Polycarbonate Based Non-chemically Amplified Photoresists for Extreme Ultraviolet Lithography

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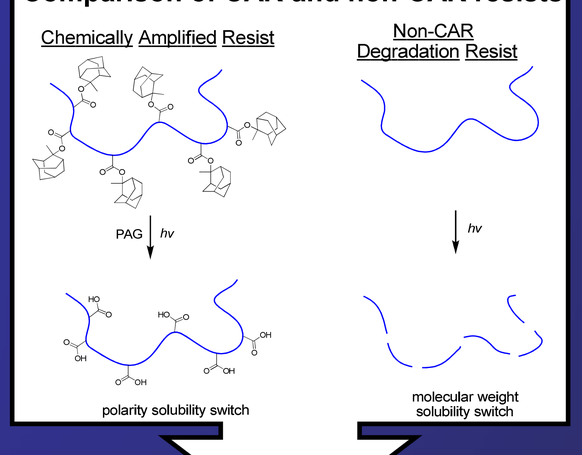
AIM - To determine if the Resolution-LER-Sensitivity (RLS) trade-off can be overcome by developing more sensitive non chemically amplified resists (non-CARs) and to gain an understanding of EUV induced chain scission which may also benefit CAR platforms.

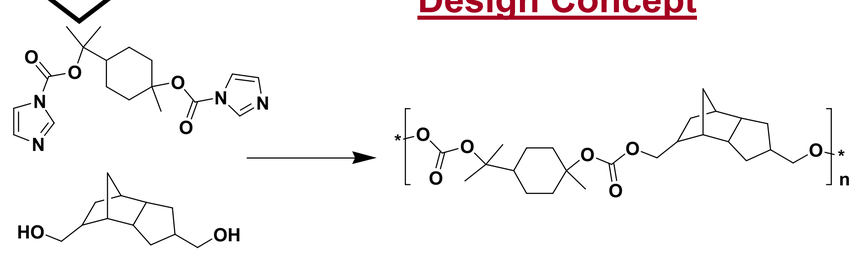
INTRODUCTION

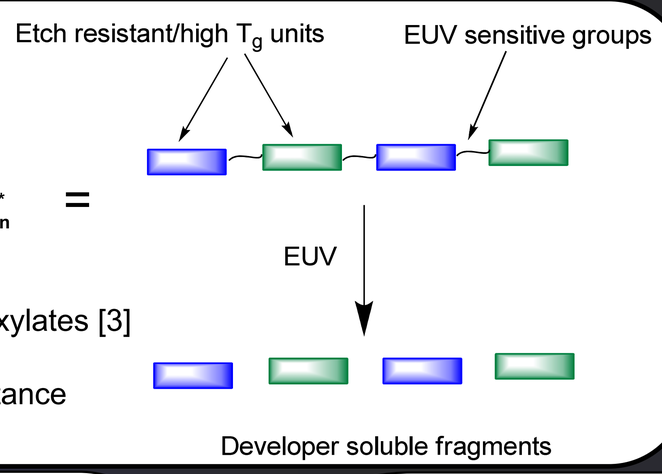
- The RLS trade-off limits the achievable LER for a given dose and half-pitch.
- For CARs a significant contributing factor to this trade-off is believed to be due to diffusion of photogenerated acids
- This has led to the resurgence in development of non-CARs, due to contrast mechanism not relying on diffusion.
- Current non-CARs, such as polymethylmethacrylate (PMMA) can be patterned to feature sizes as low as 22 nm with low LER, but lack the required sensitivity. [1]
- In part, this low sensitivity is due to chemical structure of PMMA.
- We have screened a range of chemical structures for their propensity to degrade at 13.5 nm / 92 eV and generated a predictive model that is able to screen structures *in silico*. [2]
- One target that was identified was substituted carbonates
- In this poster the synthesis and lithographic characterisation of a series of polycarbonate polymers is discussed

Comparison of CAR and non-CAR resists



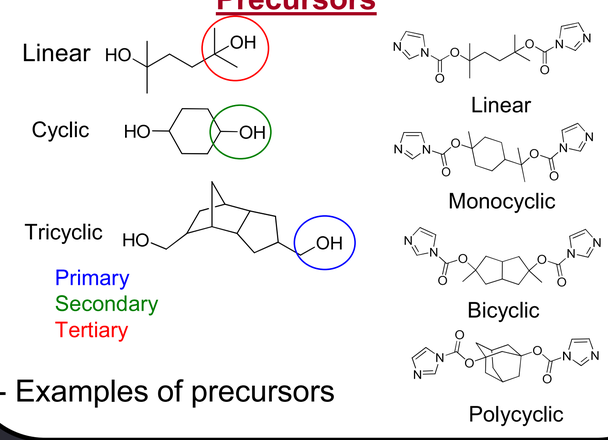
Design Concept





- Polymers prepared by condensation of diols and bis(imidazole)carboxylates [3]
- Substituted carbonate designed to be a hotspot
- Cyclic structures in backbone designed to increase T_g and etch resistance

