

Semiconductor Technology from A to Z

Photolithography

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DUV vs. EUV

Overview

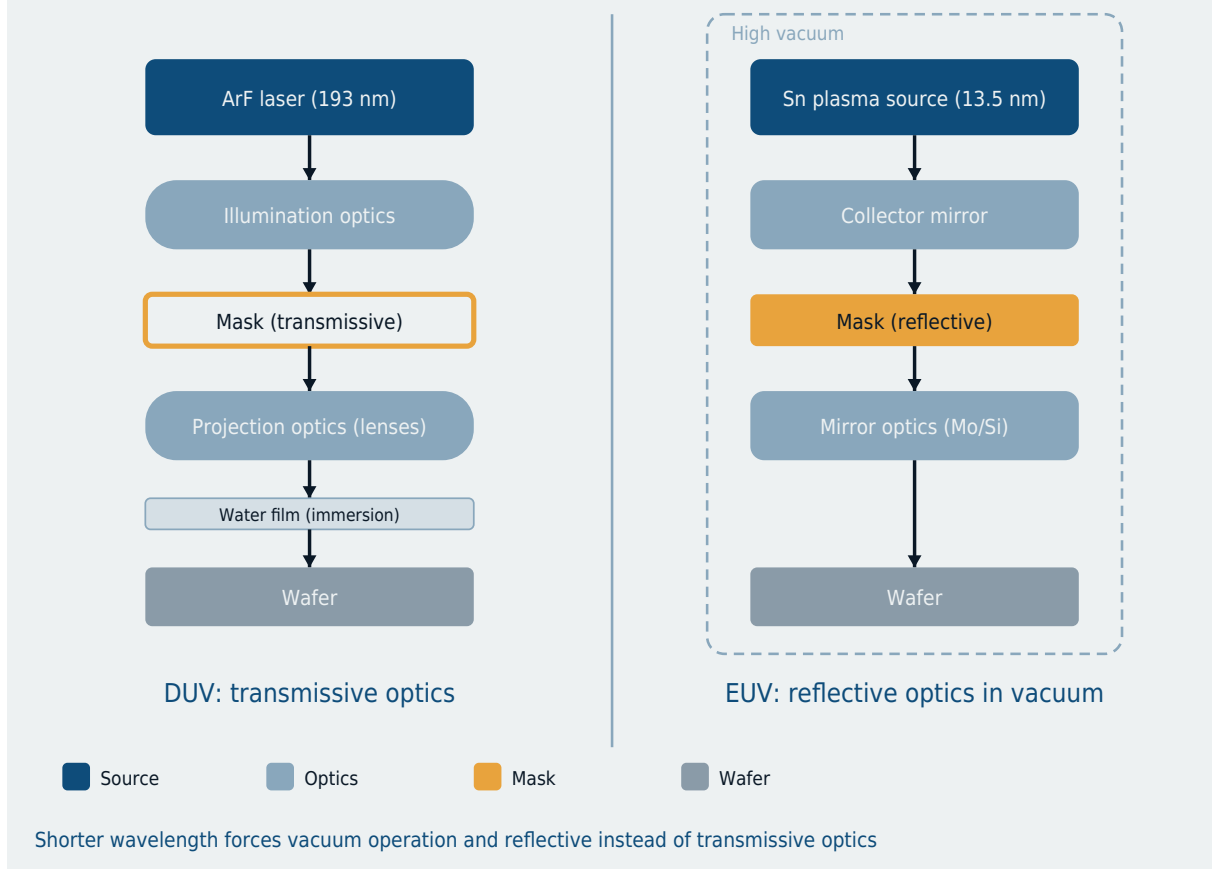
DUV (Deep Ultraviolet) and EUV (Extreme Ultraviolet) are not fundamentally different exposure methods, but two wavelength regimes of the same basic idea: reduction projection exposure, as described in the [chapter on exposure methods](#). The jump from 193 nm (DUV) to 13.5 nm (EUV) sounds like a small numerical difference, but technically reinvents almost everything – from the optics and the mask to the operating environment of the entire system.

Technology Compared

DUV systems mostly use ArF excimer lasers at 193 nm, often as immersion lithography: a thin water film between the final lens and the wafer increases the effective refractive index and thus the resolution. The optics are transmissive – light passes through a system of fused-silica lenses, and the mask is transparent like a photographic slide.

EUV radiation at 13.5 nm, by contrast, is absorbed by practically every material, including air and glass. The entire system must therefore operate in high vacuum, and lenses are useless – imaging instead relies on a system of molybdenum-silicon multilayer mirrors, which reflect a fraction of the radiation through destructive/constructive interference. The mask itself is also not a transparency but a structured mirror.

DUV vs. EUV – Exposure Systems Compared



Resolution and the Rayleigh Criterion

According to the Rayleigh criterion, the minimum resolvable feature width is directly proportional to the wavelength of the light used. The jump from 193 to 13.5 nm therefore brings an enormous resolution gain – in principle, EUV could produce far finer structures in a single exposure step than DUV.

In practice, DUV hits this physical limit already at advanced nodes. The workaround is multipatterning: a single layer is broken down into several sub-exposures, each with its own mask and etch step (LELE, SADP, SAQP), to produce structures a single DUV exposure could not resolve. This works, but multiplies process steps, mask costs, and overlay requirements. EUV can again produce many of these layers in a single exposure step – so the actual resolution gain often translates into saved process complexity, not just smaller numbers on a datasheet.

Challenges and Cost

EUV systems rank among the most complex machines ever built: the light

source generates a tin plasma by hitting tiny tin droplets with a high-power laser, with only a very small fraction of the energy used actually emerging as usable EUV radiation. Each mirror in the optical path also reflects only part of the radiation, so only a few photons per pixel arrive at the wafer – leading to statistical noise (shot noise) that causes visible edge roughness at the smallest feature sizes. Added to this is the pellicle problem: a protective film in front of the mask that prevents particle contamination must, for EUV, be nearly perfectly transparent to radiation that is absorbed by almost every material. A single EUV system accordingly costs well over 150 million US dollars.

DUV systems are technologically mature, widely available, and considerably cheaper by comparison. The price for this is multipatterning complexity at the smallest feature sizes: more masks, more process steps, and stricter overlay accuracy requirements between the sub-exposures – costs that shift into the overall manufacturing process rather than into the tool itself.

Comparison Table

Property	DUV	EUV
Wavelength	193 nm	13.5 nm
Optics	transmissive (lenses)	reflective (Mo/Si mirrors)
Operating environment	air / immersion	high vacuum
Resolution limit	lower, multipatterning needed	higher, often single-exposure
Tool cost	lower	very high (>150 M \$)
Typical use	mass production, mature nodes	leading-edge logic/memory nodes