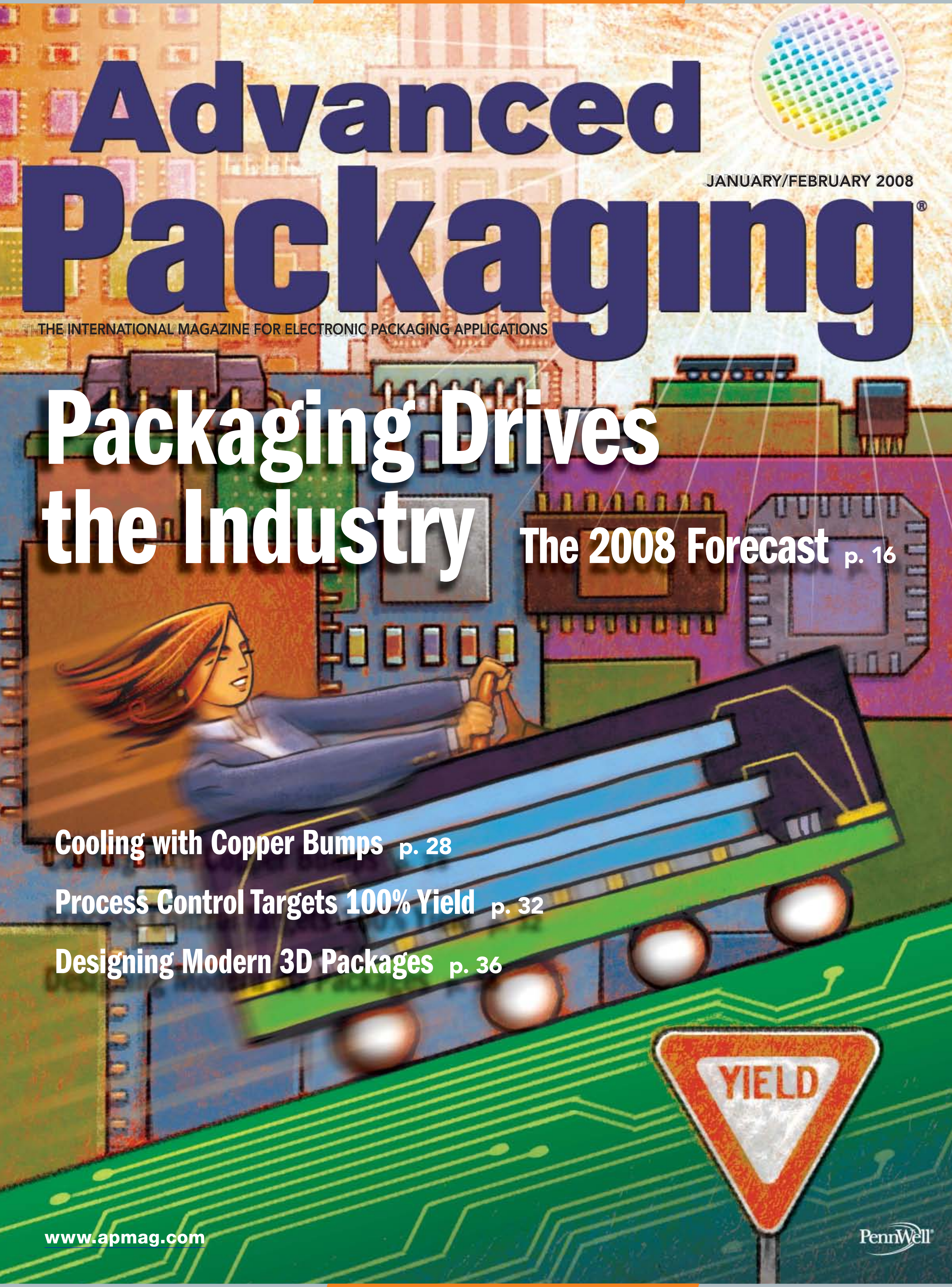

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Elastic Interconnections for Stretchable Electronics

BY JAN PROVOOST, *IMEC*

Although most electronic appliances are rigid, or at most mechanically flexible, future applications will require them to be flexible, stretchable, and offer maximum user comfort. Developments at one lab* resulted in the creation of elastic interconnections that stretch to twice their length without losing conductivity.

