Low Density Foams Used in High Energy Laser Experiments

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Wigen Nazarov,

University of St. Andrews,

School of Chemistry, St Andrews.

Outline...

- Quick overview of foams used in laser targets
  - Emphasis on to photo-initiated acrylates
- Concentrating on the difficulties and problems associated with in-situ polymerisation of acrylates
- Discussions and Questions

Foam used in targets and their Properties

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Name	Composition	Strength/ Machining	Photo/Thermal/ chemical initiation	Pore Size	Density Range mg/cc	Limitations/ Advantage
TPX foams Poly (4-methyl-1-pentene)	Carbon Hydrogen	Strong foams Can be machined	Thermal	3 - 15 micrometers	3 - 350	Tends to produce large pores CH composition
Vinyl Based (Styrene type monomer)	Carbon, Hydrogen	Strong foams at lower densities	Thermal,	1 - 10 micrometers	10 - 850	Pore distribution & Size Can be machined CH composition
HIPE polystyrene	Carbon, Hydrogen	Not very strong at lower densities high densities machinable	Thermal	3 - 15 micrometers	40 - 700	Shrinkage at low densities Strong.
Resorcinol-formaldehyde (RF) foams	Carbon, Hydrogen & oxygen	Strong foams *Machinable IF carbonised*	Chemical - polycondensation	Nanometers	20 - 850	Lower densities fragile Can be carbonised & machined
Acrylic Foams	Carbon, Hydrogen Oxygen	Free standing foams not strong below 100 mg/cc	Photo-initiated (also can be thermally initiated)	0.1 - 1 micrometers	5 - 800 (3 mg/cc *possible - depends on target*)	Not machinable, oxygen Adaptable foam
Aerogels (silica)	(Silicone) Oxygen	Strong foams/ machining at certain densities	Chemical	Nanometres	Very low density (1 mg/cc - 800)	Oxygen Very Low density possible

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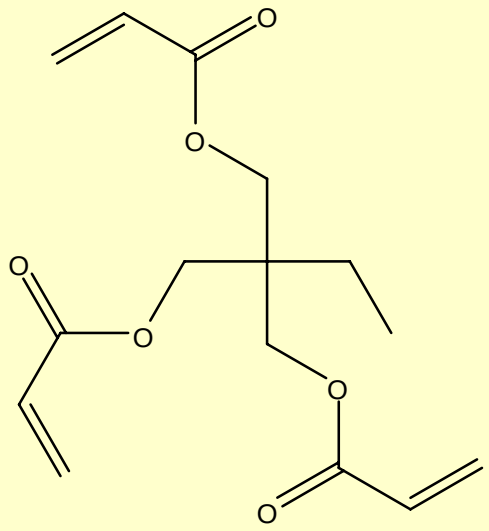
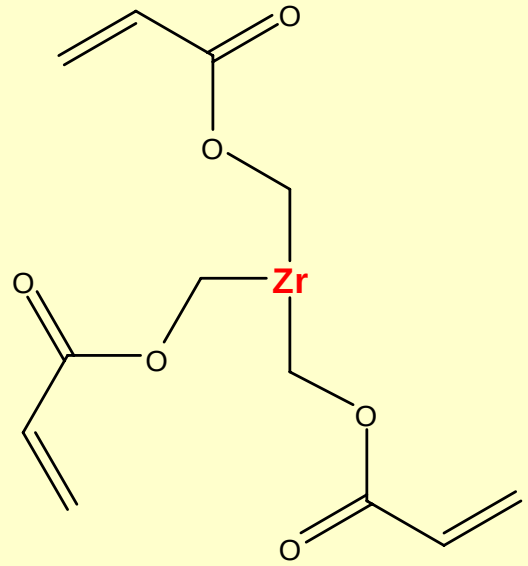
Chemical Formula: $C_{15}H_{20}O_6$
Molecular Weight: 296.32
Elemental Analysis: C 60.80; H 6.80; O 32.40



TriMethylolPropane TriAcrylate
TMPTA

Chemical Formula: $C_{12}H_{15}O_6Zr$
Molecular Weight: 346.47
Elemental Analysis: C 41.60; H 4.36; O 27.71; Zr 26.33



tris(acryloyloxymethyl)zirconium

Common Questions..

What is the lowest density possible foam-filled target?

