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THE HONG KONG
POLYTECHNIC UNIVERSITY
香港理工大學

Development of Face Shields by 3D printing

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Opening Minds • Shaping the Future
啟迪思維 • 成就未來

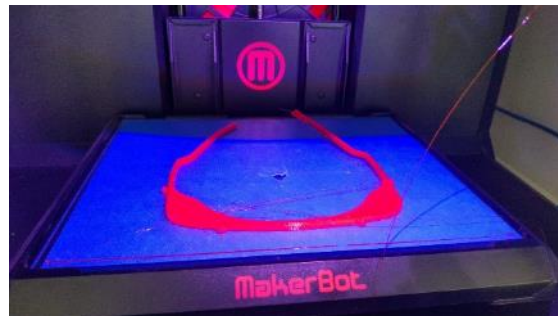
Agenda

1. Development of Reusable 3D Printed Eye Visor to Queen Elizabeth Hospital (QEH)
2. Development of Face Shields for Hong Kong Hospital Authority (HA)
- Design to Production by 3D printing
3. Development of Vacuum Formed Face Shields for General Public by 3D printing



3D Printed Eye Visor

- > On 6th Feb. , Queen Elizabeth Hospital (QEH) contacted U3DP to 3D print eye visor for their frontline staff. U3DP started all the digital processes immediately.
- > The quantity that QEH requested per day is far more than the maximum printing capacity of U3DP. Therefore, **reusable eye visor** is an option



Single use visor printed by Makerbot



Visor samples provided by QEH



3D Printed Visor made by PLA



Reusable 3D Printed Visor made by ULTEM

3D Printed Eye Visor

9 Days to response the urgent need

- > After 2 days (8/2) study, U3DP decided to use a high strength and heat resistance material for printing reusable visor frame
 - Complied with ISO 10993 Bio-Compatibility Certification
 - Heat Deflection (HDT) over 200 °C can be used for normal hospital sterilizing operation
- > At the same time, U3DP also used 30 sets of desktop FDM 3D printer ,Makerbot, to build single use eye visor for QEH
- > As a result, 500 pcs of reusable visor frame and 200 pcs of single use visor frame were delivered to QEH on 15th Feb.



Fortus 900mc in U3DP



Reusable visor "as build" condition

ULTEM 1010 Resin 

ULTEM 1010 resin is a high-performance PBT thermoplastic that offers excellent strength, thermal stability and the ability to withstand clean autoclaving. ULTEM 1010 resin is available in a general purpose grade as well as a certified grade (CE) for those customers who want to take advantage of food contact certification for special applications including food production tools and custom medical applications. ULTEM 1010 resin offers the highest heat resistance, chemical resistance and tensile strength of any PBT thermoplastic and is ideal for aerospace and automotive applications.

Mechanical Properties*	Test Method	Value	2010 Certification
Tensile Strength, Yield (Type 1, 0.125", 0.27mm)	ASTM D638	462 MPa (66,500 psi)	451 MPa (64,800 psi)
Tensile Strength, Ultimate (Type 1, 0.125", 0.27mm)	ASTM D638	611 MPa (87,700 psi)	600 MPa (86,900 psi)
Tensile Modulus (Type 1, 0.125", 0.27mm)	ASTM D638	2,770 MPa (400,000 psi)	2,620 MPa (379,000 psi)
Tensile Elongation at Break (Type 1, 0.125", 0.27mm)	ASTM D638	0.25%	0.25%

Material Data Sheet of ULTEM 1010

3D Printed Face Shield

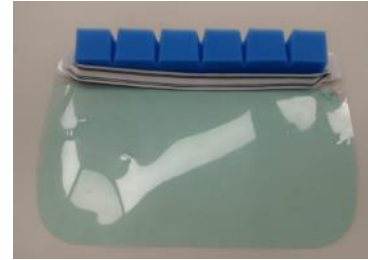
> As the same time, on 8th Feb., Hospital Authority (HA) also approached us to solve the critical face shield shortage issue.

> **Daily consumption of the disposable face shield is 30,000 pcs**

> A face shield sample was provided to the team for design review.

