UV-curable silicone rubbers open up new fields

B. Ganter, St. Boßhammer, and U. Irmer
Momentive Performance Materials GmbH, Leverkusen

The growing demand for combinations of elastomers with other plastics, electronic parts or temperature-sensitive materials is driven by new industry trends in consumer goods, medical technology and lighting. Silicone elastomers are well known for their outstanding UV stability, excellent heat ageing properties, high chemical resistance, low compression set and for retaining their mechanical properties over a temperature range from -40°C to 200°C. These properties favour silicone elastomers for a wide range of applications in the consumer goods, automotive, energy and healthcare industries. A detailed overview is given in the publication by O. Franssen and H. Bayerl [1].

INTRODUCTION

Various curing methods are employed for vulcanising silicone elastomers. It is common practice to use peroxides or platinum catalysts, which enable the crosslinking reaction to take place at temperatures above 120°C. Momentive has developed a new family of silicone elastomers in which vulcanisation is achieved with UV light. This has the advantage of very rapid curing at low temperatures, allowing silicone elastomers to be combined with temperature-sensitive materials. Processing can take place by extrusion or injection moulding, using special translucent moulds. This technology makes rapid, energy-efficient processing possible, since long periods of heating are no longer necessary.

CURING CHARACTERISTICS OF DIFFERENT SILICONE RUBBERS

The graph shows a comparison of the vulcanisation curves for UV-curable silicone rubber, a platinum-curable liquid silicone rubber (LSR) and a peroxide-curable high-consistency rubber (HCR) in order to illustrate the advantages of vulcanisation with UV light as mentioned in the introduction (Figure 1).

Vulcanisation of the UV-curable silicone rubber blends only starts when the light is switched on.

UV CURING

UV lamps

Conventional gas discharge lamps can be used to produce UV radiation. Lamps with either electrode technology or microwave excitation can be employed.

Both produce similar spectra, depending on the gases used in the lamps (Hg, Hg with Fe doping or Hg with Ga doping). Mercury vapour lamps with iron doping are preferably used for UV-curable silicone elastomers.

Figure 1. Vulcanisation of UV-curable silicone rubber blends only starts when the light is switched on.
The various gas discharge lamp systems differ in the position of their generator, life span and power-on mode (stand-by or on-off). For injection moulding systems, therefore, only lamps with electrode technology are suitable since their generator can remain outside the mould and does not have to be directly connected to the lamp (Figure 2). For extrusion, lamps with either microwave or electrode technology can be used (Figure 3).

The size and performance of the lamps required depend on the parts to be vulcanised. For extrusion of UV-vulcanising high-consistency silicone rubbers, lamps with a power output of 200 W/cm (arc length approx. 20 cm) are generally used, while the injection moulding of large-volume parts requires a number of lamps with this output in order to illuminate all areas of the component.

With the progress made in the development of LED light sources, these can now also be used. UV LEDs emit light at a specific wavelength, avoiding unnecessary ranges of the spectrum such as IR radiation, which in turn increases the life span of the mould material significantly. Energy consumption and floor-space requirements are also much lower for LED lamps, and so these can easily be integrated into an injection moulding system.

**UV-curable liquid silicone rubbers (LSRs)**

Liquid silicone elastomers are generally injection moulded at mould temperatures of 180 – 200°C. UV-curable LSRs can be processed with the same equipment but a transparent mould is necessary so that UV light can penetrate. Special grades of Plexiglas can be used as the mould material, which allow a large part of the UV light to pass through as well as possessing greater UV stability compared with conventional Plexiglas.

The low vulcanisation temperature means that the finished parts display virtually no shrinkage and have fewer air inclusions. Since vulcanisation only starts when the light is switched on, scorch (a common problem in heat-curing systems) can be avoided. This technology allows high-quality goods to be produced, which generally require no rework. Cycle times can also be reduced significantly with UV curing. Silicone parts with wall thicknesses of up to 100 mm can be vulcanised in less than 5 minutes. With the conventional thermal process, by contrast, curing can take up to 30 minutes. Thus, this process allows significant time and energy savings to be achieved. The process is illustrated in Figure 4.

Items for the high-voltage industry, in which silicone elastomers with these kinds of wall thicknesses are manufactured for insulators or cable accessories, can be mentioned as an example. With the aid of UV Electro 2X5 UV-curable silicone elastomers, these items can be manufactured quickly, with high energy efficiency and in very high quality (fewer air inclusions, no shrinkage) (Figure 5).

UV technology also makes it possible to process LSR with heat-sensitive plastics using conventional injection moulding machines. One example that can be mentioned is the combination of LSR with polypropylene, for which joint processing in a single mould has already been demonstrated [2]. This opens up the possibility of combining almost any plastics, particularly inexpensive ones, with silicone elastomers (Figure 6). It is also possible to add temperature-sensitive substances, such as medicinal products, to liquid silicone rubbers and to vulcanise them under UV light.

**UV-curable high-consistency silicone rubbers**

High-consistency silicone rubbers (HCRs) are often vulcanised at temperatures of over 250°C in hot air tunnels in extrusion processes. Hot air oven sections
of over 10 m in length are generally needed for this. The Addisil UV EX UV-curable silicone rubbers are processed and shaped with standard extruders. Only one UV lamp, which is generally no more than 30 cm long, is needed for vulcanising. This saves both energy, since there is no longer any need for long heating tunnels at high temperatures, and floor space in the production area, since the vulcanisation line is much shorter (Figure 7).

The vulcanisation process takes place extremely rapidly with UV curing (command cure), so that no bubble formation can be observed even in thick-walled parts. Extrudates, such as e.g. complex profiles, can be produced with highly accurate dimensional stability.

Extrusion at low temperatures also allows silicone rubbers to be coextruded with heat-sensitive plastics, or enables temperature-sensitive substances/materials to be incorporated. One very interesting application is the continuous encapsulation of LEDs [3]. In the past, it was only possible to make these light tubes in complex processes involving casting techniques, which are limited to a specific length (Figure 8).

As already indicated in the introduction, the UV curing of silicone rubbers is based on platinum-catalysed hydrosilylation, during which no cleavage products are formed during extrusion or injection moulding. Various UV materials have undergone and passed biocompatibility tests (ISO10993, USP Class VI, volatile matter), and can therefore be used in the healthcare, food and consumer goods sectors.
**CONCLUSIONS**

The vulcanisation of silicone rubbers using UV light is opening up new areas of application for silicone elastomers, since UV vulcanisation enables extremely rapid curing to take place at low temperatures. Silicone elastomers vulcanised by UV light display the same properties as thermally cured elastomers. The processing operations remain similar and existing injection moulding or extrusion equipment can still be used. UV lamps have to be integrated into the process and, in the case of injection moulding, special transparent moulds have to be made. In exchange, there is no need for prolonged heating periods (LSR) or long vulcanising ovens at high temperatures (HCR).

This process makes it possible to combine silicone elastomers with heat-sensitive plastics, components, chemicals or medicinal products, which would previously have led to the destruction of the material or product because of the high curing temperatures. Thus, new 2-component applications which were previously impossible are being opened up for silicone elastomers.

**REFERENCES**