

# Projection materials - a guide for selection

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This document provides an overview of projection materials that we have been researching for various mixed reality applications. These applications demand diverse solutions for the projection of computer graphics under changing conditions and using differing equipment. Just to mention a few examples: Our work includes applications within environments providing very different lighting conditions, for example. Sometimes those can be tightly controlled (i.e. in a theatre) but often necessary lighting is determined by other factors (i.e. office situations). A similar range of lighting problems is encountered when considering indoors and outdoors applications. There are often other restrictions caused by the environment. An example would be an environment that requires back projection to save space or an environment that requires a particularly big screen for large groups of users. In addition to the factors mentioned above, we are using different projectors and computers producing the graphics from differing software sources.

One of the key elements in any of these projection set-ups, besides projector and quality of the graphics, is the actual *projection surface*. The following overview is intended as a resource that enables us and other Equator partners to choose projection surfaces to suit different project requirements.

## 1. Selection criteria

The following is a listing with explanations of the criteria that we used to assess the different materials. These will hopefully prove useful for the future selection of projection materials for different applications. For each material we look at:

### *Projection Requirements*

Does the material require front or back projection or does it allow both? Is a certain angle of projection required? Does the material require control over the lighting in the adjacent space?

### *Projection qualities*

What level of sharpness can be expected? What is the resolution like?

### *Traversability*

To what extent is the material suitable for the creation of a 'traversable interface'. 'Traversable interfaces' are projected surfaces that can be 'stepped through' to create the illusion of physical traversal from physical space to virtual space projected on the screen. The issue of traversability was one of the starting points for this overview (Boriana Koleva, Holger Schnädelbach, Steve Benford and Chris Greenhalgh, 'Traversable Interfaces Between Real and Virtual Worlds', published in proceedings of CHI 2000 conference, The Hague, Netherlands).

### *Shapes/Curvature*

What kinds of shapes are available? Can the material be curved (Two-dimensional curves create cylinder segments while three-dimensional curves create dome segments or other freeform shapes)?

### *Maintenance / Durability*

How can the surface be kept clean? How susceptible is the surface to physical damage?

### *Maximum Dimensions*

What are the maximum dimensions the material is typically available in?

### *Weight/m<sup>2</sup>*

What is the weight per square metre for the thickness typically required for a projection screen?

### *Cost/m<sup>2</sup>*

What is the cost per square metre for the thickness typically required for a projection screen?

### *Manufacture*

How is the material made?

### *Source / Reference*

Where can the material be sourced from? Projects or applications this material has been used for?

### *Advantages*

Summary of the material's advantages.

### *Disadvantages*

Summary of the material's disadvantages.

## **2. The materials researched**

This section provides a list of the materials we looked at with a short description of each material. The list is split into two categories: rigid materials (i.e. glass) and flexible materials (i.e.PVC).

## **2.1 Rigid materials**

### **2.1.1 Glass**

#### *Translucent*

Planar transparent glass whose surface has been treated so one can only partially see through it (i.e. shadows, figures). Light is still transmitted but at a reduced rate

#### *Patterned*

Planar transparent glass to which a pattern (i.e. dots) has been applied. The dots act as the surface holding the image leaving transparent gaps between them.

#### *Chromatic*

A chromatic gel is layered between two layers of planar glass. This layer can be triggered to switch between a transparent and translucent state. In the translucent state chromatic glass can hold an image.

### **2.2.2 Plastics**

#### *Translucent*

Planar transparent plastic (i.e. acrylic) whose surface has been treated so one can only partially see through it (i.e. shadows, figures). Light is still transmitted but at a reduced rate.

#### *Patterned*

Planar transparent plastic (i.e. acrylic) to which a pattern (i.e. dots) has been applied. The dots act as the surface holding the image leaving transparent gaps between them.

#### *Professional projection material*

Planar transparent plastic (i.e. acrylic) to which a system of lenses has been applied. The lenses typically increase the levels of light transmission, viewing angle and contrast.

#### *Holographic*

Planar transparent plastic (i.e. acrylic) to which a transparent film containing a lens system has been applied. Holds an image although transparent.

#### *Fibre reinforced*

Plastic material moulded together with glass or carbon fibre to produce a very strong surface.

## **2.2 Flexible Materials**

### *Professional Projection screens*

Flexible plastic material that has been treated to improve projection quality for front or back projection.

### *Household plastics*

Flexible plastic material like shower curtain or table cloth that happens to have the right qualities for projection purposes.

