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INNOVATIONS IN 3D PRINTING MATERIALS FOR ADDITIVE MANUFACTURING

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COLORADO PHOTOPOLYMER SOLUTIONS CPS

- **Introduction**
- **Prototyping**
- **Targeted Performance Properties**
  - Improve the dimensional stability
  - Uniform properties
  - Targeted properties for Additive Manufacturing
  - Importance of the Printer/software

Type	Technology Example	Typical Materials
Extrusion	Fused filament fabrication (FFF) (Fused deposition modeling (FDM))	Thermoplastic, clay, edible materials
Powders	Selective laser sintering (SLS)	Plastics, metals, ceramics
Lamination	Laminated object manufacturing (LOM)	Paper, metal foil, plastic film
UV Cured	Stereolithography (SLA)	Methacrylates, Acrylates

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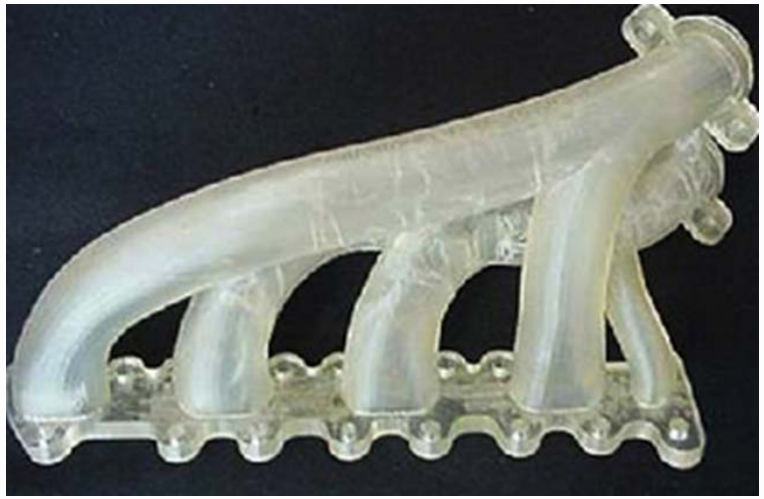
Advantages of 3D Printing with UV

- Highest level of build resolution
- Smooth surfaces without requiring finishing
- Typically stronger in the z directions from chemical bonding between layers
- Wide range of materials available for the resins
- Faster builds when using more powerful lasers/lights
- Able to make clear objects
- Ability to make moving parts
- Easy to finish or paint



Disadvantages of 3D Printing with UV

- Performance of the cured object is limited by the materials used in the formulation
- Cost of formulated resins
- Machine costs can be higher than other 3D Printing technologies
- In some systems, the cured resin can absorb moisture thus changing the properties such as stiffness.
- Requires proper handling of the liquid formulated resins

Prototyping

- Earliest applications for 3D printing
- Used to create static 3D Objects
- Models, patterns, prototypes, etc.
- Formulation strategies well known
- Improvements are now incremental

Prototyping Resins for Additive Manufacturing

Additive Manufacturing (AM) – Use of 3D printing for mass production.
AM requires targeted performance properties

