environmental purity of 99.98%

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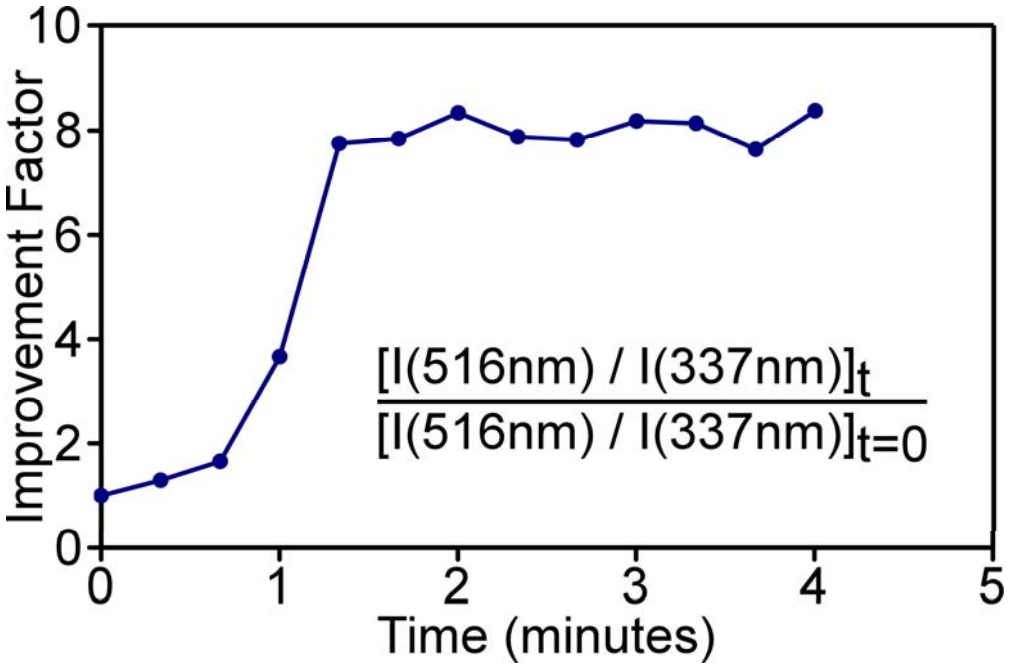
Organic Gas Purification



Ratio of C_2 to N_2 during gas purification

- Purifies environments with organic gases
- Oxygen and nitrogen removed
- Increased carbon concentration by 8x relative to nitrogen

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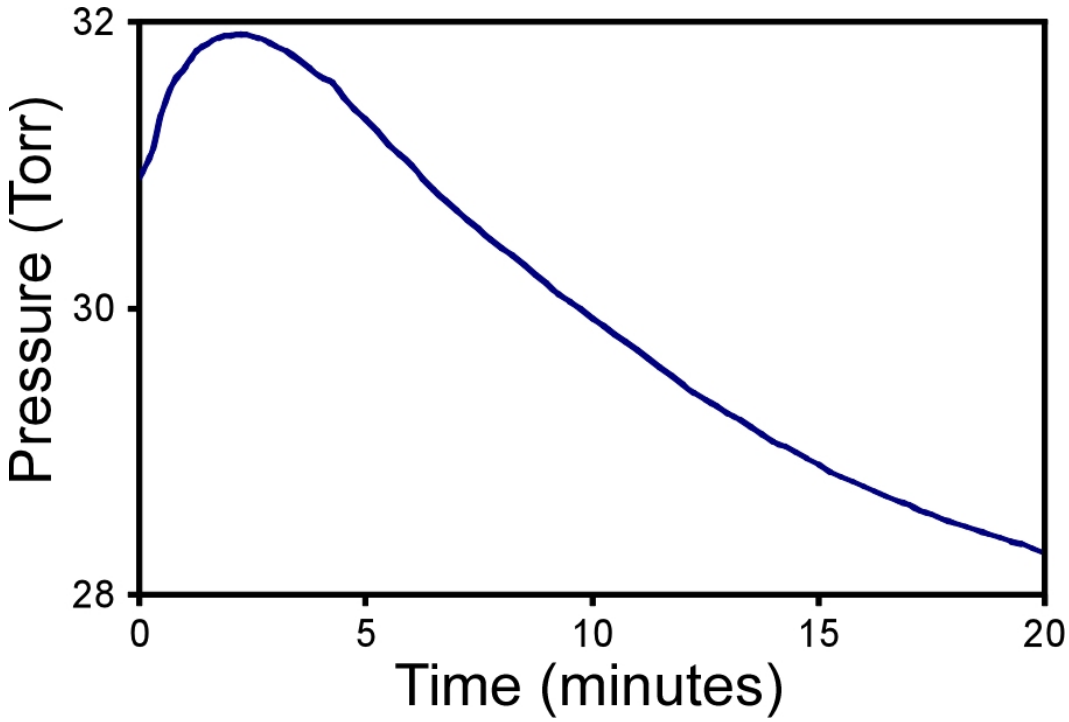
Pressure Control



- Microdischarges can absorb enough oxygen and nitrogen to reduce package pressure
- Air environment, 4 cm^3 package
- Pressure held steady for 10 hours between discharges

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Conclusions

- Purification technology which selectively sequesters contaminating gases and humidity
- Allows tuning of packaged gas environments
- Complement or replace thin-film getters
- Operates at ambient temperatures, from cryogenic to 1000ºC
- Requires no heating
- Easy to fabricate and package
- Has reduced nitrogen concentration by 50x and oxygen concentration by 16x

- Thin film and capped packages have been developed
- Wafer-scale encapsulation techniques available

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Thank You

Questions?

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Parameters

- Electron Density: 10^{9} - 10^{11} cm^{-3}
- Ion Density: 10^{9} - 10^{11} cm^{-3}
- Electron Energy 50 eV – 400 eV
- Electron Temperature: $5.8x10^{5}$°K to $4.6X10^{6}$ ˚K

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