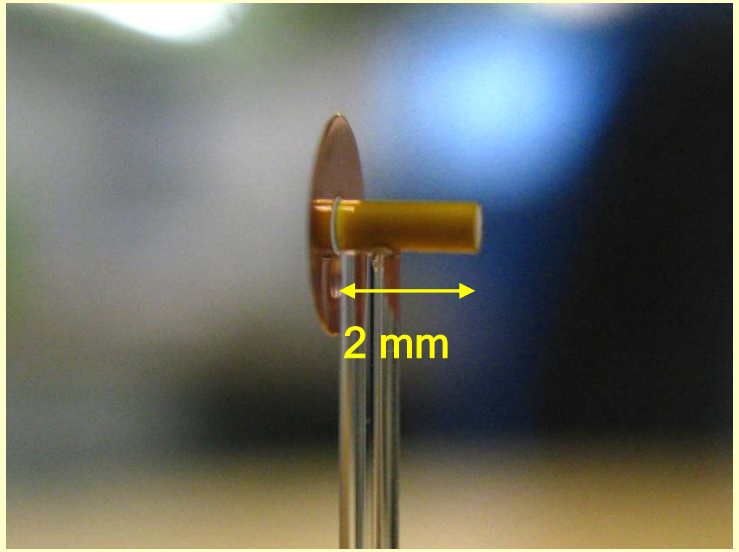
How quickly can it be made?

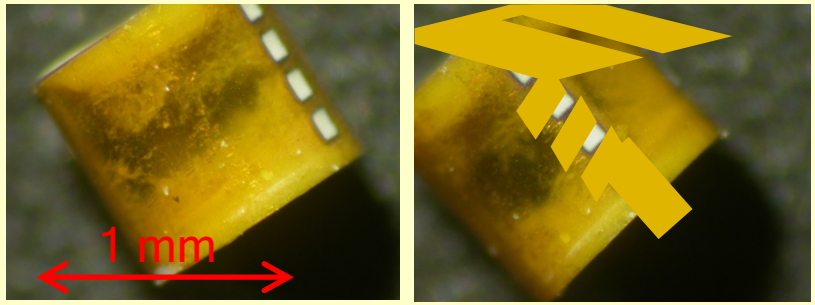
Answer Depends on many factors,

Relevant to acrylate in-situ polymerisation

- How big is the volume of the target to be foam filled –
- What is the aspect ratio.

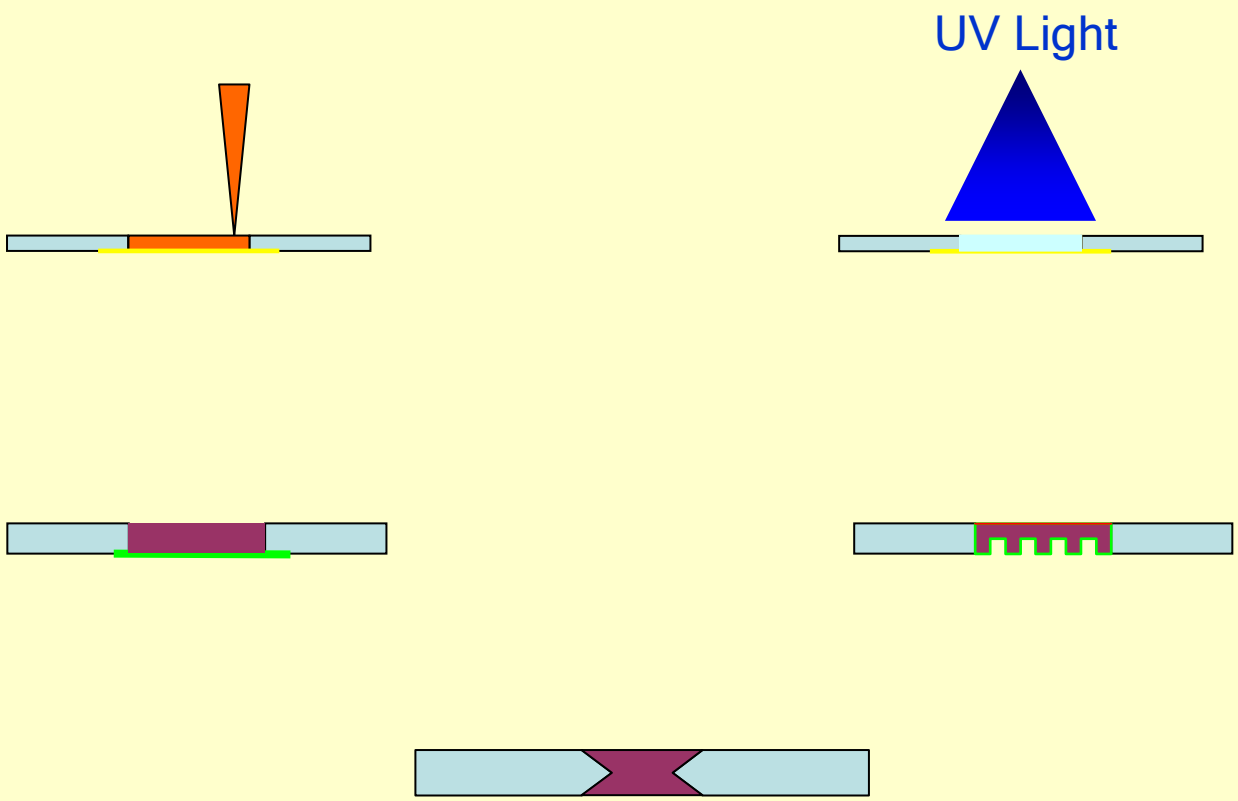
- Is it transparent to UV?
- Is it a simple foam fill (pure foams with no high Z loading) or high Z doping (Cl, Br, metal particles etc.)



