Ion beam mirrors for EUV lithography

Dual ion-beam deposition is being employed to produce high-quality multilayer mirrors for extreme ultraviolet lithography, says Roy Clampitt.

BROAD ION BEAM sources were developed in the 1960s in national laboratories, particularly in the USA, Europe and Russia. The main purpose of this work was to create an ion propulsion mechanism for spacecraft. Since then, the USA and Russia have launched many so-called 'ion thrusters'. In 2002, the European Space Agency launched a satellite using such a device for the first time.

Once the limitations of wet-etch processing of ICs had been recognised, spin-off companies such as Ion Tech and Commonwealth Scientific began to exploit emerging markets for earth-bound ion beam (dry) materials processing. The parallel energetic flux of these broad-beam sources enables more precise profiles to be achieved without the use of toxic wet chemicals. A vacuum environment is required, however.

The ion beam etches or 'sputters' material through energetic collisions with the surface, removing material atom by atom. There is little if any 'implantation' of the primary ions into the surface at the energies employed. This contrasts with the now established semiconductor wafer ion implantation of dopants, which is achieved mostly at much higher energies.

It was soon shown that when an ion beam sputtered away a target material onto another substrate, the sputter deposit was of high quality — dense and with few defects. Furthermore if an additional ion beam illuminated the sputter-coated substrate during this process, thin films and even multilayer films could be produced that are of a quality far higher than achievable by more traditional methods, such as physical vapour (e-beam) and magnetron deposition.

Extreme ultraviolet technology

One of the first commercial, multilayer film applications to adopt this 'dual ion-beam deposition process' was aircraft ring-laser gyroscopes. (Ultra high-quality multilayers are essential for gyro performance.) Honeywell emerged as a major player in this technology. Nowadays, fibre-optic, solid-state gyroscopes are gradually supplanting the traditional ring-laser type, which means that the market for high-quality multilayers has declined.

In the emerging market of dense-wavelength-division multiplexers (DWDM), the dual ion beam process has also been shown to produce the highest quality multilayers. Remarkably, this has coincided with another, more urgent, requirement for high-quality multilayers.

In the International Technology Roadmap for emerging lithographic processes, extreme ultraviolet (EUV) lithography has been identified as the next wafer-stepper technology, staving off the adoption of e-beam, X-ray or (focused) ion beam lithographies. To achieve practical EUV lithography, however, two major technological challenges must still be overcome. These are the development of (typically) a 100W EUV source and of reflective optics (which have not yet been used by the production semiconductor industry).

Why reflective optics? No known lens material can focus and transmit (200nm) EUV light efficiently. Consequently, the expertise required for the development of reflective optics must be sourced not from the traditional CaF_2/MgF_2 (UV) lens manufacturers, but from a completely different discipline – namely, that with knowledge of fabricating X-ray optics. In this technology, the X-rays are focused by glancing incidence from precision-fabricated multilayers of materials such as molybdenum and silicon. Obviously, high reflectivity from these multilayers is essential if this technology is to achieve, economically, next-generation EUV lithography.

Burgeoning markets

There are vigorous EUV source and optics programmes in the USA, Europe and Japan: Xtreme Technologies GmbH has announced a 35W 135nm EUV source. In the USA, a leading X-ray mirror manufacturer has reported EUV mirrors with a reflectivity of 57 per cent (close to the theoretical maximum of 74 per cent),which were fabricated by the dual ion-beam deposition process (private communication).

So after almost 40 years of broad ion-beam materials processing, new commercial markets are still emerging. Few doubt that the now-dormant DWDM market will re-assert itself, and thus provide another fillip for this technology. ■

Author & Company profile

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