Lab researchers embedded interconnection wires with a 2D undulating pattern in an elastic silicone film. The 2D springs were designed and optimized in cooperation with a group of specialists** in mechanical modeling and reliability prediction. The researchers inferred, based on finite element analysis, that an undulating horseshoe shape is the ideal form for the connection wires. It dissipates the stretching and flexing stresses better than comparable elliptical patterns. Second, they further improved the stress resistance of the interconnections by splitting each interconnection wire into four parallel wires with a smaller width. Initially, gold was selected as a material for the wires, because of its high ductility, which allows for greater stress resistance.

The resulting interconnection wires consist of four parallel tracks, each 15 µm wide, made of a 4-µm-thick gold layer and coated with a 2-µm-thick nickel layer for soldering to components. At regular intervals, in positions where the deformation stress is calculated to be minimal, neighboring tracks are cross-connected. This allows for fail-safe operation in case of fabrication errors or mechanical failure.

The interconnection wires are embedded in a silicone polymer substrate: polydimethylsiloxane (PDMS). By itself, PDMS is an electrical insulator, but becomes conductive when, for example, silver particles are added. This modified polymer can carry a signal over short distances. Should a wire be overstretched, resulting in a microcrack, the surrounding polymer will still conduct the signal, bridging the gap.

The researchers made interconnections with different angles and radii for the horseshoe shape. circuits were tested by stretching them in the longitudinal direction to the point of electrical failure, which a rupture in the gold tracks could cause. The best interconnection stretched from 3-6 cms without failure. Moreover, all interconnections recovered their conductivity when returned to their normal length.

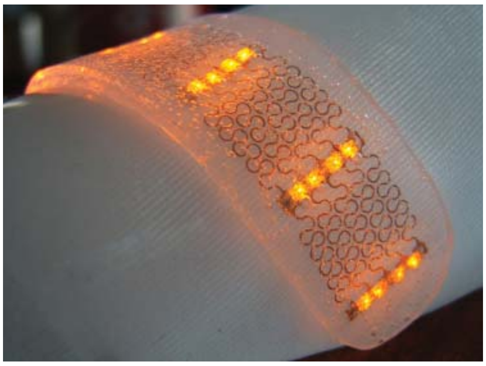

Figure 1. Stretchable LED-circuit embedded in PDMS, fixed on textile, and washed repeatedly in a standard washing machine.

To assemble the stretchable interconnections and the more rigid electronic components, joints were soldered using normal electronics assembly methods. Next, the silicone polymer was molded around the assembly, taking care not to cause any bubbles in the silicone. For each design, a dedicated mold is made. This mold takes into account the locations on the assembly where the rigid parts are located. At these locations, the silicone wrapping should be thicker so that the circuitry is locally less stretchable.

The researchers now also study the use of conducting materials other than gold, such as copper, the standard material in PCB manufacturing. Wiring with copper is more cost-effective than with gold. But the main reason is the drive to develop a technology that is compatible with existing industrial PCB and assembly practices to facilitate the technology's transfer to a production environment.

Ongoing research projects aim to create flexible and stretchable electronic and sensor circuits. Real-life stretchable appliances will be hybrid, and will contain rigid or flexible components connected with stretchable circuitry. The circuitry will stretch and bend like rubber or skin while preserving its conductivity. The goal is to combine this stretchable interconnection technology with flexible circuit technologies, as developed in the EC-SHIFT project. An example is the ultra-thin chip package, or UTCP, which is only 100-µm thick.

Within 3 years, and based on current research results, a technology and demonstrator will be ready for commercialization. The first flexible and stretchable appliances might appear in intelligent clothing, followed by medical applications. The circuits will also be washable, which is a big step forward for intelligent clothing. First commercial products might be clothing with signalization, using LEDs and sensors, to track movements. **AP**

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