Microstructure Engineering: An Alternative to Coatings

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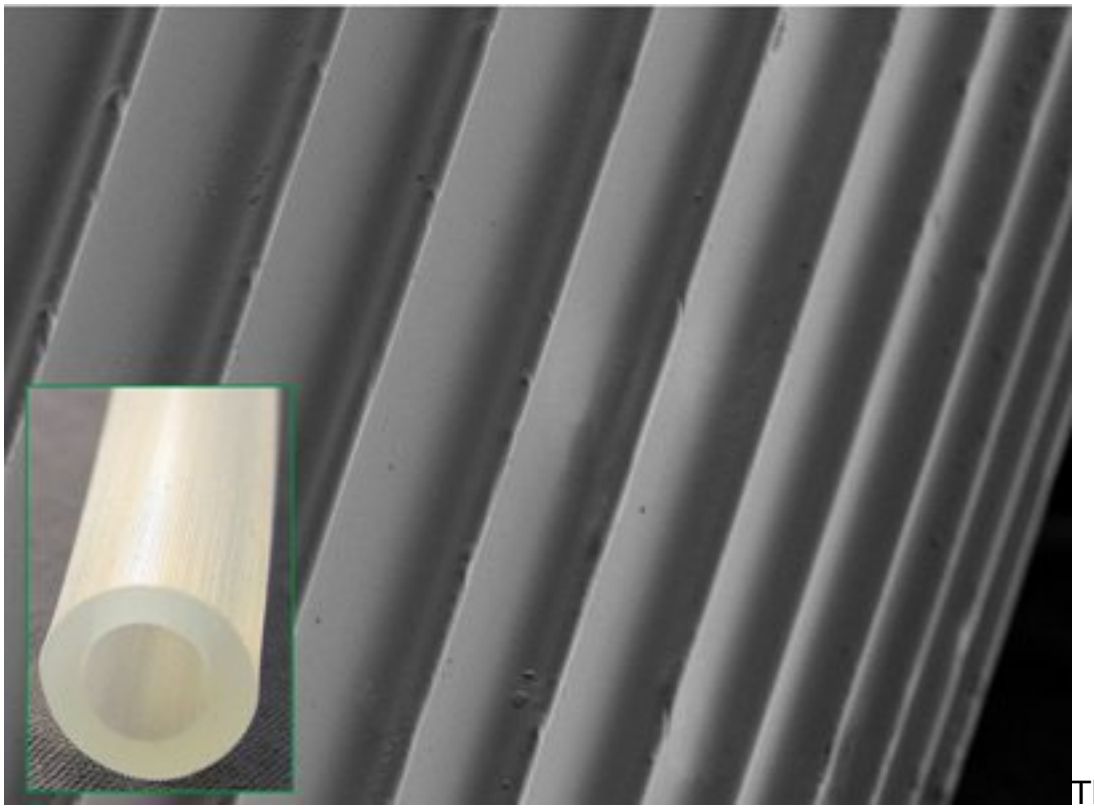
While coatings can offer an array of benefits to medical device components, in certain cases, they can also come with adverse effects that impact the overall efficacy of the product. An innovative technique—microstructure engineering—enables a surface treatment to be accomplished during the component fabrication process, providing an alternative to coatings.

