Excimer laser gases

An exciting application for lithography

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The familiar, colorful electric glow of neon signs can transform into a powerful – and invisible – tool for making leading-edge microchips by adding small amounts of other simple gases. They're called excimer lasers because the light is emitted by excited dimers of two molecules (*Figure 1*).

They generate particular wavelengths of light in the deep ultra violet (DUV) spectrum, which has wavelengths even shorter that those produced by the sun. These lasers are used to help pattern the circuiting of microchips, band layers of transistors together, and even correct our vision.

Excimer laser gas mixtures are a combination of rare gases (argon, krypton, xenon, or neon) and halogen gases (fluorine or chlorine). The mixture of gases determines the wavelength of DUV light produced. Argon+fluorine+neon (193nm) and Krypton+fluorine+neon (248nm) are the two most common mixtures used. In terms of volume; neon makes up approximately 96–97.5% of the mixture.

Neon, krypton, and xenon, along with helium and argon, are considered rare gases, and are only present in the air in trace amount. In order to extract them in viable amounts from the air separation process, large-scale units with at least 1,000 tons per day of oxygen capacity are needed. The largest air separation units (ASUs) can produce one cylinder's worth of xenon every two days.

Xenon and krypton have a higher boiling point relative to liquid oxygen and are collected in a separate column that is designed to remove hydrocarbon impurities and oxygen, leaving a crude mix of 90% krypton and 7-8% of xenon that is further purified off-site.

Neon, which has a lower boiling point relative to oxygen, is normally extracted from the lower pressure column of an ASU, along with nitrogen; the crude product contains 50% neon and is transported to a separate enrichment plant to be purified using cryogenic separation technologies. This makes manufacturing, purifying, and storing these gases quite challenging.

The heaviest rare gases – krypton and xenon – are removed from air as liquids at temperatures above the condensation point of the major components of air, which are nitrogen, oxygen, and argon. Argon is then separated from oxygen and nitrogen by the fractional distillation of liquid air.

Industrial quantities of fluorine are produced via the electrolysis of molten potassium fluoride/hydrogen fluoride mixture. Fluorine is produced as a gas, which bubbles to the surface of the mixture. After capture, the fluorine is purified and carefully packaged in order to safely contain this highly reactive gas.

Specific mixtures of rare gases with halogens are carefully blended in specially prepared cylinders to ensure homogeneity and long storage life. Advanced analytical capabilities are essential to ensure they adhere to strict quality parameters for blend accuracy and purity.

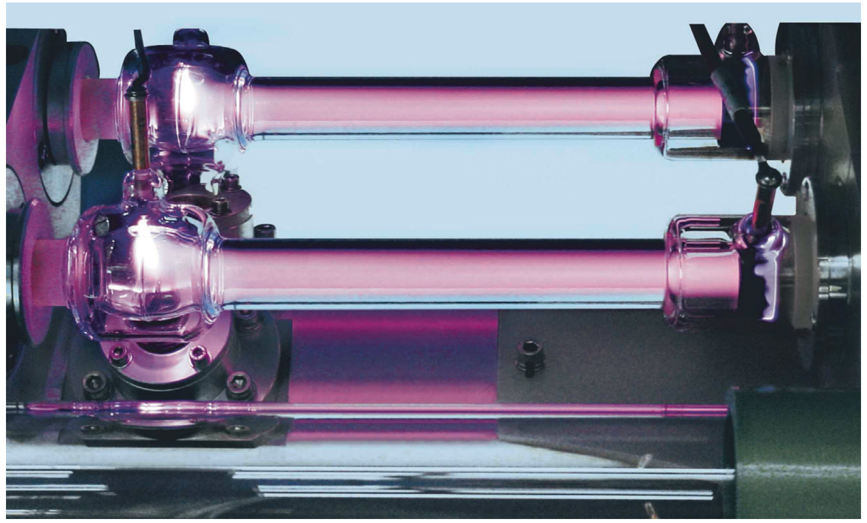
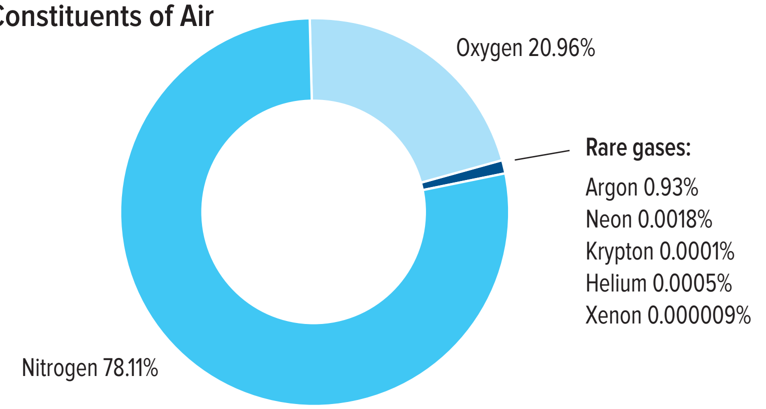
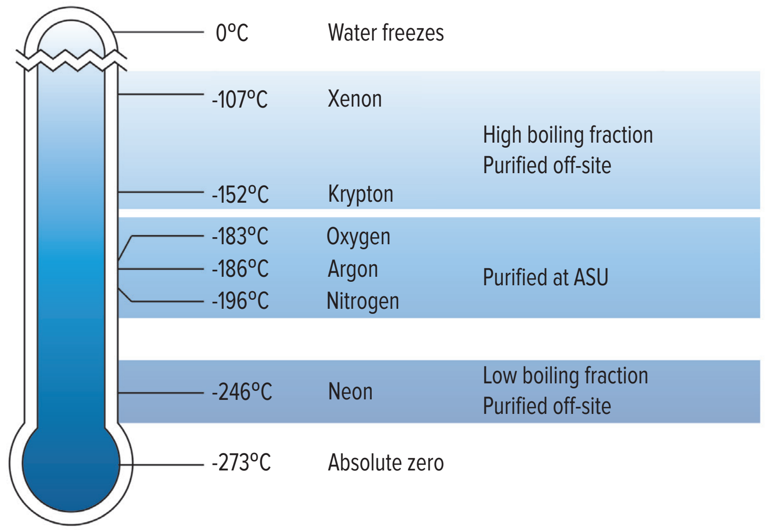


