Investigation of increasing the strength of the iphone 11

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Introduction

Apple is currently designing the iPhone 11 and aims to improve on the recent iPhone X in regards to its strength which has been raised as a concern by consumers. Forbes compiled a list of some of the issues that were found by consumers and one of the most frequent and detrimental was the glass screen of the iPhone cracking or shattering. Another key issue was that the phone was quite easily bent as the back frame was not strong enough. In the next iPhone, Apple aims to increase the strength of the iPhone so that breaking the phone is not an issue for every day users. As the materials engineering team assigned to this project, we have been assigned the task of improving the strength of the iPhone. There is a move amongst portable technology manufacturers to make their devices thinner and in doing this, they often make the glass of the devices thinner as well. This compromises the strength of an already weak material and makes improving the strength of the material an even more important task for materials engineers.

The previous release, the iPhone X uses Gorilla Glass 5 designed by Corning specifically for use in smart phones. Previous iPhones (before the iPhone 8 and 8 Plus) had a lightweight metal backing but this has been altered in the most recent releases. The choice to have both a glass front and back on the iPhone was based on a combination of factors including appearance, to make the phone thinner, its ease of manufacture and so that wireless charging is possible. The iPhone X also contains a stainless steel frame which is visible on the buttons around the edge of the phone. The iPhone 8 and 8 Plus instead had an aluminium alloy case which was reinforced by steel and the glass front and back. This analysis will examine potential methods of increasing the strength of the iPhone so that it is more durable and so it could be potentially be used as a thinner piece. For the wireless charging process to work, a backing like glass is required so in keeping with Apple's move to wireless charging, returning to a metal backing will not be explored. The focus of this investigation will be on increasing the strength of the glass used in the iPhone 11 to increase the strength of the entire outer shell of the phone.

Background

The glass currently used for phone screens is actually a synthetic glass-ceramic. The first glass-ceramic was made by accident in 1952 by a chemist named Don Stookey at Corning Glass Works, the company that provided glass to Apple for the iPhone X and many previous iPhones. A faulty thermostat caused a sample of glass to be heated to 900 C instead of 600 C. When Stookey returned to collect the glass, he found a white plate which bounced when dropped instead of shattering. This is a result of the ' controlled crystallization' process which occurred while the material was in the furnace.

Glass-ceramics contain crystalline structures within an amorphous matrix. It is the crystalline phases which determine the properties of the material. The heat treatment of the material is controlled to produce a specific percentage of crystalline material in order to obtain desired properties of the material. At the Federal University of Sao Carlos, the method used to obtain this material is heat treatment at 700 C and then a second heat treatment at 900 C which results in a glass-ceramic that is transparent, hard and has a low density. The transparency of the glass is a result of a lack of grain boundaries and pores within the microstructure.

Glass-ceramics have properties that are a combination of both glass and ceramic properties. This is because glass-ceramics contain both an amorphous phase and crystalline phases (typically 95-98%). Glass is an amorphous solid and so planes of atoms are not able to slip past each other. As the stress builds up inside the material and is not able to be released, it becomes concentrated and can cause a crack. The crack causes the stress to increase and so more bonds break and the crack increases until we see the glass breaking. Ceramics are crystalline and contain both ionic and covalent bonds. As crystals, the strong interactions between atoms make it difficult for planes to slip past each other and so the material is brittle. Ceramics resist strongly in compression but break when they are bent. Hence, the glass-ceramics combine both the strength of the glass and the toughness of the ceramic. Composition of Gorilla GlassGorilla glass is the glass used in the iPhone 8, 8 plus and X. Gorilla Glass is made from an oxide of silicon and aluminium with sodium atoms (aluminosilicate). It begins as a combination of silicon dioxide (sand) and a mixture of naturally occurring chemicals. This mixture is melted down and then cooled, producing sheets of glass. The glass is chemically strengthened at the end of the manufacturing process by placing it in a bath of molten potassium salt. Potassium is more reactive than sodium and so displaces the sodium ions. The potassium ions are also larger than the sodium ions and so take up more space within the glass. This results in compressing of the glass which strengthens it and makes it more resistant to damage as there is more elastic potential energy stored in the glass.