### *Cotton*

Translucent fabric material ordinarily used for curtains etc that happens to have the right qualities for projection purposes

### *Gauze*

Semi-transparent fabric ordinarily used for curtains etc. that allows back and front projection while maintaining some transparency.

### *Beads on nylon threads*

Translucent plastic or glass beads lined up on threads of nylon or similar material to form a curtain.

### *Line*

Nylon or similarly translucent line assembled in a curtain, a principle that has been used in early curved projection screens.

### *Water*

A fine spray of water produced using insecticide nozzles

### *Smoke/fog/haze*

A curtain of haze particles that can be used for projection purposes

## **3. Appendix - overview of materials and properties**

The following table provides an overview of the materials researched. It is split into rigid materials and flexible materials.

# Rigid materials

Materials	Description Features	Projection Requirements	Projection qualities	Traversability	Shapes/ Curvature	Maintenance / Durability	Max. Dimension	Weight/m <sup>2</sup> (at appropriate thickness of each material)	Cost/ m <sup>2</sup> +	Manufacture	Source/ Reference	Advantages	Disadvantages	Materials
Glass - Translucent	Translucent. Distributing light evenly. Constant quality of transparency.	Requires back-projection. Project straight on. The gain is not as good as with professional materials. Needs control over lighting conditions	Projection seems reasonably clear, no definite data available, angle of view limited, light transmission is high (75%)	In form of a door set-up. Sheets are mounted to rotate or slide out of the way.	Typically rectangular. Corners can be rounded off. Other shapes possible as long as materials remains planar.  Can be curved in two dimensions (cylinder segments) with diameter constraints. Can be shaped in three dimensions (dome segments) with great cost.	Simple, cleaning like normal window.  Durable under normal circumstances. Does not scratch easily.	Standard stock 3210x1500 MM (Solaglas).  Max. 6000x3210 MM (Solaglas).	~30 kg.	~ £ 85 for sandblasted.  ~ £ 110 for acid etched	Float glass is acid etched (very smooth surface) or sand blasted (interesting rough patterns).	www.solaglas.co.uk  none available	Cost. Availability. Light transmission. Frame less fixture.	State of transparency fixed. Weight.	Translucent Glass
Glass - Patterned	Glass with pattern applied to typically one side.	Depending on the way the pattern is created: allows back and front projection. Gain is low. Needs control over lighting conditions.	Pattern reduces resolution and brightness. This also reduces the sharpness. Angle of view limited. Light transmission is medium to high, reduced due to the pattern.	In form of a door set-up. Sheets are mounted to rotate or slide out of the way.	Typically rectangular. Corners can be rounded off. Other shapes possible as long as materials remains planar.  Can be curved in two dimensions (cylinder segments) with diameter constraints. Can be shaped in three dimensions (dome segments) with great cost.	Simple, cleaning like normal window  Durable under normal circumstances, does not scratch easily	3400x1900 MM	~30 kg.	price not available	Patterns screen-printed onto glass. Translucent ink available  Or, bonded to glass at very high temperature.	www.solaglass.co.uk  none available	Availability. Light transmission. Frame less fixture.	State of transparency fixed. Weight.	Glass - Patterned
Glass - Chromatic	Instant switch between transparent and translucent states by applying electricity. Power on switches to transparent state.	Requires back-projection. Project straight on. The gain is not as good as with professional materials. Needs control over lighting conditions. Needs to be	Projection seems of good quality (not tested ourselves). Light transmission is medium to high.	Only as door set-up and hindered by heavy framing necessary around all edges.	Typically rectangular. Corners can be rounded off, other shapes possible as long as materials remains planar.  Can be curved in two dimensions (cylinder segments) with diameter constraints (very	Simple, cleaning like normal window  Durable under normal circumstances, does not scratch easily	2800x1000 MM, there can be larger sizes this will be very costly (Solaglas)	~30 kg.	~ £ 1500	Product name (Solaglas Privalite), LCD element is layered between two sheets of float glass	www.solaglas.co.uk  BBC studio	Change of Transparency. Synchronisation of this with performance. Complete visual permeability, if desired. Light transmission high.	Cost. Weight. Availability only from one company. Fixing and handling complex.	Glass - Chromatic