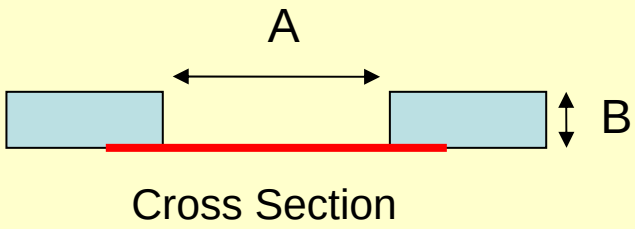


Cylinders Laser machined by Jonathan Griffiths, AWE.

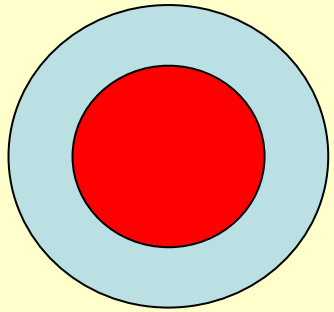
Thin Profile Foam-filled (washer) - In-situ Polymerisation



Foam-filled washer



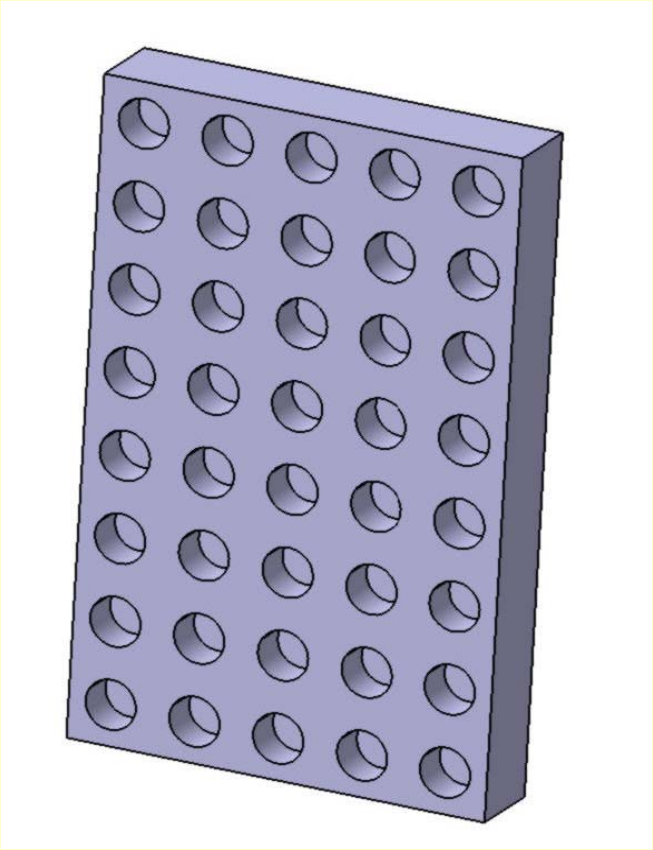
Cross Section



Top View

- It is possible to foam fill the hole with very low density foam – flat and level to the surface.
- How low density depends on diameter (A) and thickness (B):
  the smaller the A & B is, the lower the density.
- It is possible to fill as low as 3 mg/cc for B = 50 µm & A = 200 µm depending on thickness of film, high Z loading etc.

