Crash-testing for Micro-assembly

In traffic, collisions between cars normally occur by accident. In micro-assembly, collisions between components are managed: components are assembled as quickly as possible, keeping the cycle times short, and assembly costs low. The collision impact has negative effects on the assembly process; high collision forces can lead to damage of the components, and significant placement inaccuracies can result from the vibrations caused by the impact.

Micro-system technology:
- Miniaturized systems with high-value functionalities
- Based on silicon and non-silicon materials and technologies
- Multi-disciplinary: fluidics, optics, materials, mechanics, electronics, biology

Scope
During pick & place motions it is not exactly known when the final positioning of the components is reached due to tolerances of the component heights. Components collide at a certain speed: even very low collision speeds (less then 0.2 m/s) can result in acceleration of more then 200 G. With this type of acceleration, a car would go from 0 to 200 km/h in less then 0.03 seconds!

In order to be able to improve micro-assembly processes, the negative effects of the collision impact have to be reduced. To fulfill the ever-increasing demands of the industry for quicker assembly, the following is required:
- More assembly cycles per hour
- Smaller impact forces (necessary for assembling more fragile products, such as small lenses in hybrid micro systems)
- Higher placement accuracies

Research
To reduce the negative effects of the collisions, greater knowledge about the impact is required. The phenomena that occur during the impact have therefore been analyzed in order to predict the behavior of the components during the collision.
An experimental setup was used to verify the predictions by filming the actual behavior of the components. A high-speed camera equipped with a special set of microscope lenses made observation of displacements of the gripper and products of less then 5 µm possible.

The test-setup has enabled visualization of the collision. This provides us information about placement accuracies and collision forces:
- Mass of moving components which collide with the product
- Collision speed
- Breaking free of component from gripper tip
- Gripper stiffness
- Overconstrainedness of gripper during collision
- Rebounce of gripper
Development and design
Optimization for minimal mass, gripper tip shape and gripper stiffness are standard design criteria when developing a gripper for micro-assembly. A great deal of research and development has been carried out on gripper design criteria. Therefore in this project, the focus has been on development of a statically determined gripper, and on prevention of gripper rebounce.

The placement action causes the part to be overconstrained, because both gripper and target area add constraints (position & force) to the part. When the gripper becomes overconstrained, high stress build-up can take place which can lead to vibrations of the gripper when the extra constraints are removed, either due to product release or gripper rebounce. Placement inaccuracies result from the gripper vibrations, these therefore have to be reduced.

Rebounce of the gripper has to be prevented because it causes an extra impact on the product and vibrations in the gripper. The standard solution for preventing the gripper from rebouncing, is to place a pre-tensioned spring between the gripper and the drive unit. The disadvantage of this concept is that this solution almost doubles the maximum collision force. Therefore a new solution has been developed for preventing the gripper from rebouncing without introducing a significant increase in collision forces.

Results
A new gripper concept has been developed based on the research findings. The main advantages of the redesigned gripper are:
- No gripper rebounce during collision, with minimal increase of maximum collision force (<10%)
- Statically determined gripper design (no overconstrained during collision)
- Small mass of moving components which collide with the product (<1g)

A prototype of the redesigned gripper has been built and tested.

Patents are pending for the design solution: ‘preventing rebounce without significantly increasing the collision forces’ and ‘statically determined gripper construction’.