Vacuum grippers based on the Bernoulli principle are state of the art.

New approaches to wafer handling now aim to overcome the disadvantages of conventional handling systems.

Throughput rates of 3,600 wafers per hour demand the accommodation of extreme holding and transverse forces, without impairing positional accuracy and without damaging the wafers.

Photos (2): J. Schmalz

That calls for highly specialised handling. Under such acceleration, the wafer will otherwise start to flutter, and this oscillation could then even lead to rupture. The accommodation of high acceleration rates is one quality parameter of a handling system. Another is the ability to avoid “straightening” the rarely truly flat wafers during picking – another typical source of breakage.

Generally speaking, two types of handling system can be differentiated: those which operate with minimal contact and those whose grippers take a proper hold. This difference also characterises two innovative approaches which aim to overcome the disadvantages of the presently applied technology.

High-speed levitation with ultrasound

The handling systems of South German specialists Zimmermann & Schilp Handhabungstechnik GmbH pick up the wafers “contact-free”. This is achieved by way of an ultrasound air bearing, which can be used...
Ultrasound is vibration at frequencies above the range of human hearing, i.e. greater than 20 kHz. It spreads as a longitudinal wave in gases and liquids – in other words a wave which oscillates in the direction of propagation. In solids, additional transversal waves are produced. Ultrasound applications are already widespread in engineering and medical technology.

The physics of the ultrasound air bearing, however, are explained with fluid dynamics rather than with acoustics. Fluid dynamics is the field of science which concerns itself with the fluid properties of gases and liquids. On the basis of fluid dynamics principles, the ultrasound air bearing causes reproducibly shaped, stable or instable substrates and films to hover without physical contact. The central component is an aluminium, stainless steel or glass plate, in which vibration is induced. The edge length may vary from a few millimetres up to 1.20 metres, depending on the dimensions of the object to be lifted.

Sales Manager Ludwig Adam describes the decisive process steps as follows: “Simulation software calculates the exact frequency required in accordance with the material, its shape and the material thickness. The calculated tool, the sonotrode, then oscillates very uniformly over its whole surface and the resultant slightly asymmetrical sinusoidal waves lead to compression of the air in the gap between the vibrating transducer, the sonotrode, and the substrate to be lifted.”

The pressure between the substrate and vibrating surfaces increases on account of the cyclic compression and decompression, due to the greater proportion of compression. “The ultrasound air bearing thus creates a supporting air film between the vibrating surface and the workpiece,” as Adam continues. “The ambient atmosphere, whether air or process gas, is used to build up the pressure. In this way, the sonotrode can apply considerable repelling forces on the substrate.” The substrate hovers at a set height between 20 and 500 micrometres.

The force profile is similar to that of a conventional air bearing, except that the ultrasound bearing needs no complex compressed air supply. The Zimmermann & Schilp concept is nevertheless not completely contact-free. According to Adam, the workpieces are moved with the aid of belt transport pins or with flat belts and an ultrasound system tilted to an angle of 5 to 10°. The contact, however, is merely spot or linear contact at the workpiece edges.

Graphic: Zimmermann & Schilp

The central component of an ultrasound air bearing is a precisely machined aluminium, stainless steel or glass plate, in which vibration is induced. The air between the vibrating surface and the workpiece is compressed and decompressed cyclically due to the greater proportion of compression. The ultrasound air bearing thus creates a supporting air film between the vibrating surface and the workpiece. Adam explains the process steps as follows: “Simulation software calculates the exact frequency required in accordance with the material, its shape and the material thickness. The calculated tool, the sonotrode, then oscillates very uniformly over its whole surface and the resultant slightly asymmetrical sinusoidal waves lead to compression of the air in the gap between the vibrating transducer, the sonotrode, and the substrate to be lifted.”

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Graphic: Zimmermann & Schilp
not on the surface. This is a significant advantage compared to other gripper concepts, because the ultrasound air bearing avoids chemical contamination of the wafer surface.

Hovering wafers can also be transported over breaks in the transfer systems. It is consequently possible to provide for wafer inspection with optical sensors or line cameras by carrying the wafers over a gap up to 20 mm wide.

**Alternative: full-surface contact**

Vacuum specialists J. Schmalz GmbH (Germany) have approached the problem of handling from a different direction. Their solution revolves around a special vacuum gripper, the newly developed “SWGm”.

Vacuum as a means to pick up wafers is nothing new. Conventional vacuum grippers – inexpensive and easy to use – can be imagined as a kind of suction pad. They thus grip the wafer in small areas, and precisely that is the disadvantage. Through the contact with relatively high pressure and through the friction of the suckers, microstructural damage and chemical contamination of the wafer is inevitable, says Schmalz manager Matthias Müller. High mechanical stresses on the wafer are another consequence, and breakage rates are correspondingly high. Even Bernoulli grippers are unable to avoid all contact. The wafer floats with a clearance of 0.5 to 3 mm, but an elastomer pin is still required to effect the transport motions.

J. Schmalz has developed the vacuum gripper concept further: the SWGm picks the wafers up over their whole surface, and not just at individual points. Schmalz has thus taken a step back from the “non-contact” principle, not least because it is not properly feasible in practice. Instead, Schmalz lowers the contact pressure by reducing the vacuum intensity and above all by enlarging the sucker area to just a few millimetres less than that of the wafer to be processed. This greater area takes up the very high transverse forces which arise during wafer transport. The process time can thus be shortened without placing additional stress on the wafers. Müller: “With these grippers, we have been able to realise cycle times of less than one second.” That is a performance which goes beyond the current state of the art.

**Throughput rate of 3,600 wafers/h**

J. Schmalz offers the SWGm for a throughput rate of 3,600 wafers per hour. According to the figures provided by the company, the output is 50 to 100 % higher than that of a Bernoulli gripper system. The favourable energy balance is also emphasised: the SWGm consumes only half as much compressed air as competitor methods, and in some cases only a quarter as much. In the case of a 50 MW line with 50 wafer grippers in 24-hour operation, this lower air consumption already adds up to a saving of € 50,000 compared to a Bernoulli system. And that, as the company points out in its product description, is not even taking into account the necessity to degrease the compressed air supply to the Bernoulli grippers. If this is neglected, the inflowing air could cause surface contamination and decisively impair the quality of the solar cells.

The economic benefits are further enhanced by a special expansion of the application possibilities. The gripper area of the standard SWGm measures 146 x 146 mm – i.e. 10 mm less than the 156 mm of a 6”-plus wafer on each side. This overhang can be illuminated from below and inspected from above by a monitoring device. “That enables us to check for proper alignment and possible breakages at the edges during the handling process,” says Müller. The large-area grippers according to him are a feature unique to his company.
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