> In view of the patent concern, the team decided to design **our own face shield**

- Small batch of production of 3D printed frames were produced to meet the urgent need
- Connecting with the local industry for mass production to fulfil HA's demand



Disposable Face shield samples provided by HA



3D Printed face shields developed by U3DP PolyU

3D Printed Face Shield

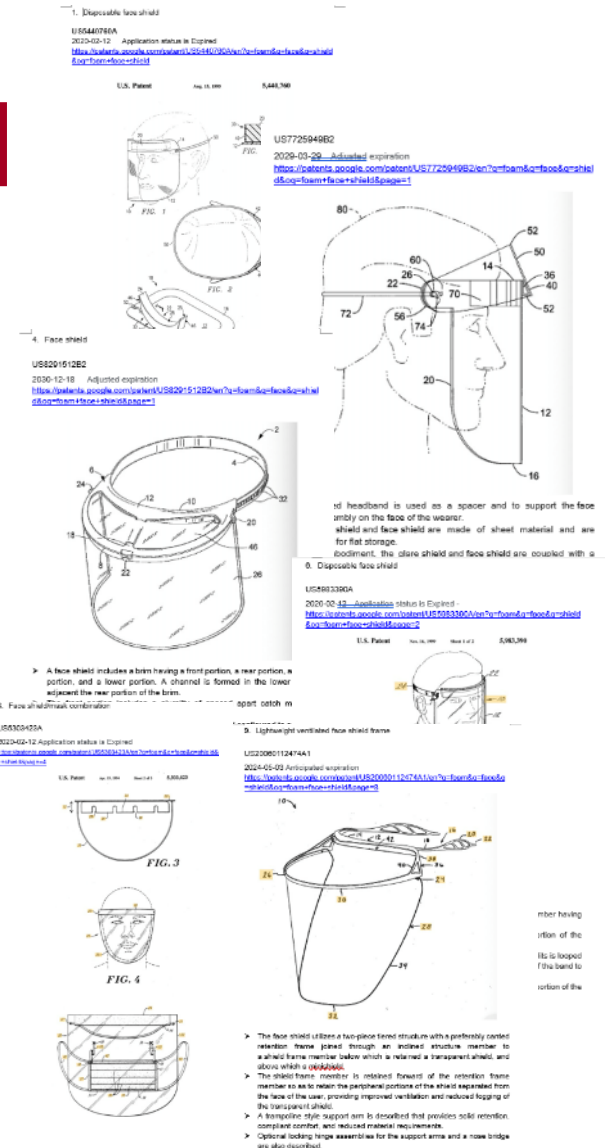
- > The World Health Organization's health care facility recommendations for standard precautions include **a face shield as an alternative** to the use of a medical/surgical or procedural mask with eye protection
- > The face shield is design for infection control and it should be complied with Occupational Safety and Health Administration's (OSHA) Bloodborne Pathogens Standard 1910.1–030
 - Masks in combination with eye protection devices, such as goggles or glasses with solid side shields, or chin-length face shields, shall be worn whenever **splashes, spray, spatter, or droplets of blood or other potentially infectious materials may be generated and eye, nose, or mouth contamination can be reasonably anticipated.**

3D Printed Face Shield

> Patent search to avoid infringing other IP

> Design Considerations

- Fully comply with OSHA 1910.1030(d)(3)(x) requirement
- Compatible with the use of N95 mask
- Comfortable to be worn for a whole day
- Adjustable tightness
- Light in Weight
- Anti fog
- Fit for different users, i.e. male and female



3D Printed Face Shield

> With the help of 3D Printing, total of 6 design iterations were conducted in 7 days

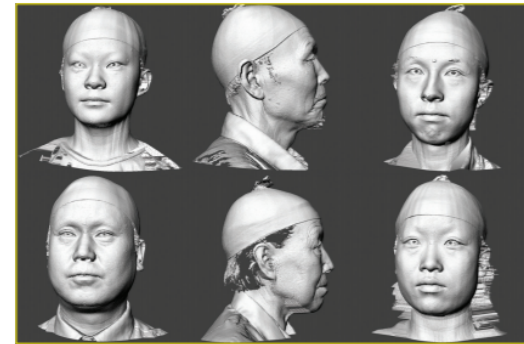
8 Feb 2020

14 Feb 2020

Design 1	Design 2	Design 3	Design 4	Design 5	Design 6
					
-The first design reference to the eye visor	-Shorten the braces to avoid interfering with head	-Barb design for better securing the transparent cover sheet	-Wider edge for supporting forehead -Wider elastic band	-Adjustable tie slots for elastic band -Foam tape is added	-Apply Asian head data to finalize the design