Precursors



- Examples of precursors

Effect of Structure on Properties

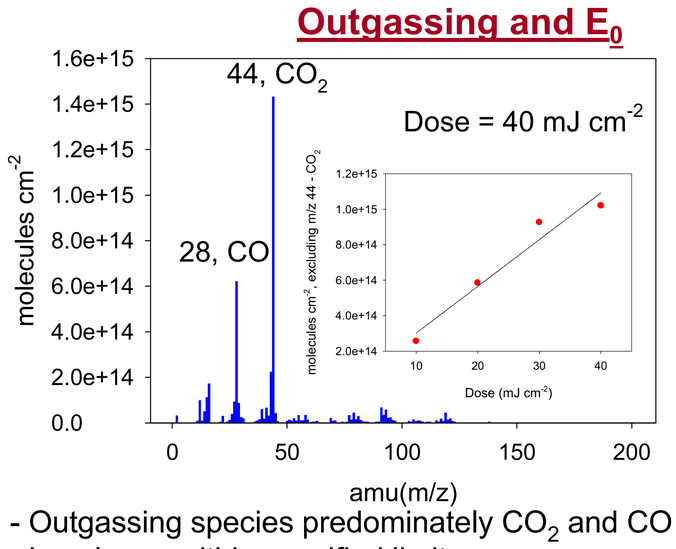
Polycarbonate	M_w:	PDI	T_g (°C)	Ohnishi Parameter
	10.3k	1.5	68.4	3.62
	5.2k	1.4	92	3.25
	13.6k	1.8	125	3.71
	11.0k	1.6	127	4.09
	34.2k	1.6	134	4.40
	4.2k	1.4	172	3.80

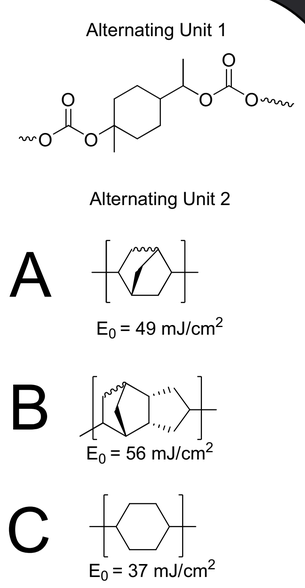
-Table shows examples of polymers synthesised and results of characterisation

-By varying structure T_g can be tuned from ca. 70 – 170 °C

- Ohnishi parameters for many of the structures that contain alicyclic groups are comparable to those reported for ArF resists
  - Expect etch resistance to be similar to ArF resists
  - Needs experimental verification

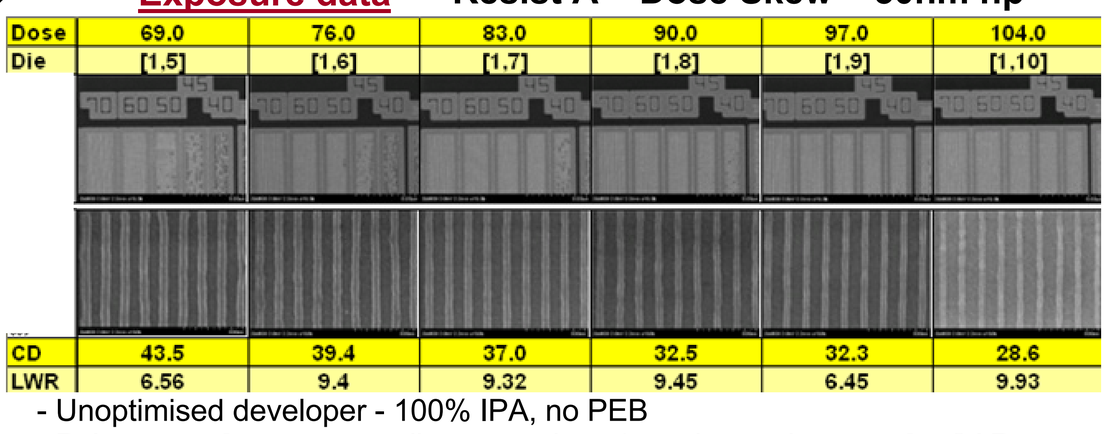
Outgassing and E_0





- Outgassing species predominately CO_2 and CO
- Levels are within specified limits
- E_0 for selected series is dependent on hydrophobicity
- important to consider outgassing levels and species in design of polymers