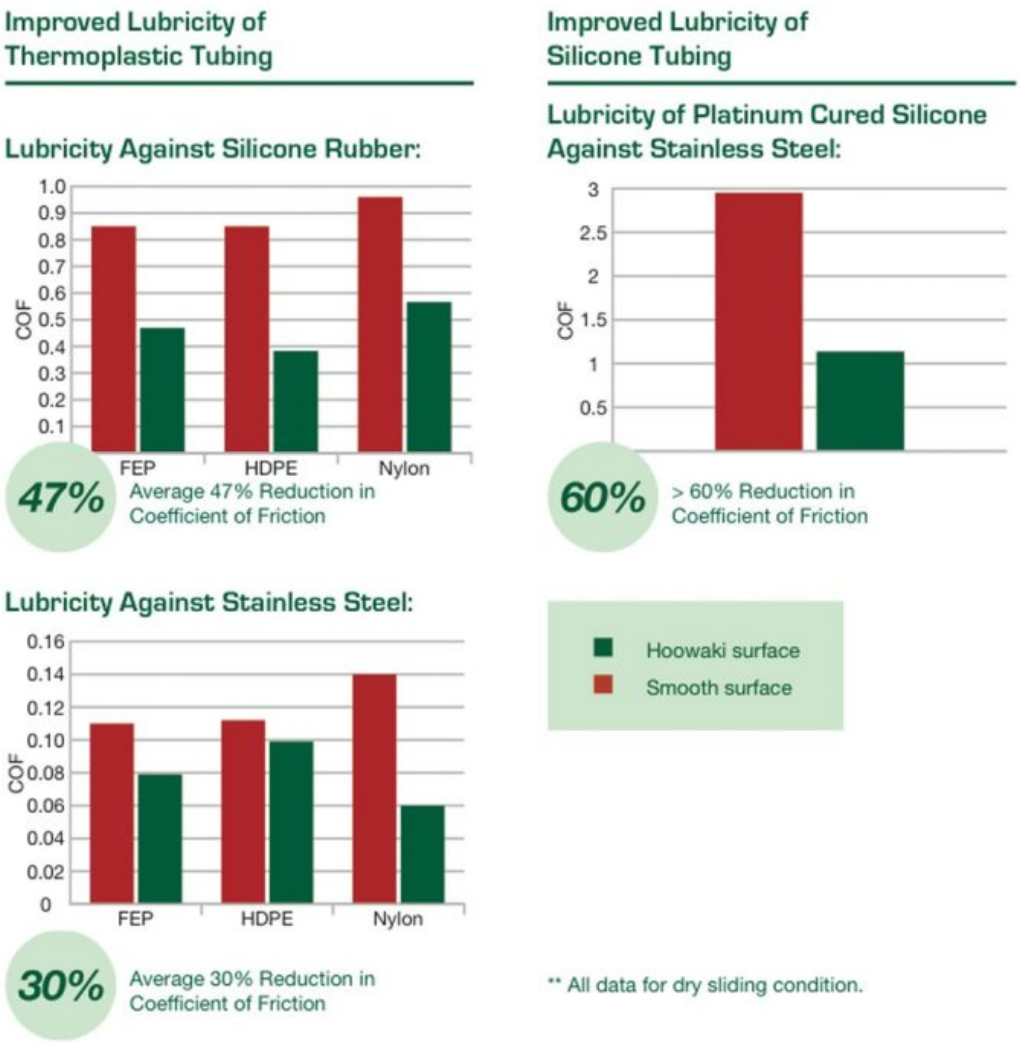
Current technology to address low friction and low tack on extruded and molded medical devices is limited to coatings, lubricants, additives, or base material changes. While these options provide improved performance, they can be very expensive, add steps to the manufacturing process, flake or deteriorate during use, and/or degrade the integrity of the base material. With medical applications, these options limit the effectiveness of an otherwise innovative design and complicate testing and validation, extending time to approval.



The technology of microstructured surface engineering can modify surface structure to affect a wide range of parameters to include hydro-phobicity, drag, contact angle, slip angle, fluid

retention, etc. For medical device designers, this technology often provides similar or better low-friction performance while allowing the device designer to optimize the base material selection to achieve mechanical, biological, or cost targets. An example surface is shown in Figure 1. The microstructures remove the contact area from the product surface without reducing the volume and strength of the product. Lowering the contact area reduces the interference between the product and the opposing surface, allowing the surfaces to slide past each other with less drag force. Microstructure surface engineering specifically designs the pattern to create a surface applicable to a specific friction regime or surface tension.