Limitations of Prototype Resins

- Hard
- Brittle
- Non-flexible
- Cost

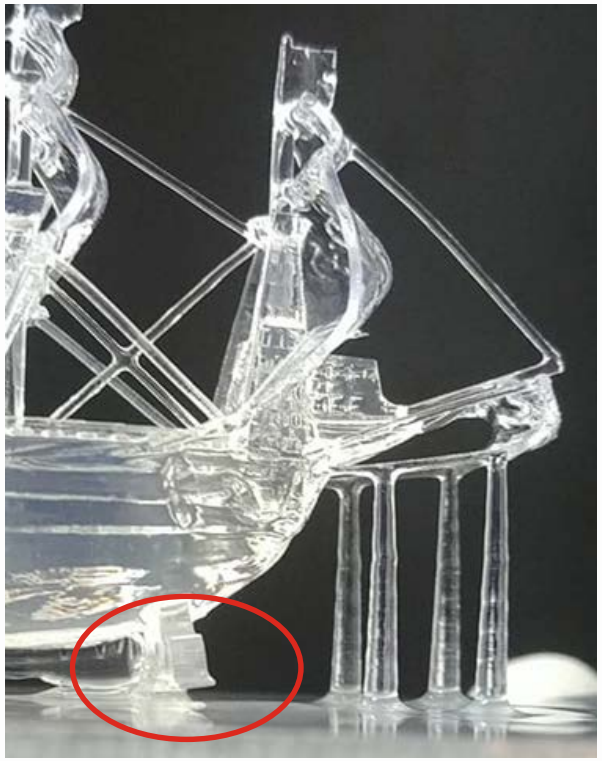
Targeted Performance Properties

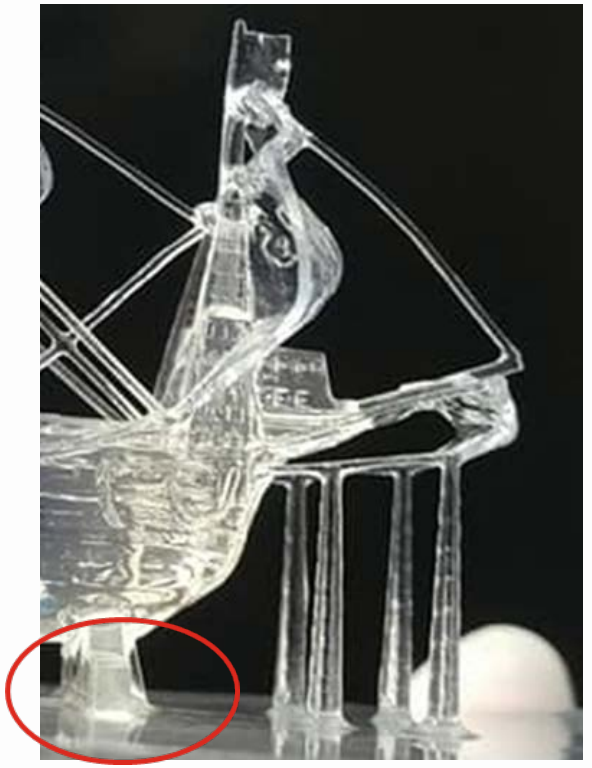
Achieving desired AM properties through formulation

- Needs to be dimensionally accurate
- Uniform properties – Incomplete Cure
- Ability to mimic existing plastics
- Printer hardware/software

Dimensional Stability

warping and shape deformation usually due to shrinkage stress





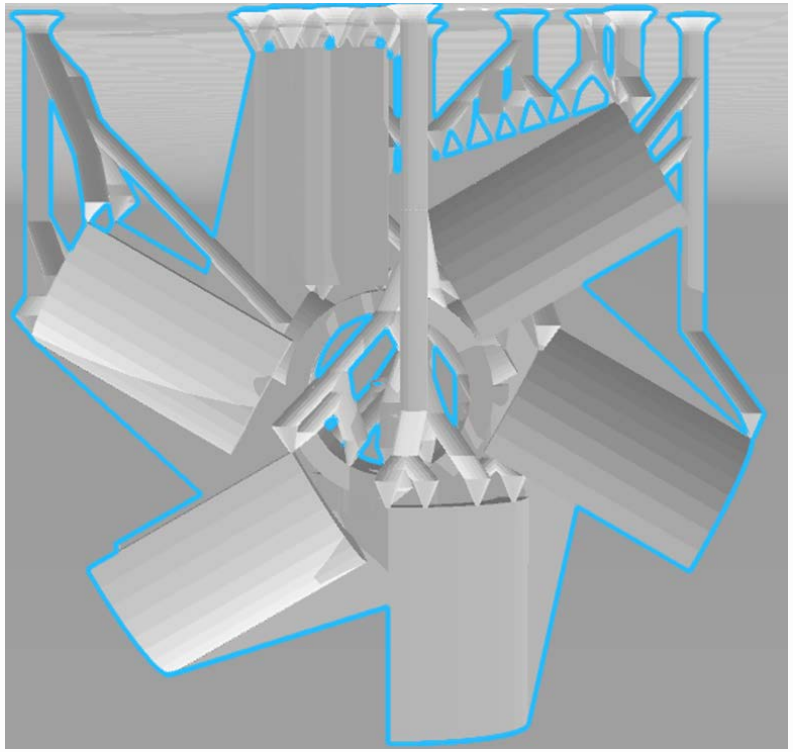
Routes to improve dimensional stability

- **Thiol**
  - Uncured Resin Stability issues. Unusable on PDMS windows.
- **Cationic**
  - Lacks good photoinitiators for 385-405 nm range
  - Smaller range of usable starting materials
- **Increase molecular weight of formulation**
  - Leads to increase in viscosity.
  - Longer print times.
- **Modify object to reduce dimension changes.**
  - Challenging to find correct configuration.
  - Potentially not an option on some printers.

Thiol based Chemistry Approach

- Uncured Resin Stability
  - Custom additive packages for each 3D Printing formulation
- Interactions with the printer window
  - Commonly used PDMS windows will not work with Thiol based formulations
  - Requires other windows such as Teflon
- Understanding the critical nature and concentration of the Thiol components