Figure 1. Seen here is the excitation of the excimer gas mixture in a laser discharge tube. The gas mixture is introduced into a chamber called the resonator and an electric current is passed through it. The electrons in the atoms of the gas molecules absorb the current and become "excited"; they start moving from low to high energy orbit around the atoms nucleus and in this process, they emit particles of light.

Constituents of Air



Boiling Points



Applications

- **Photolithography:** The photolithography process is key to the miniaturization of microchips. A scanner acts like a slide projector: it takes the light from a source, used to transfer an image from a master pattern, etched in a piece of glass, onto a semiconductor wafer that is covered with light sensitive chemical films. This image is the pattern that will form the minute circuitry of the microchip.

- **Annealing:** Excimer lasers are also used in the manufacturing of higher-end display screens with better resolution and color fidelity. A laser beam is used to heat and fuse several thin layers together, making the device faster and more energy efficient.

- **Medical:** Excimer lasers produce wavelengths around 200nm and can precisely remove material via ablation as opposed to evaporation. Ablation avoids thermal damage to the surrounding material, and therefore results in minimal scarring when used to cut human tissue. This property makes it ideal for use in corrective eye surgeries and in the treatment of certain dermatological conditions.

Market

The current market for laser gases in electronics is around 300 million liters per year and growing. This growth is being driven by the overall growth in the microchip manufacturing capacity, which is expected to increase at a 6% CAGR (compound annual growth rate) from 2016-2023, and by the use of multiple patterning at leading-edge nodes. Multiple patterning lithography means performing the same patterning step 2X, 3X, 4X times with a DUV laser to make the same feature, which at larger dimensions only took one patterning step. This is done to create more circuit features like transistors, without increasing the physical size of the chip. The use of excimer laser gases increases with the increase in steps.

Future

EUV (Extreme Ultraviolet lithography) is a next-generation lithography technology that is being developed to enable further shrinkage of features in microchips and will indirectly use both carbon dioxide (CO_2) and hydrogen.

EUV produces an extremely small wavelength of light – 13.5nm – that enables chip manufacturers to perform fewer patterning steps compared to DUV. The EUV light is produced using an indirect light source. A laser beam generated using a CO_2 laser is used to hit a tiny tin droplet, which in turn generates EUV light. Some of the residual tin debris accumulates in the light collector, and this chamber has to be cleaned regularly using hydrogen. The CO_2 laser itself is generated using a mixture of high purity nitrogen, helium, and carbon dioxide. EUV will largely be complementary to DUV lithography and will not replace it in the near future.

Excimer laser gases are crucial in making smaller device features such as transistors and capacitators. This helps in packing more computing power in a smaller unit area, thereby making our electronics devices much faster and energy efficient.

Linde's SPECTRA® laser gas mixes have enabled leading-edge photolithography for more than 20 years. Linde is a primary manufacturer of key rare gases and fluorine, and has proprietary technologies for the handling and treatment of cylinders along with world-class mixing facilities that ensure quality and homogeneity. SGR

More information

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