In the manufacturing process, Corning makes every effort to reduce the number of weaknesses in the structure. This includes ensuring that glass is poured into a perfectly flat plane so that it does not need to be polished which is a process that introduces weaknesses into the material. Corning is looking into varying the composition of their Gorilla Glass 5 for their next release, Gorilla Glass 6. They are aiming to make a glass that is easier to chemically strengthen so that an increase in compression is easier to achieve.

New research

Scientists at the University of Tokyo have been working on a new type of metallic glass with strength comparable to some metals. The aim of the research was to create glass that was both hard and crack-resistant from Al2O3-SiO2 glasses. Creating glasses which combine these features is very important in the applications of transportation, electronics and construction. In order to be ‘ crack-resistant’, the glass should have low brittleness and be resistant to surface damage. The most effective method of doing this is to use chemical or physical strengthening methods to create a compressive stress later at the surface of the glass. This can prevent crack initiation and further propagation. Hardness was measured based on scratch hardness, scleroscope hardness and indentation hardness. Scratch hardness is the resistance to abrasion, scleroscope hardness is the amount of energy that is used in deforming a specimen elastically and indentation hardness is the resistance of a material to local indentation. In creating this glass, alumina is combined with tantalum oxide using the aerodynamic levitation technique. In the aerodynamic levitation process, the solid materials are lifted into the air using a stream of oxygen gas and a laser is used to melt the material which prevents the issue of nucleation occurring at the container interface. By using this method, this research improves on previous attempts to synthesise glass containing alumina in which the material crystallised when it touched the sides of a container. In the experiment, glasses were made with varying ratios of Al2O3 to SiO2 and then tested using the Vickers hardness test. With increasing Al2O3 content, the glasses became both harder and more resistant to radial cracking. The glass produced was colourless and highly transparent and so would be suitable for use in phone screens and electronics applications. The glass has a high elastic modulus and can be made more thin while still maintaining strength.

Suggestions

The current procedure to create glass for the iPhone by Corning already makes use of a number of techniques to increase the strength of the material. These include chemical strengthening in a molten metal salt bath and ensuring flat pouring. These procedures have already been refined to get glass of the quality used in the iPhone X so it is likely that Corning has already exhausted many of the possible changes that could be made to the material to strengthen it. Corning has not made their testing data available to Apple and so the Apple materials design team will need to do their own experiments. A possible suggestion for improvement to the Corning method is to look into the use of chemical strengthening with a rubidium salt bath. Rubidium is larger and more reactive than sodium and potassium and so would displace more readily and introduce more compression into the structure if it is possible for this exchange to occur. Rubidium is more expensive than potassium and so this may not be a suitable solution for the strengthening issue on the industrial scale. This variation should be explored with aluminosilicates containing sodium and also with aluminosilicates containing potassium to explore the effects that displacing these atoms with rubidium can have. It would be necessary to analyse the test result of this experiment and compare this to the increased cost of the glass to manufacture to determine whether it is a realistic solution to the problem.

Alternatively, the new research in Japan into aluminosilicate glasses is very promising. It would be very beneficial for the materials engineering team to conduct experimental tests into the optimal ratio of Al2O3 to SiO2 using the aerodynamic levitation technique for strength purposes. The procedure for synthesis and testing could be derived from that used in the research paper. The research showed that increasing Al2O3 content made the glasses harder and more resistant to radial cracking. This test was limited however as the highest proportion of Al2O3 that was tested was 60%. Testing at a higher proportion may show even greater hardness and crack resistance. After exploring these two potential alternatives and doing the appropriate research, a stronger glass may be identified which can be used in the iPhone 11. Things to consider when making this decision include safety of manufacture, safety of use, cost, ease of manufacture and whether the strength change is significant enough to consider completely changing the glass manufacturing process.

Conclusions

This report has outlined the current methods used to create glass for use in electronic devices like the iPhone. Two potential methods of creating strengthened glass were identified. The first of which involves following a similar procedure to that currently used by Corning but changing the molten salt bath from a potassium salt bath to a rubidium one. Rubidium is more reactive and larger in size so has potential to react readily and to increase compression in the glass, thus increasing its strength. The second method described involves conducting more research into the ideal ratio of Al2O3 to SiO2 for a glass prepared using the aerodynamic levitation technique. Previous research into this technique showed increased crack resistance and hardness with increasing amount of Al2O3 but the test results were limited. These options should be researched thoroughly by the materials engineering team at Apple in order to determine whether stronger glass can be produced using either of these methods.