Reference Formulation – No Thiol



Thiol Formulation

Control – No Thiol

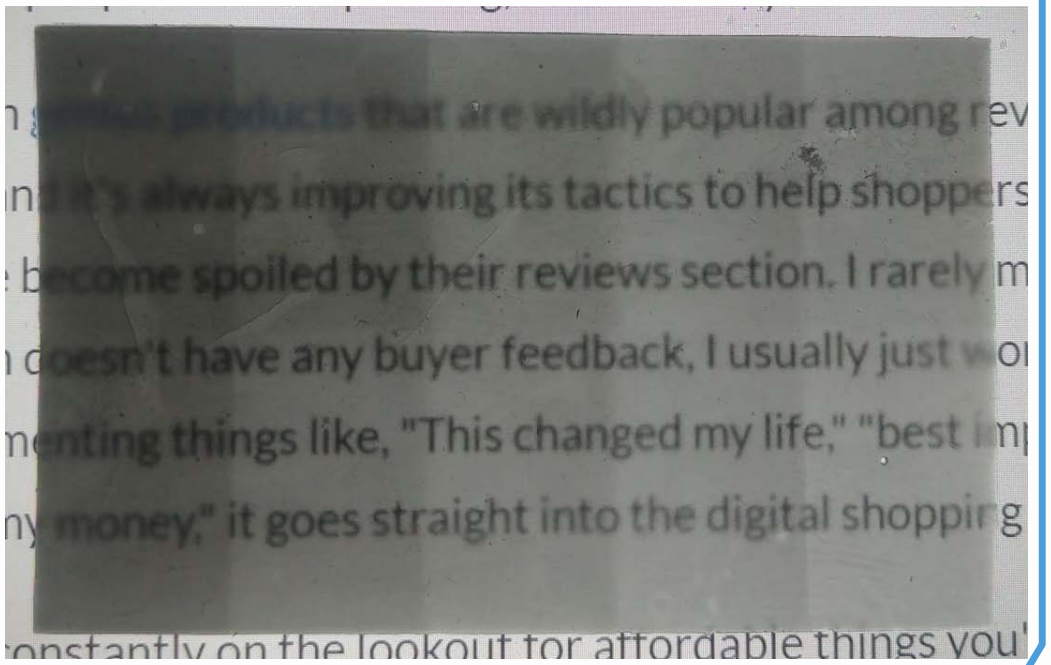
Thiol Containing Formulation

Properties Of Printed Materials

Type:	Acrylate	Acrylate + Thiol
Viscosity (cps)	160	200
Print Speed (mm/hr)	54	54 (non-optimized)
Strength (mPa)	25 (8)	48 (3)
Elongation (%)	2.1 (0.8)	6 (0.1)
% Curl	>4	3

Incomplete cure

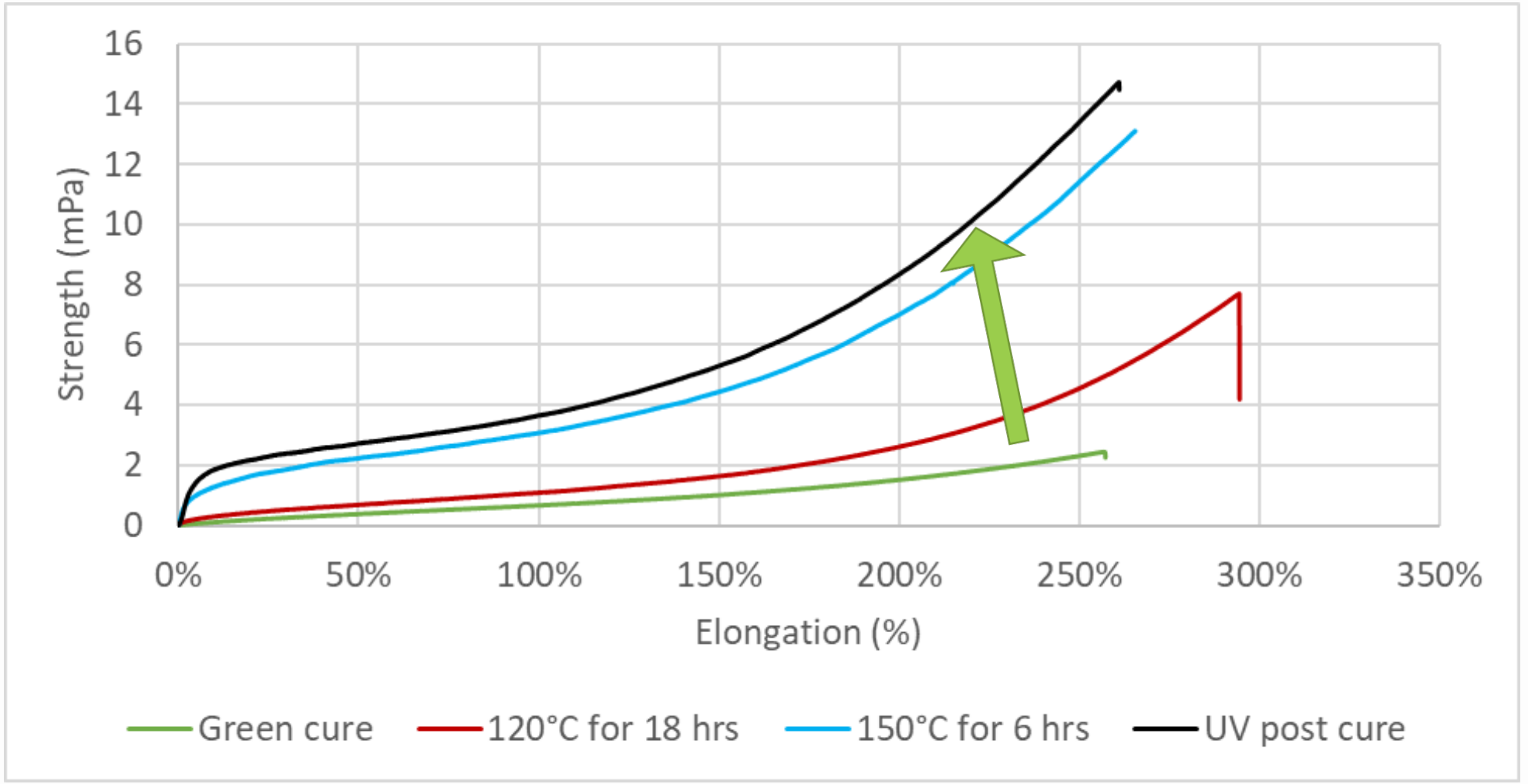
- Prints are initially in a “green” or under cured state
- Level of UV light is a function of depth in post cure
- UV blocker reduces cure depth
- This results in non-uniform properties



