TOUCHSCREENS HAVE BEEN USED IN PUBLIC ACCESS terminals for well over three decades. The earliest applications were information kiosks, bridal registry terminals, gaming systems, and ticket vending machines. These touchscreens were built with curved cathode-ray tube (CRT) displays and were relatively expensive for the time. The rise of thin-film transistor (TFT) LCD technology in the early 1990s enabled lower-cost flat-touch sensors to be mated with flat displays, which caused prices to drop. Eventually diagonal sizes grew, which greatly broadened the market for touch displays.

In addition to applications where there was direct public access, many applications such as point-of-sale terminals and machine control became touch-enabled, where a smaller group of employees had access to the touchscreens. Applications such as public information systems, ticket vending, and digital signage in airports, malls, and other public spaces have proliferated over the years. In the past five years, increases in labor costs at retail establishments—particularly fast-food restaurants—have caused a surge in public-access order-entry touchscreens. With the ubiquity of touch on displays on both private devices (phones, tablets, and computers) and commercial devices and machines, most people who encounter a display expect touch functionality. Until the COVID-19 pandemic, people generally did not consider a touchscreen as a potentially dangerous surface. Things have changed.

PANDEMIC FEARS ABOUND
Early in the pandemic, the lack of information and research regarding the transmission routes of the SARS-CoV-2 virus meant that people had to fear multiple possible ways of getting infected. Many viruses are spread quite easily by surface contact. This caused all of us to wipe down surfaces, food packaging, mail and parcels, door handles, and other surfaces as well as wash our hands after any contact with a new surface. While the SARS-CoV-2 virus does live on surfaces, we now know the main transmission path between people is from aerosol particles from the respiratory system. Nevertheless, the public is still quite wary of uncontrolled public surfaces that could be contaminated. Numerous articles1,2 have reported that the public has become hesitant to use public touchscreens. The designers of end products have looked to the touchscreen industry to offer options to allow safer use of their touch-enabled products and the supply chain has tried to respond to that demand.

EXAMINING PUBLIC VERSUS PRIVATE USE CASES
Almost everyone carries a touchscreen with them everywhere they go. That normally takes the form of a telephone, since a...
non-touch-enabled phone has all but disappeared from the marketplace. Your phone and other personal devices (tablet, notebook, all-in-one PC, and home appliances) that are always under the control of you or your family pod—or for which you are sole user—do not present a problem for virus contamination. Cross-contamination is a possibility with these devices when interacting with surfaces outside of the control of your home, but no more so than any other object that you might touch, such as a door handle or steering wheel. People have dealt with this situation with alcohol-based gel disinfectants or chlorine wipes to clean off their hands and surfaces. The problem, of course, exists when a surface that is meant to be touched by many people may become contaminated with respiratory aerosols from coughing, sneezing, speaking, or breathing. Moreover, people tend to linger for a while when directly facing a touchscreen surface to complete their transaction, increasing the potential for a large viral load to be deposited on the surface. When people can see many others in line ahead of them using a touchscreen, they will fear contacting that surface themselves so soon after another person has used it. A touch surface that is inherently antimicrobial can help reduce the potential for transmission of infectious diseases.

**ANTIMICROBIAL COATINGS REDUCE RISK**

New and existing technologies may greatly reduce the risk of infection by surface contact with a touchscreen. One way to deal with the contaminated surface is to frequently clean the surface per CDC guidelines. While effective, it is impossible to physically clean a surface between each user when a public access touchscreen may be used by many people only minutes apart. Imagine trying to clean an order-entry kiosk at a fast-food restaurant between users during a lunch rush. Therefore, the desire is to have a surface that is inherently antimicrobial/virucidal so that the surface continuously attacks any viral loading applied to the surface.

There are various ways to create such a surface, including physical structures, coatings containing copper or silver ions and titanium oxide (TiO$_2$) photo-active coatings. Copper and silver are both well known as being germicidal and have been used for that purpose since antiquity. Except for the physical structures, which can physically puncture the cell wall of a microbe, other materials all work by acting as catalysts to create reactive oxygen species (ROS) such as hydroxyl radical (-OH) and singlet oxygen ($^1$O$_2$) on the substrate’s surface. These ROS react with the microbes’ cell membranes and cause cell death by oxidizing the cell membrane or directly disrupting the cell DNA. As catalysts, the materials are not consumed in the reaction themselves, which allows the coatings to function indefinitely.

While there are some coatings containing silver or copper that can be sprayed onto a surface in the field, these are usually short lived in their effectiveness, as they can be worn off with repeated use. At this time, the market is focused on coatings that are permanently functional. The two primary materials and processes are copper and/or silver metal ions that are embedded in the surface of the glass using an ion-exchange process and TiO$_2$ coatings that are fired to the glass surface.

**Fig. 1.**

Silver or copper ions diffuse into the glass surface from a high-temperature salt bath. Afterward, the glass surface is rich in silver or copper ions.

We will focus on these two processes, as they are what is currently available in the marketplace for glass-based touchscreen surfaces, such as those used in projected capacitive touchscreens.