		translucent state.			expensive).									
Plastics - Translucent	Typically acrylic plastic (Perspex). Sanded or sand blasted on one side.	Requires back-projection. Project straight on. The gain is not as good as with professional materials. Needs control over lighting conditions.	Projection seems reasonably clear. No definite data available. Angle of view limited. Light transmission is medium to high.	In form of a door set-up	Typically rectangular. Corners can be rounded off. Other shapes possible like circular shapes for example.  Can be curved in two dimensions (cylinder segments) Can be shaped in three dimensions (dome segments) with great cost.	Relatively simple. Avoid scratching. Attracts dust due to electrostatic charges.  Abrasion is higher than with glass, more easily scratched.	3000 MM x 2000 MM (Amari Plastics Plc. Nottingham)	~ 8 kg	~ £ 45 + the machining on one side	One surface is sanded down with mechanical sander or by hand. Can also be sand blasted ?	Amari plastics, Nottingham  Traversable boundary - sliding door.	Cost. Simple fixing and handling. Light weight Frame less fixture.	State of transparency fixed. Thermal movement. Electrostatic charge.	Plastics Translucent
Plastics - Patterned	Typically clear acrylic plastic (Perspex), With printed, painted or adhesive film patterns of dots or bands.	Depending on the way the pattern is created: allows back and front projection, Gain is low. Needs control over lighting conditions.	Pattern reduces resolution and brightness. This also reduces the sharpness, Angle of view limited. Light transmission is medium to high, reduced due to the pattern.	In form of a door set-up	Typically rectangular. Corners can be rounded off, other shapes possible like circular shapes for example.  Can be curved in two dimensions (cylinder segments) Can be shaped in three dimensions (dome segments) with great cost.	Relatively simple, avoid scratching. Attracts dust due to electrostatic charges.  Abrasion is higher than with glass, more easily scratched.  Abrasion and scratches on the pattern possible.	3000 MM x 2000 MM (Amari Plastics Plc. Nottingham)	~ 8 kg	~ £ 45 + the cost of applying the pattern	Clear materials has pattern applied by: spraying it on with template, printing it on if the thickness of the material permits it or by the application of an adhesive film that is patterned.	Amari plastics, Nottingham for the basic material. Screen printer for the printing process on film.  Majic tele-conferencing system	Cost . Simple fixing and handling. Light weight Frame less fixture.	State of transparency fixed, Thermal movement Electrostatic charge	Plastics - Patterned
Plastics - Holographic	Transparent professional screen that holds a back-projected image.	Requires back projection. Projection has to hit surface at 35 degrees angle from the back.	Projection quality is good and clear even in daylight situations. Sharp image.	In form of a door set-up	Typically rectangular, corners can be rounded off, other shapes possible like circular shapes for example.  Cannot be curved?	Relatively simple, avoid scratching. Attracts dust due to electrostatic charges.  Abrasion is higher than with glass, more easily scratched	40" and 60" diagonal, DNP Denmark	~ 8kg	40" £4500 60" £6500	Lens system is applied to plastic film which is in turn applied to the plastics.	www.dnp.dk  Hugo Boss stores - Hannover and New York	Clear when not projected on to, Complete visual permeability.	Cost. Thermal movement Electrostatic charge	Plastics - Holographic
Plastics – Professional projection screens	High image quality on a purpose made material.	Requires back projection. Gains up to 5 are possible. Viewing angle reduces with higher gains. Different versions for different	High image quality with good sharpness and contrast even in daylight conditions.	In form of a door set-up	Typically rectangular, corners can be rounded off, other shapes possible like circular shapes for example.  Cannot be curved (will depend on	Relatively simple, avoid scratching. Attracts dust due to electrostatic charges.  Abrasion is higher than with glass	Standard stock ~ 2740MM x 3650MM at 4:3 ratio, larger sizes possible	~ 8kg	~£1375 for optical systems ~£625 for diffusion type	The optical system is edged into either side of the surface. The diffusion type is made by chemical treatment	www.dnp.dk or www.stewartfilm.com  Home cinemas. Point of sales displays	Optical quality Simple fixing and handling. Light weight. Frame less fixture. Expertise readily available.	Cost. State of transparency fixed. Thermal movement. Electrostatic charge.	Plastics – Professional projection screens