Microstructure engineering is a relatively new science derived from the study of structures found in nature. The physical phenomena of gecko feet, lotus leaves, rose petals and many other plant and animal microstructures interacting with other surfaces has long intrigued scientists. The best attempts to mimic surface phenomena found in nature have been tried through chemistry and employed through coatings and lubricants. These attempts have fueled the explosion of polymer science over the past several decades. Incorporating micro and nano surface structures on base materials has been limited by traditional surface machining techniques. Structured micro patterns can be applied today with lasers, but this is a slow and costly process for bulk surface transformation. Surface finishing via abrasion is cost effective for bulk surface treatment, but it is only capable of random surface patterns, not designed discrete surface patterns on a bulk surface. Recent dramatic advances in bulk surface machining on the micro and nano level allow discrete engineered structures to be applied to a bulk surface in a cost-effective manner. This technology opens the door to pursuing the new science of micro surface engineering for improved product performance.



[1]Manufacture

These microstructure surfaces are formed in the base product polymer and applied during the extrusion or molding process. No additional process steps are required and die/mold life is anticipated to be equivalent to standard, non-patterned tooling. The micro pattern is engineered to achieve the desired surface characteristics and subsequently applied to the extrusion die as a negative of the shape required on the finished product, taking into account shrinkage, draw down or other processing parameters. The same engineering is employed for injection or compression molded products.

Friction Testing

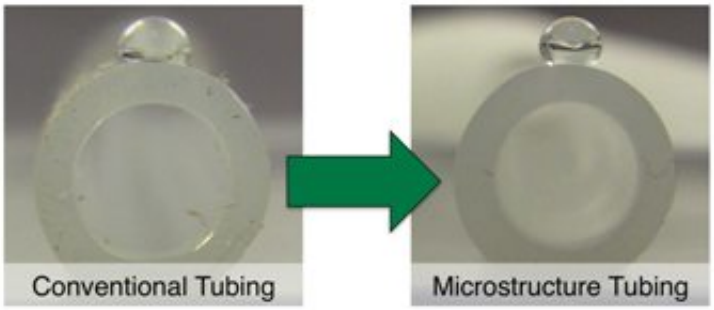
As shown in Figure 2, thermoplastic tubing with microstructures outperformed conventional thermoplastic tubing by 47% when sliding against silicone rubber, and by 30% when sliding against stainless steel (both measurements made for dry sliding). Figure 2 also shows a bigger change for silicone rubber, where the sliding friction against stainless steel drops by 60% when microstructures are added to the surface. The greatest effect occurs for sliding against compliant materials, such as silicone or vinyl rubber. The compliant materials naturally conform to the area of the medical device, creating a high contact area, as compared to the behavior of stiffer materials like steel. Reducing the available contact area has a greater effect with compliant materials.

Microstructured surfaces also have lower tack or stickiness than conventional surfaces, particularly for low-durometer materials. These surfaces will not stick to themselves or other tacky surfaces, making them easier to store and deploy for use, as well as lowering the damage to these products. Coatings and fillers used to reduce tack are often washed or dissolved away before use because they change other properties of the product. Microstructured surfaces do not change the material properties of the product, and therefore do not need the removal step.

Other Characteristics

A “pop” or pinch test can be performed for the microstructured silicone or low durometer tubing. The sticking effect will not be totally eliminated; therefore, the “pop” is not silent, but is significantly muted in comparison to the conventional tubing.

Surface	Static Contact Angle	Slide Angle
Conventional Tubing, ID	105°	32°
Conventional Tubing, OD	108°	N/A
Microstructure Tubing, ID	125°	18°
Microstructure Tubing, OD	128°	N/A



[2]Figure 3 shows contact angle measurements for one microstructured surface and one conventional surface in silicone rubber tubing. The microstructured surface has increased the static contact angle by 20° and lowered the sliding contact angle by 14°. Water-based liquids flow across the microstructures more easily than the typical surface.

Conclusion

Currently available options to achieve the desired surface properties of friction, tack, surface tension, and tactile feel often limit the development of more specialized and complex medical device design. Micro surface engineering is the science of imitating surface structures found in nature, translated to specifically designed micro patterns and realized with best in class, high volume tooling to provide product designers with solutions not previously available.

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