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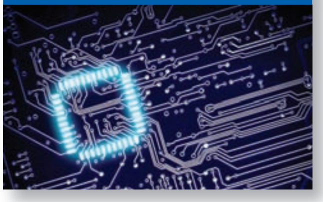
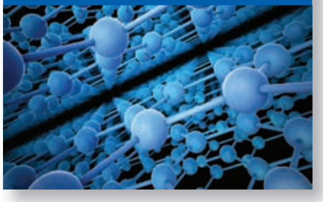
## Directed self assembly



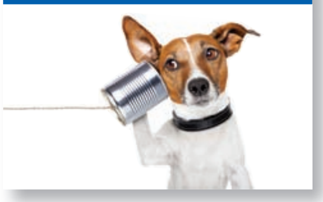
## Wafer cleaning legislation

## Getting more out of graphene



## Chip spending increases

## MEMS microphones



# Innovation in materials recovery

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AN ANGEL BUSINESS COMMUNICATIONS PUBLICATION

# Innovation
## in materials recovery

Paul Stockman, Technology Manager at The Linde Group explores the complex procedures deployed to sustain a secure and reliable supply of material in the electronics Industry.

THE UNMATCHED TECHNOLOGICAL PROGRESS demonstrated in the semiconductor manufacturing industry has ultimately been made possible through an industry norm of constant technical and engineering innovation.

In this fiercely competitive and diverse market, the constant drive for progress has driven manufacturing complexity. Production of semiconductor devices such as microprocessors and memory is becoming increasingly sophisticated, requiring manufacturers to optimise process performance with increasing levels of resolution and accuracy. For materials suppliers, the portfolio of materials required continues to grow, and as a result, so does the supply chain complexity and quality requirements.

This pressure is exacerbated by a number of factors: a scarcity of key materials, such as the well documented reduction in the supply of helium and complex supply chains. To stay ahead of the curve and reduce operating costs, ensuring a secure and reliable supply of materials is vital.

In fact, it is becoming increasingly important to consider exactly where materials are coming from to ensure consistent quality, stable supply and ultimately the lowest overall cost of ownership. Electronics manufacturing plants are not always located in the optimum position for material supplies, making it vital to think about how materials could potentially be recovered, purified and re-used on site, saving both shipping costs and reducing logistics risks.

### Three Recovery Options

To meet current industry demands we presently operate three main types of materials recovery solutions – tailored to individual customer requirements. Firstly, there is the on-site, closed loop approach where waste materials are recovered and returned into the customer manufacturing process via purification and quality control systems.

This solution can be used for materials such as helium and argon. Another alternative is on-site, open loop recovery. In this case, materials are recovered on-site but then removed and re-used for other applications – for substances like sulphuric acid. The final option is off-site recovery, which is mainly used for high cost materials. Here, the materials are recovered before shipping off-site for recovery and purification, for example, in the case of xenon.

All types of recovery can offer numerous benefits including cost reduction, supply chain security and a lower carbon footprint. Let's now take a look at these three options in more detail, and in relation to helium, sulphuric acid and xenon which are so vital to electronics manufacturing.

### Helium: Finite resource and specialised recovery

Firstly, let's take Helium which is recovered via the on-site, closed loop approach.

Even though helium is an abundant element in the observable universe, on earth it is a relatively rare and non-renewable resource, found in the ground and co-located with some natural gas deposits.

In electronics manufacturing, helium is used at hundreds of points in the fab for cooling, plasma processing, and leak detection – however, its recovery is not straightforward. Helium is recovered as part of the natural gas extraction process and is not economically viable to be produced on its own.

To combat this issue, we have been closely involved in the design and manufacture of equipment to


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separate, purify, and liquefy helium to a temperature of -269˚C. Only in its pure, liquid state can helium be economically transported across the globe. By combining several core technologies, we have created a hybridized plant design to extend helium recovery to electronics applications, where the waste streams are often more dilute and contaminated.

Consequently, groups of large fabs clustered in one major site will be able to receive the real benefits of this helium recovery system, benefitting in terms of cost.

## Sulphuric acid: Fresh water and logistics

The recovery of Sulphuric acid falls under the second category of materials recovery: on-site, open loop recovery. The drivers for sulphuric acid recovery are very different from that of the previously discussed Helium. The benefits here are reduction of disposal costs and associated demands for fresh water and waste water volumes.

Sulphuric acid is used in electronics manufacturing to remove sacrificial materials, to dissolve stray particles, and to otherwise clean semiconductors. Disposing of the used acid involves first neutralizing and then diluting the waste until it is acceptable for general waste water discharge to local standards.

The Linde Group joint venture, AUECC, is recovering sulphuric acid from the waste material, reducing costs and community waste flows. Using proprietary exchange technology enables the recovery of a high percentage of sulphuric acid from a customer's waste material each time. The material can be purified for re-use in the electronics or other industries.

At the largest semiconductor sites, the logistics of delivering fresh sulphuric acid and removing liquid waste can lead to congestion of delivery vehicles and large storage facilities. Therefore, by moving in acid recovery, the logistics traffic and facilities can be significantly eased.
The result: reduced disposal costs, lower environmental impact, lighter traffic.

## Xenon: Rarity and recovery

Finally, let's turn to Xenon, which is recovered off-site. Xenon is a particularly rare gas, with approximately only one part in 10 million in the atmosphere.

In electronics manufacturing, xenon is used in small amounts in lithography lasers, and in higher amounts and concentrations in etch applications. In fact, sometimes xenon is used as itself in plasma etching, and alternatively as the fluorinated compound $XeF_2$.

Xenon is obtained from large ASUs as a 1:13 crude mixture with krypton and this mixture is then separated, purified, and packaged at one of our global rare gas manufacturing centres. Due to the low starting concentration, only about 10 million litres of Xe are made each year.

So, how does the process work? Xenon is captured in proprietary vessels, shipped back to the global rare gas centres for re-purification. The original customer receives a credit for the xenon recovered at their site.

Recovering xenon in this way can have real tangible results. Ultimately, being able to recover molecules of xenon enables expansion of supply for customers, and stabilises the cost of the material for larger users.

## Processes for a sustainable future

In a world dependent upon manufacturing processes requiring the use of limited resources, coupled with an ever increasing demand for electronic goods, finding innovative solutions to increase the sustainability of manufacturing is not an easy feat.

The responsibility falls on companies within the manufacturing industries to employ technologies that reduce waste, increase productivity, recycle and purify, and lift the strain on natural resources.

These are now being achieved in ways that contribute towards lower costs, provide flexible logistical solutions, and benefit the environment for a sustainable manufacturing future.

THE LINDE GROUP

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## Enabling smarter electronics manufacturing through innovative gas and chemical technology.

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