		daylight conditions.			whether a lens system can be designed that works for curved screens)	more easily scratched								
Plastics – Fibre reinforced	Plastic made from resin and various kinds of fibres (glass, carbon ...).	Front projection should be no problem, back projection will depend on how translucent the material is in practice.  Gain is probably low. So it will require control over lighting conditions.	Image quality will be affected by pattern of fibres. Light transmission is low.	In form of a door set-up	The most 'shapeable' material. Can be curved in three dimensions (dome segments and free form shapes) according to the form work used.	Relatively simple, avoid scratching. Attracts dust due to electrostatic charges.  Abrasion is higher than with glass, more easily scratched. Very durable. Structurally very strong and durable.	Difficult to give maximum size for. Depending on space and form work available during manufacture.	~ 10 kg	Info not available. Depends too much on actual shape and requirements.	Fibres are laid out in form work, resin is applied, this can be done by hand if necessary (surf boards, boards etc.)	Glass fibre plastics moulders in the yellow pages.  Boats, racing cars	Shapeability, rigidity (can be structural if necessary). can be made in the lab (with restrictions)	State of transparency fixed, Back projection might be difficult. Image quality.	Plastics – Fibre reinforced

# Flexible materials

Materials	Description / Features	Projection Requirements	Projection qualities	Traversability	Shapes / Curvature	Maintenance / Durability	Maximum Dimension	Weight/m <sup>2</sup> <i>(at appropriate thickness of each material)</i>	Cost/ m <sup>2</sup> VAT	Manufacture	Source	Advantages	Disadvantages	Materials
PVC – Professional Film and projection screens	Flexible material custom made for projection purposes. Different types for front and rear projection.	Gains up to 2 possible. Front and back projection possible. Viewing angle reduces with higher gains. Different versions for different daylight conditions.	High projection quality. Possible to use in daylight condition but not as good as rigid projection screens. Light transmission is medium to low.	In form of a curtain set-up or if mounted on rotating frame.	More or less any shape. Can be flexibly curved to create complex curvatures as part of tensile structure or tents, can also be mounted in rectangular frames.	Relatively simple. Wipe clean. Attracts dust due to electrostatic charges.  Might tear if not handled with care	Standard sizes up to 3650MM x 2740 MM (Stewart) Maximum size 13200MM x 29200MM (Stewart).  Sow together larger sizes if necessary	~ 1kg	Info not available.	PVC is treated to allow for different optical qualities.	www.dnp.co.uk or www.stewartfilm.com  Cinemas.	Optical quality. Relatively light weight. Possibility of curvatures. Sound permeable versions available (front projection). Tensile structures for immersion. Good availability.	State of transparency fixed.	Flexible Film Screens
PVC – Table cloths, shower curtains	Flexible material available in home stores and the like. Different grades of transparency and patterns available	Front and back projection possible. Needs control over lighting conditions.	Image quality is inferior to material above. Not suitable for daylight applications. Less translucent material compared to what we tested might give better results. Light transmission is medium to high.	In form of a curtain set-up or if mounted on rotating frame	More or less any shape, can be flexibly curved to create complex curvatures. Part of tensile structure or tents. Can also be mounted in rectangular frames	Relatively simple. Wipe clean. Attracts dust due to electrostatic charges.  Might tear if not handled with care.	Sizes typically available are 2m x 15m (roll). Larger sizes should be possible to find. Sow together.	~ 1kg	~ £ 5	PVC manufacture?	Home stores, DIY stores.  Showers. Table cloths. Traversable boundary demonstrator.	Price. Relatively light weight. Curvature possible. Tensile structures for immersion.	State of transparency fixed, image quality is not optimised like for professional material,	PVC – Table cloths, shower curtains
Fabric – Cotton	Fabric available in home stores and the like (different colours, densities, patterns)	Front and rear projection possible (the denser the material, the less suited it is for back projection). Suitable for some daylight applications	Image can be very good especially for front projection. Light transmission depends on thickness of material.	In form of a curtain set-up or if mounted on rotating frame	More or less any shape, can be flexibly curved to create complex curvatures, part of tensile structure or tents, can also be mounted in rectangular frames.	Wash, make sure the method of fixing the material allows that, difficult to clean while in position.  Might tear if not handled with care, will fade in light over time,	Sizes typically available are 2m x 15m (roll), larger sizes should be possible to find, sow together larger sizes if necessary	~ 1kg	~£ 2	Woven cotton threads presumably, sow together for larger versions	Home stores.  Table cloths, curtains .Traversable boundary demonstrator.	Price,. Lightweight. Curvature possible. Tensile structures for immersion. Availability. Nice unusual optical quality (the image takes on some of the patterning) Tactile quality,	State of transparency fixed, image quality is not optimised like for professional materials, gets dirty quickly and is difficult to clean while mounted.	Fabric – Cotton
Fabric – Gauze	Light mesh, fabric available in home stores and the like(different colours, densities)	Front and rear projection possible (the denser the material, the less suited it is for back	Image quality is impeded by the semi-transparent state of the material. Overlays what lies behind the screen with what is	In form of a curtain set-up or if mounted on rotating frame.	More or less any shape, can be flexibly curved to create complex curvatures, part of tensile	Wash, make sure the method of fixing the material allows that, difficult to clean while in position	Sizes typically available are 2m x 15m (roll), larger sizes should be possible to find, sow together	~ 1kg	~£ 3	Woven synthetics threads presumably.	Home stores.  Curtains etc.	Price. Lightweight. Curvature possible. Tensile structures for immersion	State of transparency fixed. Image quality is not optimised like for professional materials	Fabric – Gauze

