Cyclic Olefin Copolymers Solve Design Challenges for Microfluidic Devices

By Trey Shoop
TOPAS Advanced Polymers

Microfluidic applications have evolved and benefitted from several innovations throughout the years. New designs have expanded use from simple microanalysis performed in the lab to the rapidly growing area of Point of Care (POC) diagnostics. With these advances, the choice of materials used to fabricate biochips, cartridges, and other microfluidic components also continues to evolve.

COC Emerges as Top Alternative

Glass and polymers like silicone were the mainstays for many years. However, other polymers are increasingly being used in these applications due to their useful properties and lower cost. Materials commonly used include polycarbonate (PC), polymethyl methacrylate (PMMA), and polystyrene (PS). More recently, cyclic olefin copolymer (COC) has emerged as a highly useful and attractive microfluidic material, offering high optical clarity, low water absorption, exceptional moisture barrier, and excellent resistance to chemicals, including leading organic solvents used in chemical analysis. These properties have made COC a top choice in microfluidics applications.

Overall, COC is used in various applications, including packaging, medical devices, optical lenses, drug delivery, and microfluidics. The material's unique properties make it an excellent material for the design and manufacture of microfluidic parts used in analytical systems, research, and biomedical devices. COC can be used to replicate features including microchannels with fabrication processes such as hot embossing for low to medium throughput, and injection molding for faster production of high-quantity detailed parts.

This article will discuss how the properties of COC provide superior performance which is critical in designing sophisticated microfluidic devices and how advances in areas such as 3D printing technologies have expanded design possibilities while significantly decreasing the time necessary to produce a working prototype.

Major Differentiator is Superior Performance

COC is a copolymer consisting of ethylene and 2-norbornene, a cyclic olefin. Glass transition temperature of these amorphous copolymer grades is determined by the percentage of norbornene used. Products with glass transitions from 78°C to 178°C are available along with grades for applications requiring high heat such as steam sterilized items and polymerase chain reaction (PCR) devices.

In terms of optical performance, COC materials provide excellent transmission in the visible range, with some grades offering added UV transmission below 300nm which is useful in applications such as DNA analytics. COC exhibits one of the lowest levels of autofluorescence among available polymers - a critical property in achieving accurate diagnostic results.

Strong chemical resistance is among the desirable traits necessary in microfluidic materials because it expands the variety of reagents that can be used. COC has good resistance to acids, alkalis, and most organic solvents such as acetone, methanol, isopropyl alcohol, and DMSO which are all key components in various chemical reactions and separation techniques. Non-polar organic solvents including toluene and naphtha should not be used however, as they may attack COC. In medical and analytical applications, COC is considered to be an exceptionally high-purity product with low extractables. It complies with USP Class VI, ISO 10993, and USP 661.1. COC is also halogen-free and BPA-free.

High-flow grades of COC allow for molding of very fine details and channels, close to nanoscale replication which is not achievable with other materials. microPEP, based in East Providence, R.I., successfully injection molded a Microwell Array, reproducing features of 3-micron diameter and depth on a standard microscope slide made in TOPAS 5013 COC.

COC absorbs very little water (<0.01%), over 24 hrs. By comparison, water absorption of polydimethylsiloxane (PDMS) - the standard material used in fabricating microfluidic systems, is 0.1% or about 10 times that of COC. PC absorption is 0.02%, while PMMA is 0.3%. Therefore, changes in environmental humidity will not significantly affect microfluidic parts fabricated in COC. The hydrophobic surface of COC can be altered by such treatments as corona, plasma, and irradiation. Surface pretreatments increase surface energy, improving the wetting properties of the polymer, leading to more accurate results during analysis. A hydrophilic surface is important in allowing fluids to flow smoothly through the microchannels. In addition, surface treatment may allow for stronger adhesion when bonding COC to dissimilar materials.

Injection molding, hot embossing, thermoforming, and extrusion are the most commonly used manufacturing methods to produce COC parts. In addition, there are numerous bonding options for final assembly which result in a robust process for manufacturing scale-up.