3D Printed Face Shield

- > In addition to comply with product safety regulation, **user acceptance is important** for the face shield development, every design iteration will be tried by team member for internal design review
- > HA infection control team also provided full support to the development process. The officer came to try the new design and **gave feedbacks every day.**
- > Research data of Chinese head size from “SizeChina” project of School of Design, PolyU, was used to improve the fitting for **Asian heads.**



Size China: The first-ever digital database of Chinese size and face shape



Trial using SD's head model



Trial by HA's infection team

3D Printed Face Shield

From Design to Production (Made in HK!)

- > After 6 design modifications, the final design has been confirmed on 14th Feb.
 - 2 sizes (M and L) were made for different users
- > On 15th Feb, final design was passed to manufacturer for injection mould making and other preproduction arrangement
- > On 25 Feb 2020, mass production of the shields was started locally to meet the urgent need of PPE shortage for HA



design
to
production

3D Printed Face Shield

Join together to tackle COVID-19!

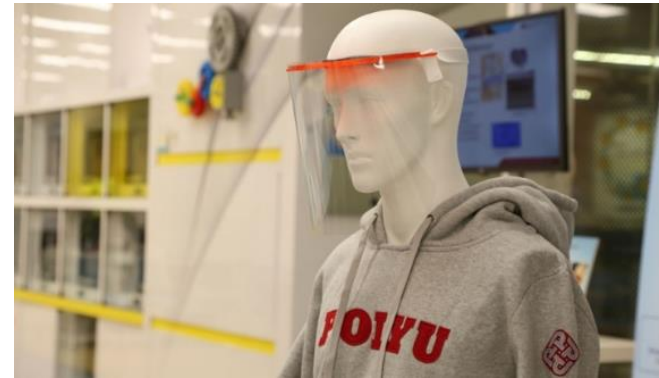
- > Before delivery of mass produced face shields, from 15th Feb to 25th Feb, U3DP played a role as a manufacturer to produce face shield by 3D printing
- > A local manufacturer donated 7000 pcs of transparent sheet for face shield production in U3DP
- > 3D printers in other academic departments were mobilized for the production
- > Volunteers from other PolyU departments also joined the production



Volunteers “workers” from PolyU joined the production of 3D printed face shield

3D Printed Face Shield

- > Finally, 800 pcs of 3D printed face shields were delivered to HA before the mass production lot was ready
- > ~1000 pcs of 3D printed face shield had been delivered to other government departments such as Fire Services and Government Logistics
- > In short, PolyU spent around 2 weeks from concept generation, design, built prototype, collecting feedbacks, improving designs, liaising with industry partners, transferring technology to local manufacturers, 3D printing shields for urgent demand, solved a critical problem for our frontline medics.



The idea Initiation of vacuum formed face shields for General Public

- > On 26 Feb, the team initiated an idea of making reusable face shields for NGO and general public
- > Design principles:
 - low cost, reusable, environmental, comfortable
 - used by general public, healthcare service providers,
 - facial expression can be seen, help reboot the human connections

Development of vacuum formed face shields

- Low cost process-- by vacuum forming, low mold tooling and machine cost
- Reusable—same type of materials for easy cleaning and re-sterilization
- 3D Printing was applied to print the vacuum forming molds
- Vacuum forming machines and Laser cutters were used during the prototyping stages



Left: general version; Right: Enhanced version vacuum formed face shields design for NGO and general public