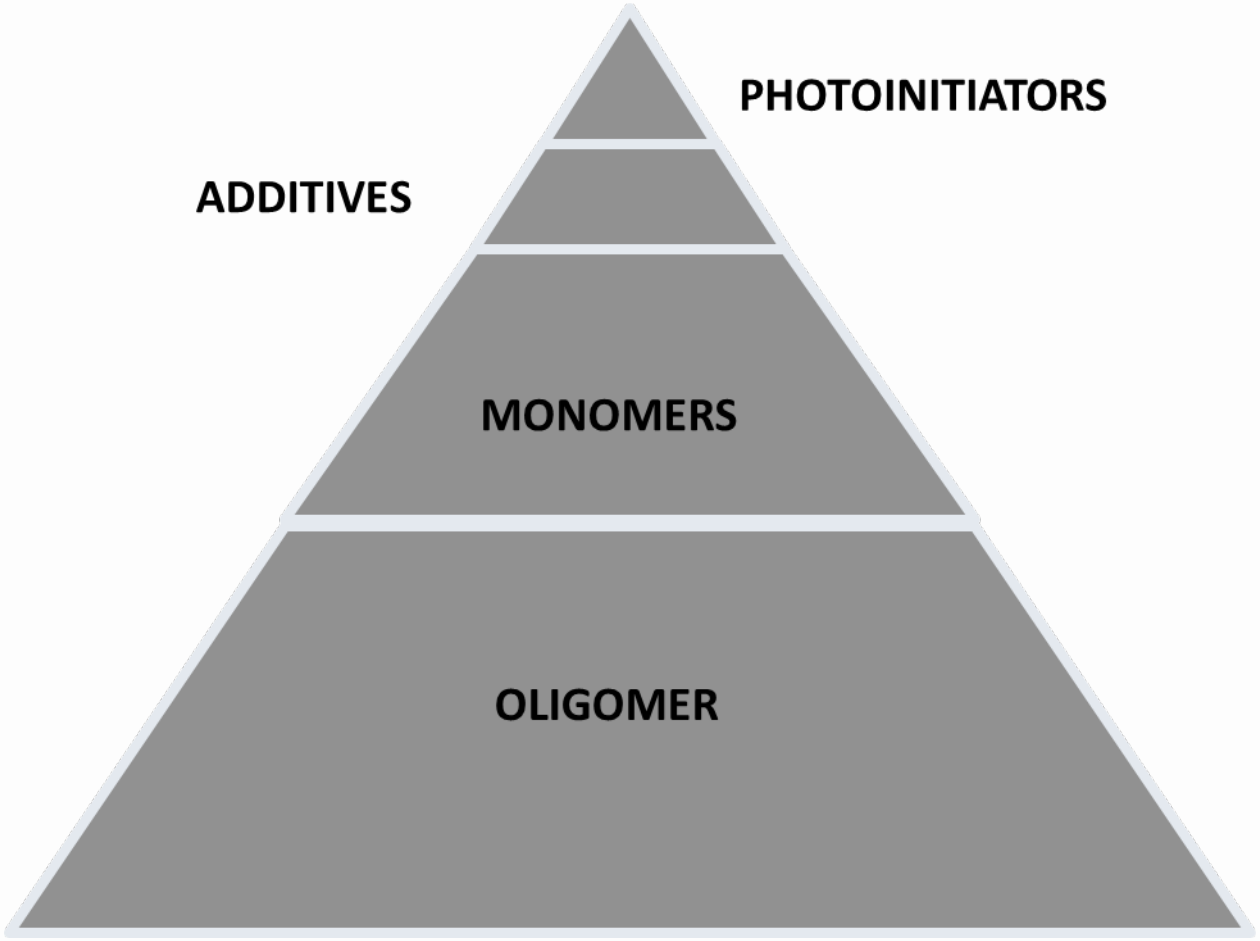
Hybrid Chemistry

- Hybrid Chemistry – combination of two or more different chemical reaction to achieve the designated properties.
- Options like cationic, moisture or isocyanate reactions may have other issues including poor prints, limited shelf life and difficulty achieving desired properties
- Thermal cure uses free radical chemistry
  - Allows the use of acrylates