Design Options Expand

The superior performance of COC can help expand design possibilities and solve challenges in microfluidics applications. Various COC grades can be used in devices requiring higher heat resistance including polymerase chain reaction (PCR). Other grades deliver chemical resistance to polar solvents and acids/bases and expand the areas where the material can be used, including aqueous formulations. Numerous options for bonding including solvent, welding and adhesive bonding result in a manageable and robust scale-up for manufacturing. Excellent light transmission and strong ultraviolet transmission (UV) makes COC a solid choice for design of lab-on-a-chip systems, particularly in bio-detection applications.

A unique commercial application comes from Sandstone Diagnostics, based in Livermore, Calif., which began work on a POC testing device in 2012. The company tested numerous materials and eventually selected COC for its superior material properties which enhanced the design and functionality of its initial system. The Trak® Male Fertility System launched in 2016 is a microfluidic device which uses TOPAS 8007S-04 COC in its disposable cartridge. The sample is transferred into a cartridge using a dropper and the cartridge is pressed onto a centrifuge which spins to initiate the microfluidic process.

COC was one of three polymers Sandstone tested in the early development stage. Ulrich Schaff, co-founder and Chief Technology Officer at Sandstone, explained that other material options such as PC, PS, and clear ABS were considered but lacked the adequate barrier properties. The main issue was that these materials would absorb fluid and transmit vapor over time. Schaff noted: “Storage of materials that are moisture sensitive or when you’re trying to keep fluid in can be a real challenge.” He added: “We needed to store a small amount of fluid, less than 1/10ml, which pushed the limits for what you can store long-term. Most plastics aren’t suitable for storing fluids for an extended period, but COC performed very well.”

Additionally, COC provided adequate durability compared with polystyrene, along with better dimensional stability than PC, resulting in flat molded parts which were tough enough for the mechanical processes of the application.

The disposable cartridge also required high transparency and low autofluorescence for efficient sample analysis. Because COC is an amorphous material, a solid ultrasonic weld of the two sections of the cartridge was achieved, according to Schaff. Among the polymers tested, COC offered the best control in welding. COC did present one challenge in pad printing. The company overcame the ink’s non-adherence by using a low-powered corona treatment combined with ink formulated for polyolefins. Now with a proven microfluidics platform utilizing COC, Sandstone is looking at additional COC-based products to bring to market.

3-D Printing Opportunities Emerge

COC can be used in common microfluidic development processes including hot embossing, soft lithography, casting, laser ablation, and photolithography. Variations on processes such as soft lithography have been successful as well, including creating a photoresist master, casting a PDMS replica, and using the replica to directly cast the device in COC. PDMS has been a standard material for fabrication of microfluidic systems due to its transparency, gas permeability, competitive cost, and ability to be rapidly prototyped. The material, however, does require a labor-intensive process for prototyping, and capabilities are limited to two-dimensional designs, thus limiting configurations. In contrast, 3D printing provides a low-cost, automated fabrication method to make 3D parts that have a high degree of resolution.