		projection), suitable for some daylight applications.	displayed on it..		structure or tents, can also be mounted in rectangular frames	Might tear if not handled with care	larger sizes if necessary					Availability. Semi-transparent quality which allows simple overlays of projected image and space behind	Image quality not as good as with cotton, gets dirty quickly and is difficult to clean while mounted	
Beads – Plastic or Glass	Beads or small flat pieces of plastic arranged in a curtain.	Front and back projection possible. Gain is low so control over lighting condition is required.	Unclear image on beads Image on plastic sheets dependent on size and gaps of those sheets. Light transmission is medium to high.	Fully traversable	Flat, corners can be rounded of. Can be curved in two dimensions (cylinder segment). Cannot be curved in three dimensions.	Wipe.  Might need a lot of looking after. Separate elements might tangle, most likely not appropriate for public use, for example.	Any useful size possible	Dependent on size of beads or plastic elements	Info not available.	Time consuming process of assembling beads on lines.	Home stores.	Traversability. Tactile quality. Interesting image quality.	State of transparency fixed. Low image quality.	Beads – Plastic or Glass
Line – Nylon or similar	Arrangement of fishing line material suspended in frame, possibly coated to improve image quality.	Not tested yet	Not tested yet	Fully traversable	Flat, corners can be rounded of. Can be curved in two dimensions (cylinder segment). Cannot be curved in three dimensions.	Difficult to judge, fibres might have to be replaced, which would be difficult, fibres will attract dust  Separate fibres might come off, separate fibres might tangle	Any useful size possible	Will depend on how many layers are necessary for good image	The components are cheap (essentially fishing rod), making it would be very time consuming.	Fix a series of lines to horizontal frame.	Angling stores.  Cinemas used line to create curved screens.	Traversability. Tactile quality.	State of transparency fixed. High cost of production ? Maintenance.	Fibres – Plastic or glass
Water spray	Fine water spray created by pumping water through downward facing insecticide nozzles.	Back projection required. Tight control over lighting conditions, not suitable for daylight applications, Water basin and pump system.	Very 'special' image quality. Low contrast. Low resolution.	Fully Traversable.	Volume of water spray, cones starting from the nozzle, thin at the top and wider at the bottom,  Curvature in two dimensions possible (cylinder segment).	Maintain pipe system	Typically 3m height and 3m width. Width can be extended	Not relevant	?	Assemble a series of insecticide nozzles along a water pipe that is suspended horizontally over a basin. Collect the water and pump round.	Plumbing supplies.  Screen for 'Desert Rain'	Traversability. Very special image quality. Sound it produces.	Wetness. Complicated and inflexible set-up (might be possible to reduce that), Image quality not suitable for every purpose. Only usable in dark.	Water spray
Smoke / Fog / Haze	Fog generated with an industry standard fog/smoke/haze machine is channelled down between two streams of air, possibly mechanism to collect it at the bottom.	Not tested yet. Good ventilation. Low air movement.	Not tested yet	Fully Traversable.	Volume of fog, falling down in a rectangular shape.  Curvature in two dimensions possible (cylinder segment).	Maintain fog system	?	Very, very light indeed	?	A pipe with the appropriate openings is suspended horizontally, experimentation for exact details, company that supports Tabaluga musical will know the details	Lighting and effect manufacturers.  Tabaluga musical	Traversability	Complicated and inflexible set-up, potentially hazardous (toxic? Cold temperature in the case of liquid nitrogen)	Smoke/Fog/Haze