Development of vacuum formed face shields

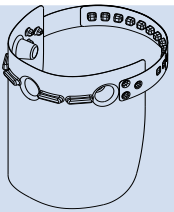
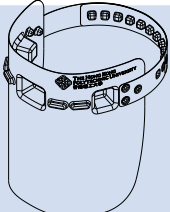
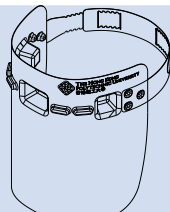
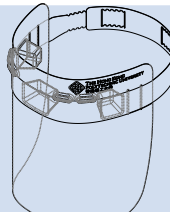
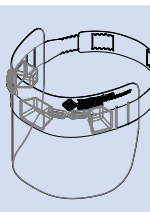
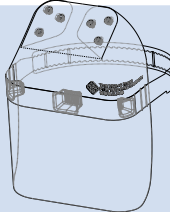
— 3D printing made rapid modification possible

More than 20 design iterations were undergoing and the major design change are as below;

26 Feb 2020

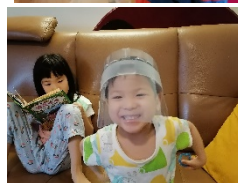


5 April 2020

GV-1	GV-2	GV-3	GV-4	GV-Kid	EV-1
					
-3 Round bulbs design for forehead and two bulbs adjustable belts	-3 Rectangle bulbs design for forehead and two bubs adjustable belts	-3 Rectangle bulbs design for forehead and two adjustable Ziczag belts	-3 Rectangle bulbs design for forehead and one adjustable Ziczag belts	-Same design with GV-4 fit for kids	-Similar design with GV-4 with full coverage with the head

Feedbacks of vacuum formed face shields

- > Although the requirement of “general use” face shield is not as high as HA’s shields, user experience is important for the design yet.
- > More than 100 samples of face shields were dispatched to some social welfare organisations collecting feedback for design improvement
- > The Kid’s version was designed accordingly to the data of HK Medical & Health Department and field test by different age group of children



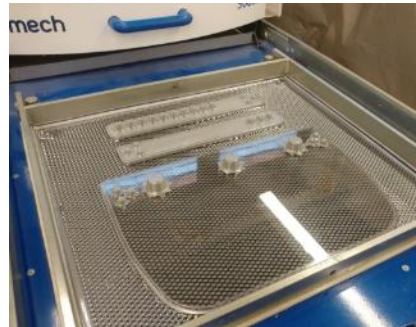
A small batch production of vacuum formed face shields at PolyU

3D printed
vacuum
forming tool

Vacuum
forming

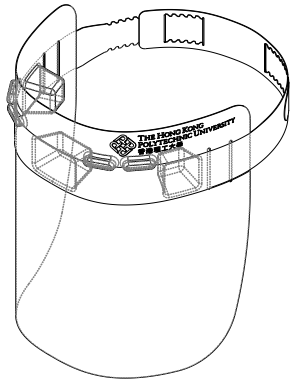
Laser
cutting

Assemble



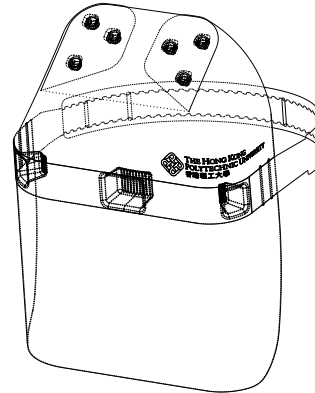
Vacuum Formed Face Shields for General Public

General Version



Vacuum formed face shield in PET, Provide splash protection, Good ventilation, Adjustable head band width, Ease of assembly, Ease of cleaning

Enhanced Version



Vacuum formed face shield in PET, Provide an additional splash protection, covering forehead, Good ventilation, Adjustable head band width, Ease of assembly, Ease of cleaning

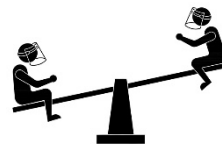
Vacuum Formed Face Shields for General Public

“Many workers have to do cleaning jobs without any protection,” she said. “With this face shield, they could do the cleaning comfortably while having certain protection from the infection. **This is not just a face shield, it sends a message to them that many people are still concerned about their well-being.**” by Tsang Yuen-kei, service head of the Hong Kong Christian Service



<https://www.scmp.com/news/hong-kong/article/3078107/coronavirus-hong-kong-university-mass-produce-reusable-face-shields>

> With our face shields for general use, we can live a normal life amid the shadow of COVID-19



Let us work together to fight against
COVID-19.

Thank you for your attention