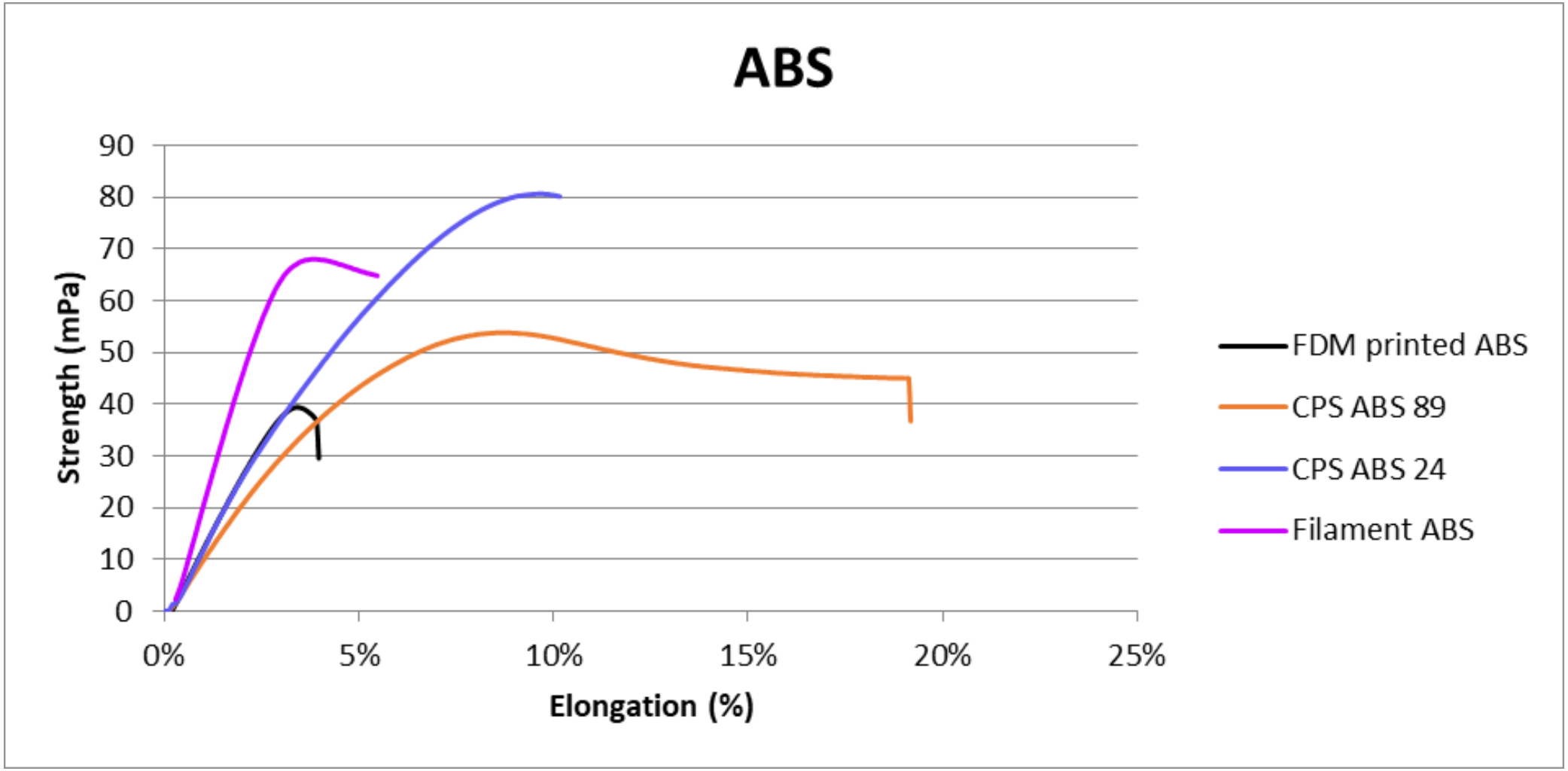
Material properties v cure conditions



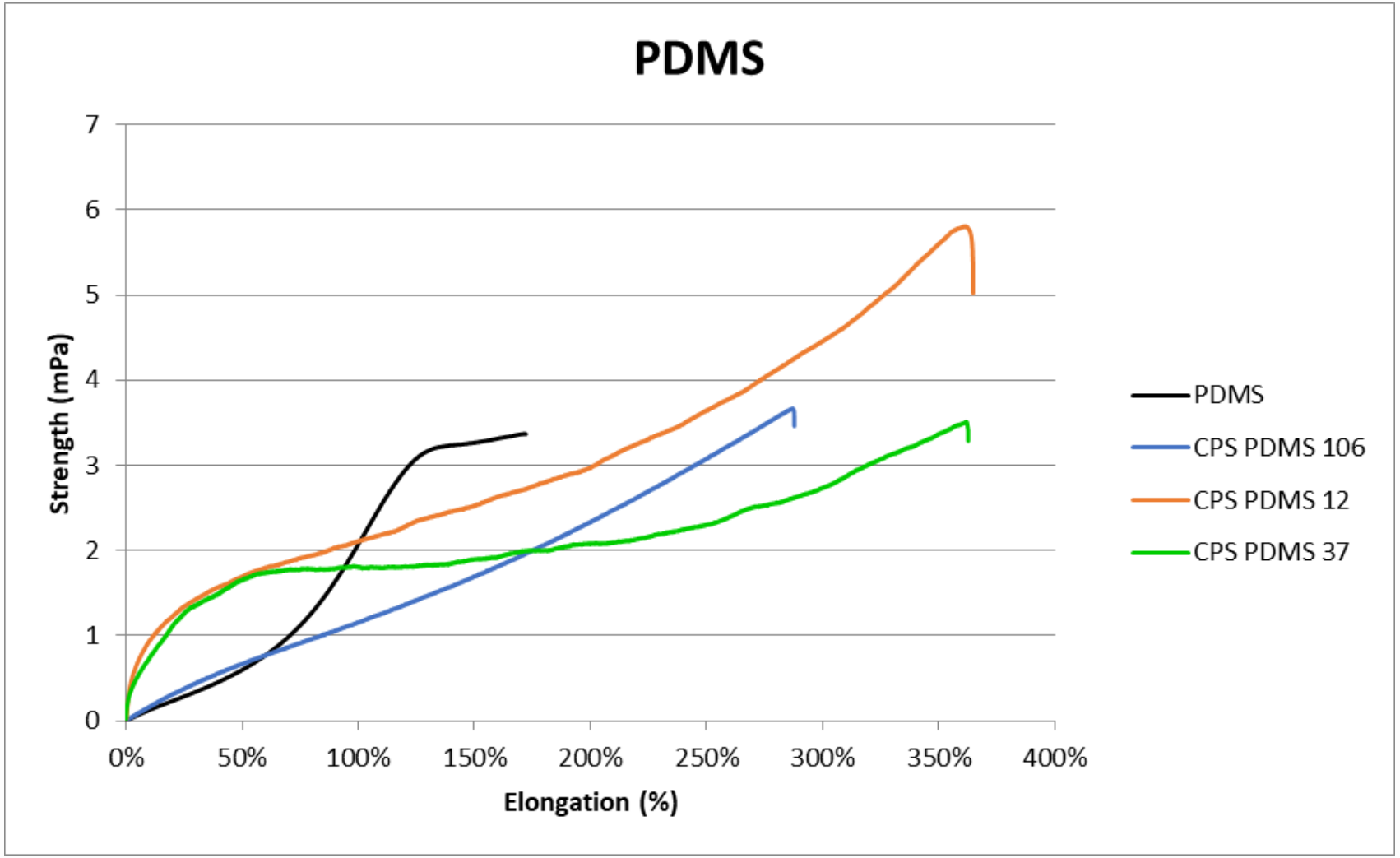
Ability to mimic existing plastics



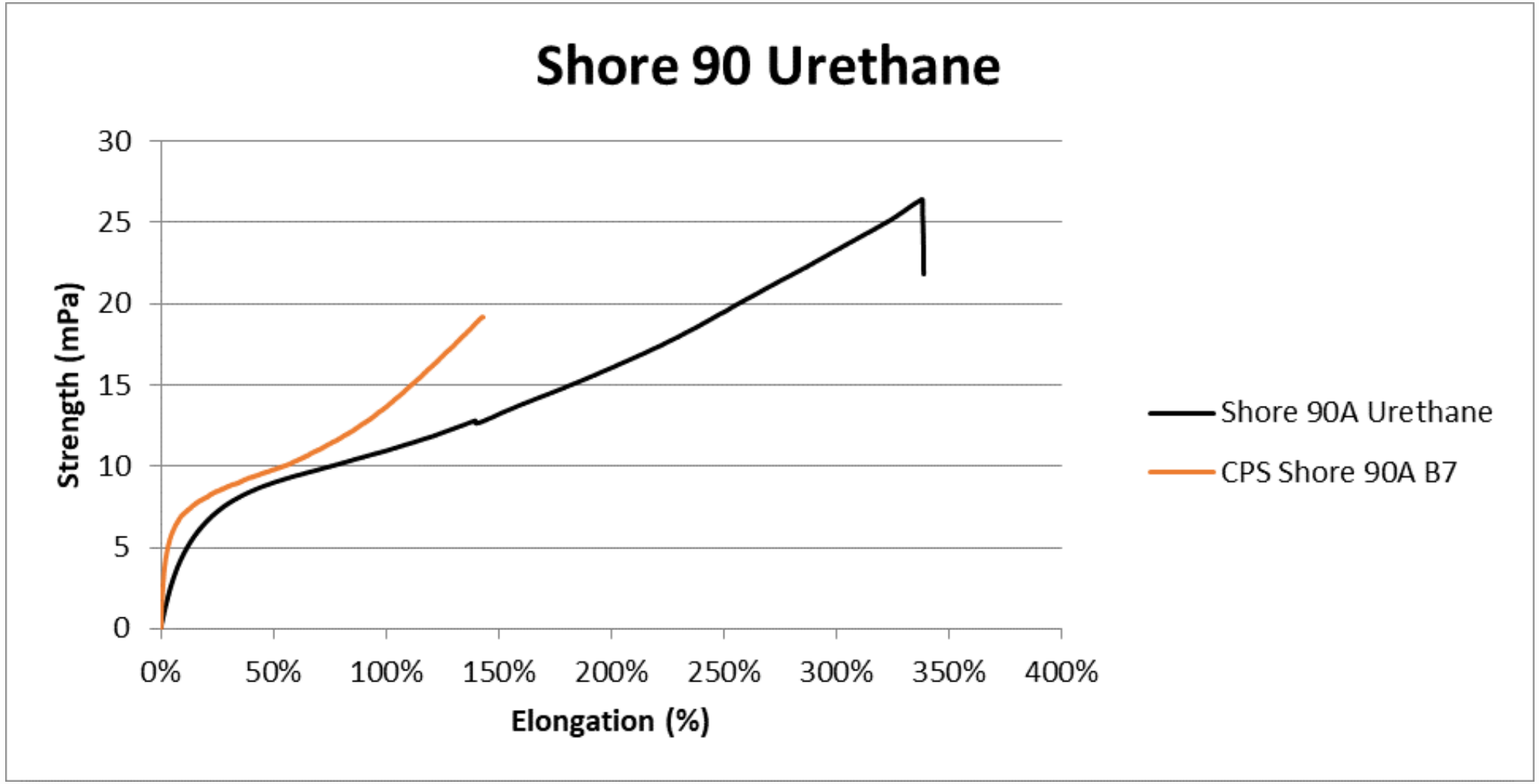
ABS Like Performance Properties



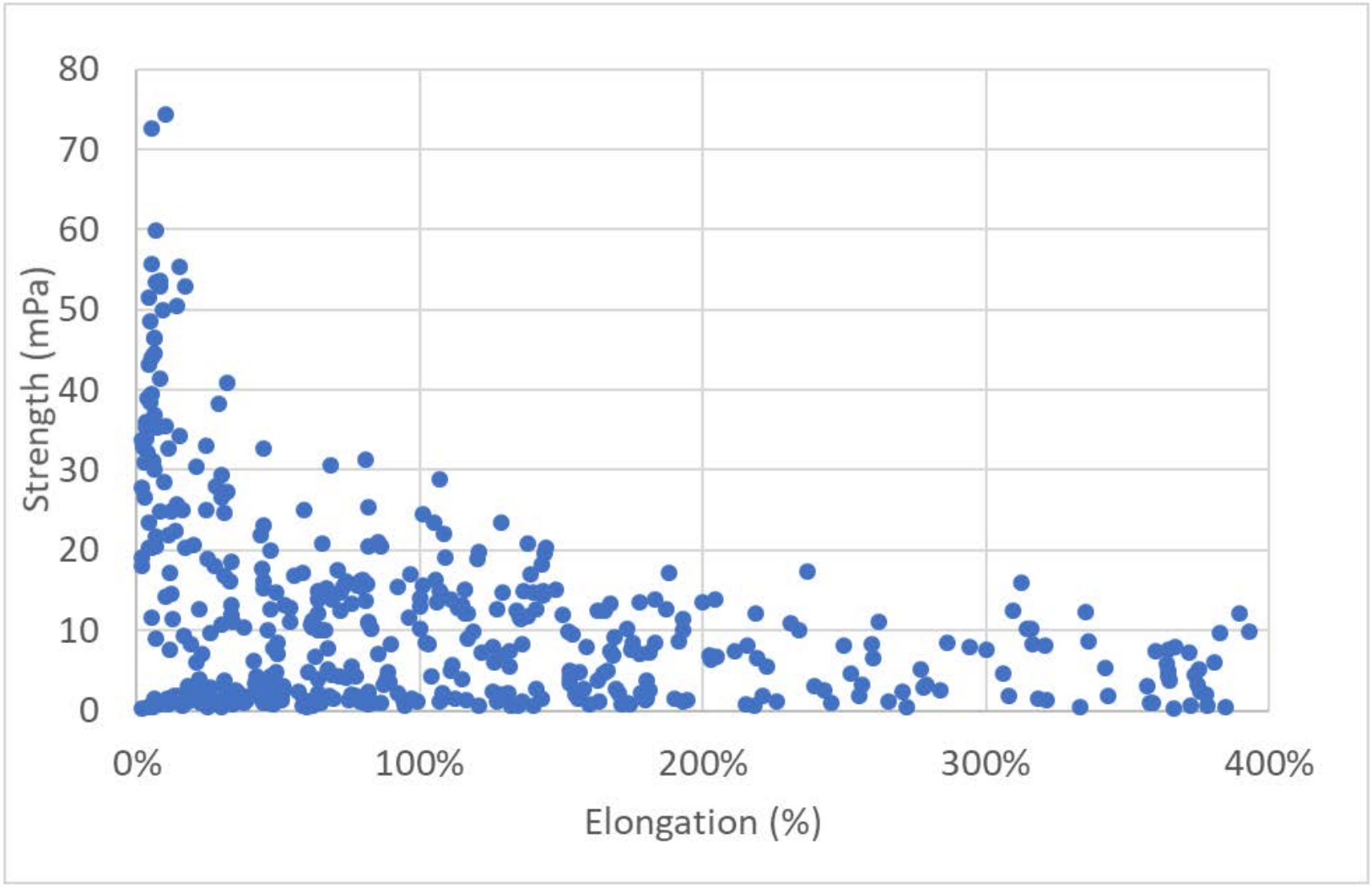
PDMS Like Performance Properties



Shore 90 Performance Properties



Targeted Performance Options