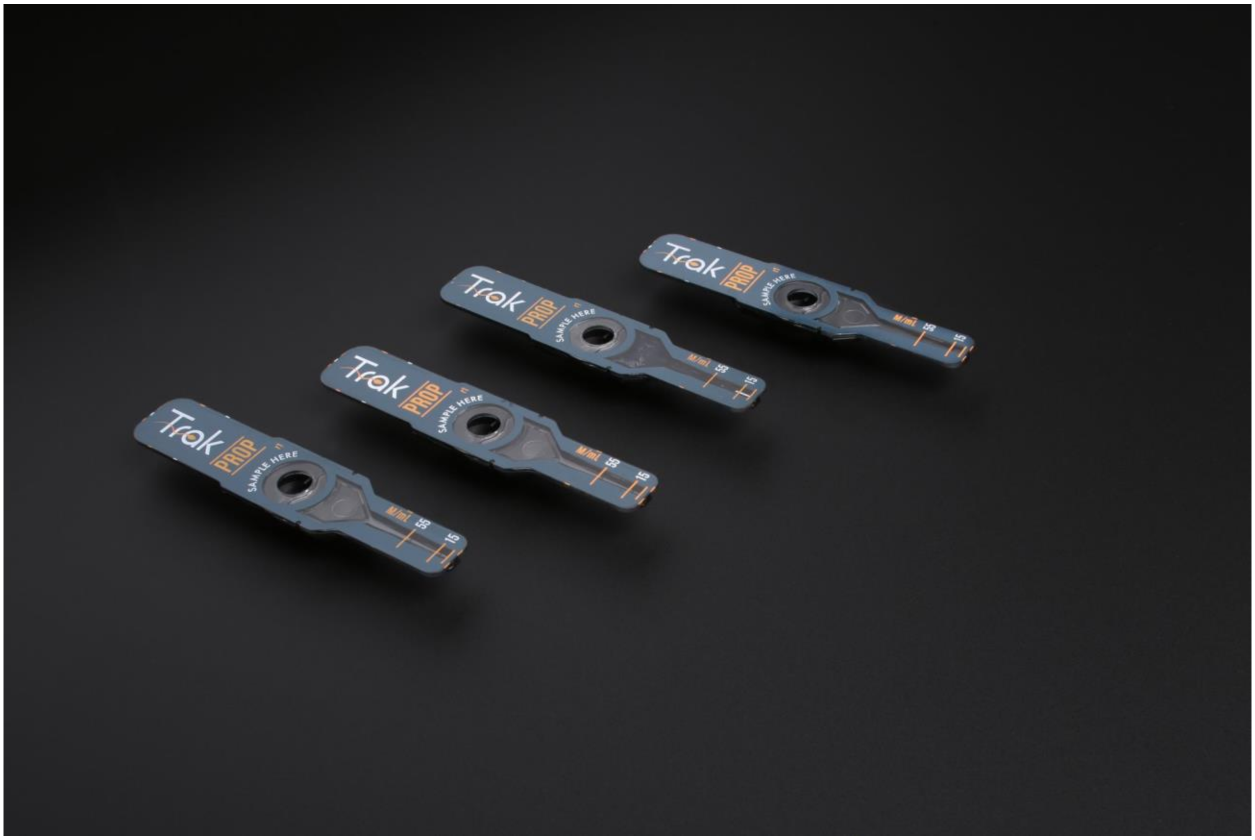
Dolomite, based in the U.K., recently launched the Fluidic Factory, the first commercially available 3D printer for fluidically-sealed devices made of COC. The printer is designed for ultimate ease of use, enabling rapid prototyping of fluidically-sealed devices such as chips, sensor cartridges, fluid manifolds, valves, connectors, and medical devices. The 3D printer is designed for use with TOPAS 8007S-04, a standard injection molding grade for high-performance medical and optical applications.

TOPAS COC was selected due to its recognition in the microfluidics industry and its clarity, purity, superior chemical resistance, and UV transparency. Users can choose a design from the selection in the Fluidic Factory’s Design Library, or create and print their own unique devices using virtually any CAD software. With this complete design flexibility, the Fluidic Factory allows for a wide range of applications, including organ-on-a-chip, point-of-care diagnostics, drug development, education, chemical synthesis, and analytical and biomedical assays.

COC's emergence as a "go-to" material in microfluidics is expected to accelerate to meet the growing demands of the healthcare industry. OEMs will continue to tap COC's exceptional property profile and its ability to enhance the design and manufacture of microfluidic parts used in analytical systems, research, and biomedical devices. Other new applications are being pursued as processors and end users look to tap these blends as a highly effective and cost-efficient method to maximize performance. As performance and regulatory demands in this area grow ever more challenging in the coming years, cyclic olefin-based products will continue to increase their share of this important market.

About the author

Trey Shoop is a market development manager with responsibility for business development and technical support for TOPAS Advanced Polymers. He has 15 years of experience in pharmaceutical sales and the last 10 years has held leadership roles in packaging and polymer sales. He earned a bachelor of arts from the University of California at Berkeley. For more information, visit www.topas.com or contact Shoop at info@topas-us.com.



Sandstone Diagnostics' Trak® Male Fertility System is a microfluidic device which uses TOPAS 8007S-04 COC in its disposable cartridge.

Dolomite, based in the U.K., recently launched the Fluidic Factory, the first commercially available 3D printer for fluidically-sealed devices made of TOPAS 8007S-04 COC.

Dolomite, based in the U.K., recently launched the Fluidic Factory, the first commercially available 3D printer for fluidically-sealed devices made of TOPAS 8007S-04 COC.

A variety of microfluidic chips are produced on Dolomite's Fluidic Factory, the first commercially available 3D printer for fluidically-sealed devices made of COC.