The process for implanting copper or silver ions into a glass surface is an ion-exchange process, which closely resembles the chemical strengthening process used to exchange potassium for sodium in soda lime glass used for touchscreen lenses. The glass is placed in a copper salt bath solution, usually copper chloride or copper sulphate, at high temperatures to enable copper ions’ higher mobility into the glass (Fig. 1). The higher concentration of copper ions in the solution drives the ions to diffuse into the lower concentration of copper in the glass. At the same time, sodium will diffuse out of the glass where the concentration is high, into the copper salt bath where sodium concentration is low. The same process is used for silver and can be used in combination with both metals to yield a glass surface rich in copper and silver. This process yields glass with a layer a few microns deep of metal ions, diffused into the surface, ready to react with oxygen in the atmosphere to create the microbe-destroying ROS. The metals do not affect the glass’s optical properties and there is no change to the transmission or reflection properties. The electrical functionality is not compromised by these metals, because there is no continuous conductive surface that could shield electric fields.

Coatings containing TiO$_2$ typically are sprayed onto the glass surface in liquid form and the TiO$_2$ is fired into the glass surface for a few minutes at high temperatures in the 500° to 600°C range. This firing process is similar to the process used for ceramic frit inks or sol-gel coatings (where the inorganic colloidal suspension, or sol, undergoes gelation into a continu-
ous liquid phase, or gel). The resulting surface is one that does not affect the glass’s optical qualities and is permanent. The TiO\textsubscript{2} coating is a catalytic material that needs light to drive the reaction to create ROS species on the surface to kill the microbes (Fig. 2). There are some newer materials\textsuperscript{5} technologies that can function with visible light, whereas previous coatings required ultraviolet light and were much less practical to use for touchscreen applications.

Both types of coating can be applied to a retrofittable lens that can be installed in the field like a screen protector for a phone or tablet. A self-wetting repositionable optically clear adhesive can be applied to the glass to allow an installed base of products to be upgraded with an antimicrobial surface (Fig. 3). The glass and adhesive thickness can be less than 0.5-mm thick, which improves the ability to apply the self-wetting adhesive in the field, because the material can be bent during lamination. Obviously, this process requires the utmost cleanliness, to avoid optical defects in the laminate that would be visible to the user. It should be noted that with projected capacitive touchscreens, adding an extra layer of dielectric materials such as glass and optical adhesives can affect the touch controller’s tuning, and a field retrofit of an additional lens also may require a field update of the tuning parameters to the touch controller.

Other materials are available in the marketplace that use coatings applied to polymer substrates.\textsuperscript{6} Typically, these contain silver ions or nanoparticles in an organic coating applied using the same wet-coating methods used to apply acrylate hard coatings to polyester. In general, however, the marketplace employing glass-projected capacitive technology prefers to maintain the glass lens’ durability, so glass fabricators are not inclined to use a polymer film laminate on the top surface. However, these

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**SUPPLY CHAIN CONSIDERATIONS ARE AFFORDABLE**

Both the aforementioned ion exchange and spray or fired coatings use processes and capital equipment that either already exist in the glass fabrication supply chain or are relatively easy to put in place. These technologies, therefore, are the most readily available and easily adopted.

Usually, the glass lens fabricator handles the coatings, which is typically the first step in the supply chain for projected capacitive touch sensors. Costs at this stage of the supply chain can range between $1.50 to $3.00 per diagonal inch over the cost of a standard lens. For the touchscreen module’s end customer, the addition of the antimicrobial coating would result in no difference in the supply chain, as compared with a standard touchscreen, other than the cost increase.

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**UNDERSTANDING LIMITATIONS TO EFFECTIVENESS**

While an antibacterial/antivirus surface is certainly helpful to reduce the number of active contagions on a surface, certain limitations still exist. In general, any active antimicrobial surface will reduce the contagions over time, with an asymptotic rate that depends on the initial contagion load, as the reaction rate is proportional to amount of contagion on the surface. This takes many minutes, not seconds, and a surface can still have enough active contagions to cause an infection 20 to 30 minutes after exposure.

In an application where users are lined up to use the touchscreen one after another (order entry, time clock, and so forth), an antimicrobial surface can’t prevent one person’s sneeze from infecting the next few people in line. In the same way that wearing masks may decrease the probability of disease transmission, neither masks nor antimicrobial surfaces can be 100 percent effective in preventing transmission.

There are also limitations to the claims that can be made regarding an antimicrobial coating’s effectiveness because materials can be used with resistive touchscreens to add antimicrobial functionality without a significant loss of durability.
of product liability limitations. Some coatings are currently undergoing testing for effectiveness against the SARS-CoV-2 virus. These tests use fairly high levels of viral load at the test’s initiation and measure the number of active viral cells after a set time interval—normally 24 hours. As is the case in many standardized testing procedures, the ability to relate that to a real-world probability of infection is difficult (if not impossible). Suppliers at all steps of the supply chain must take care to state any claims about the coatings’ effectiveness in such a way as to minimize any product liability risks.

The touchscreen industry has the capability to provide antimicrobial surfaces that can significantly reduce the risks of surface contact transmission of bacterial and viral-based diseases by employing surface treatments to the glass cover lens. These treatments are permanent and do not have any adverse effects with respect to the touchscreen’s optical or functional performance. Costs for adding the antimicrobial functionality can be quite reasonable, given the utility and value added to the final product.  

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