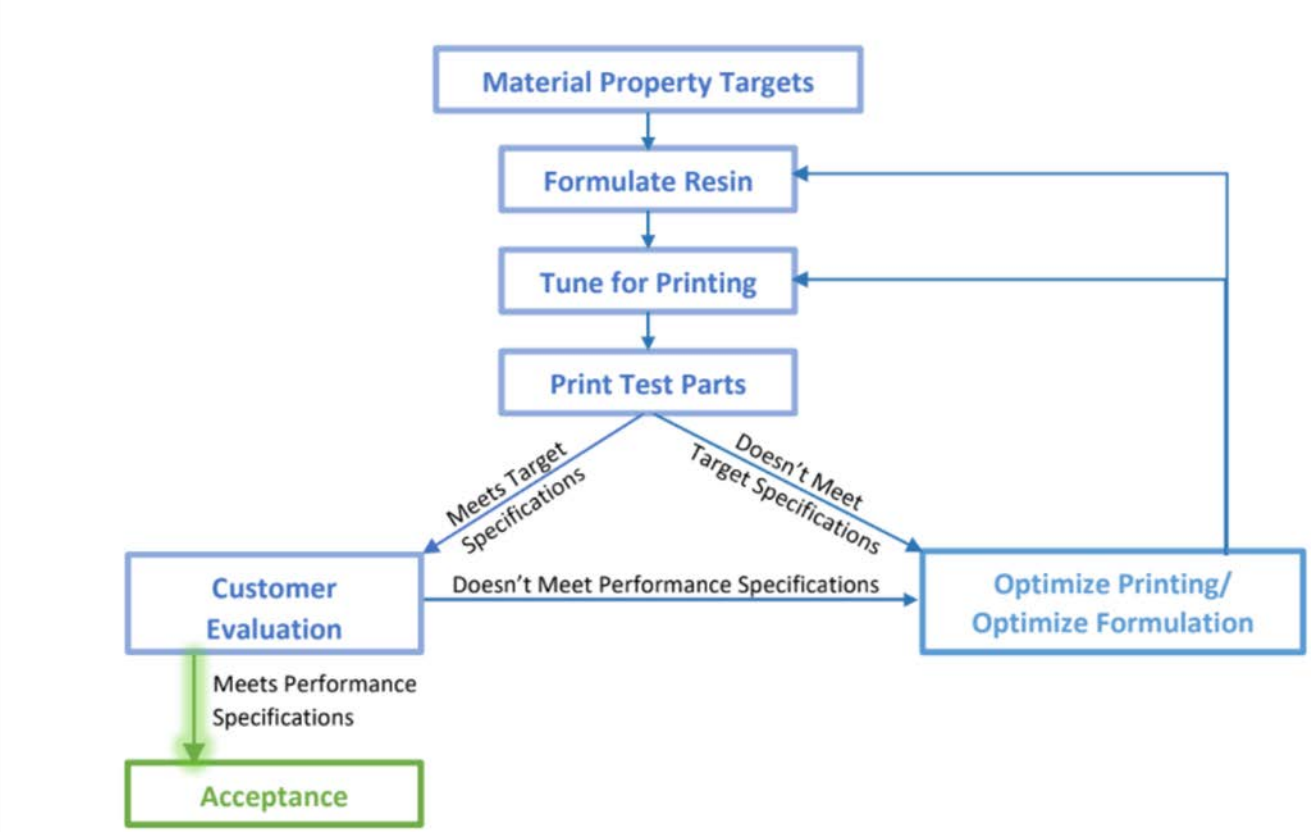


Origin printers speed material development

- Software controls light, energy, and rate of cure
- Sensors collect visual and temperature data
- Control + data = faster iteration
- Result: New material properties and applications

Additive Manufacturing material innovation

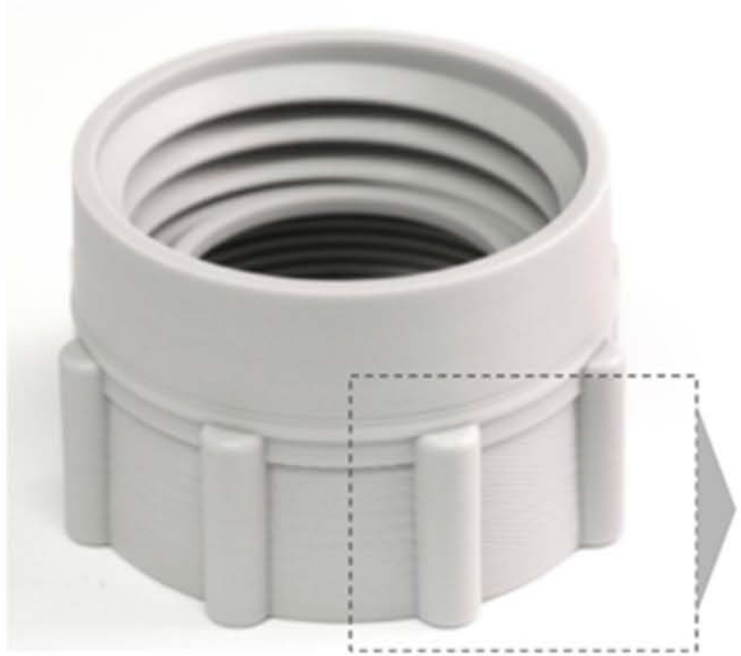
Origin’s data-rich feedback loop helps



Case Study for Additive Manufacturing

Ivaldi Group provides in-port parts on demand for maritime and offshore industries

Uses Origin to print ISO parts that get ships back into compliance and operation fast



Part: Screw connector
Dimensions: 51 x 51 x 34 mm
Print time: 52 min
Post processing time: 4 minute wash, 2 minute post cure
Feature resolution: 50 um

Results

- Faster resolution
- Lower cost
- Higher uptime

Conclusion

- Targeted Performance required dimensional accuracy
- Thiol Cure is a good route to dimensional accuracy
- Complete cure can be achieved using thermal cure/UV cure hybrid system
- Traditional plastic properties can be obtained through formulation
- The 3D printer is a key part of the success

Thank you

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