Some unforeseen problems:
Thermal Expansion Foam-filled aluminium plate

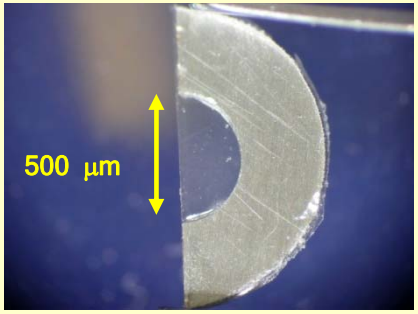


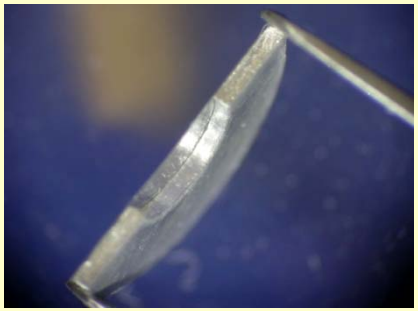
Large plates, 15 mm X 25 mm and 6 mm thick

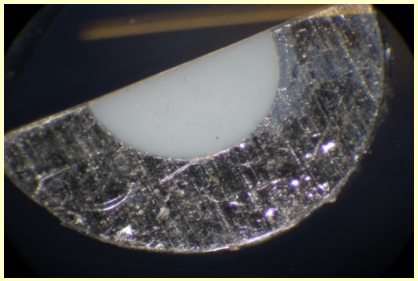
Should be very easy to make, but the thermal expansion created new problems.

Reduced the size of plate to 10mm X 20 mm and 4 mm thickness

Simple foam-fill (half-moon) & Traverse Density Targets



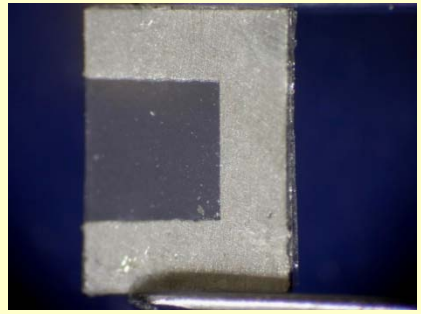


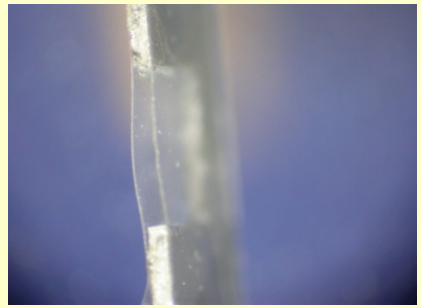


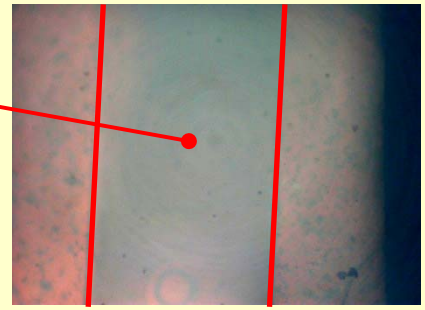
Simple foam fill –
Half moon washers on the left

More difficult - Involves more steps in production

Traverse density targets have a layer of bromine doped foam in the middle –







Bromine doped foam

Incorporation of particulate metals into foams

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- Metals can be incorporated into foams. However, depending on the complexity of the targets this could again take time to do. Metal powders tends to settle in the target, therefore the geometry of the target important.

- Pure Metals and insoluble oxides have been incorporated targets by "suspending" them in the reaction solution. The following has been incorporated in foams:

  - <u>Pure elements</u>
    - Au – (1 to 10 µm diameter)
    - Ag – (1 µm, 3 µm, and 5 µm diameter)
    - W – (0.6µm to 1.0 µm diameter) up to 90%
    - Cu - 800Å to few microns

  - <u>Oxide Powders</u>
    - Elements Such as Sc, Bi, Si, Al, been incorporated in the foam

Acknowledgments

- The research carried out at St Andrews university is supported by AWE

Discussion Topics

- Area of foam interest for different groups
- Future foams for laser targets
  - Metal foams – and special problems associated with this particular foam.
- Large quantity (mass production) of foams