Exposure data — Resist A – Dose Skew – 50nm hp

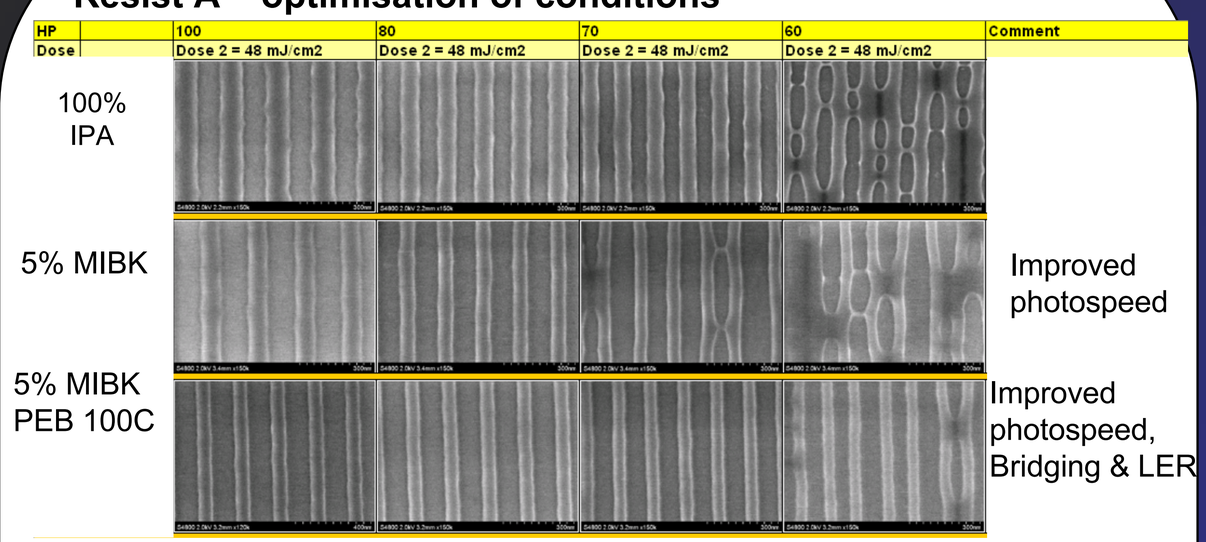


Dose	69.0	76.0	83.0	90.0	97.0	104.0
Die	[1,5]	[1,6]	[1,7]	[1,8]	[1,9]	[1,10]
CD	43.5	39.4	37.0	32.5	32.3	28.6
LWR	6.56	9.4	9.32	9.45	6.45	9.93

- Unoptimised developer - 100% IPA, no PEB
- Polymer performs very well on over-dose (not always the case for CAR platforms), allowing patterning down to 29 nm at 50nm hp (mask res 26 nm)
- Images appear smooth, but LWR measures higher than expected
  - possibly due to low Mwt, or poor interaction with developer
- 50 hp analysis gives E_{50} of ~51 mJ cm^{-2}

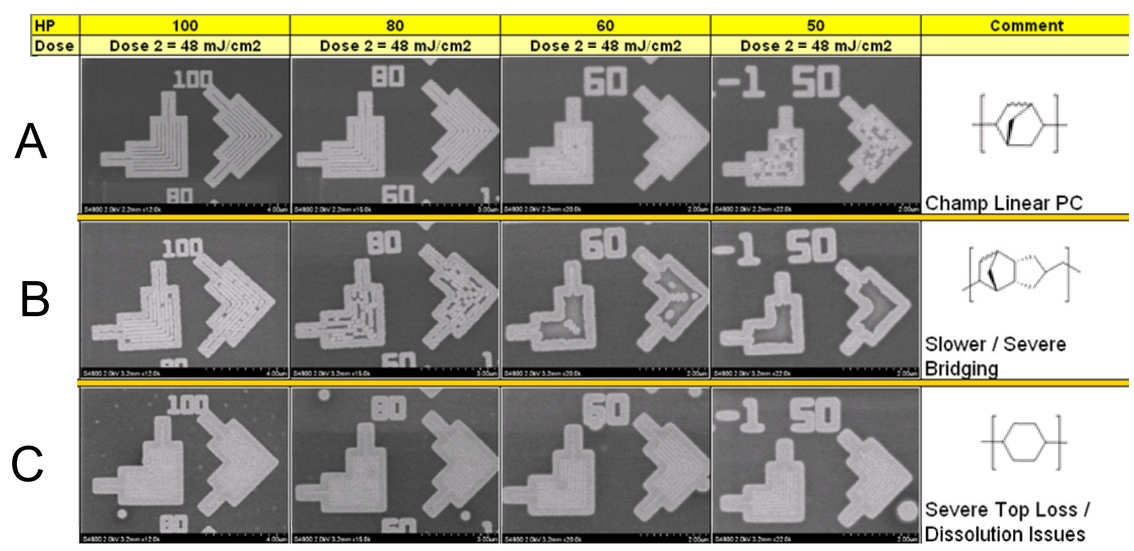
Exposure data continued

Resist A – optimisation of conditions



- With optimised developer and PEB ultimate 1:1 resolution = 60nm hp
- Primary failure mode is microbridging
  => require further understanding of resist developer interactions

Effect of Structure



- Resist A = Balanced bridging + dissolution,
- Resist B = Severe bridging limits resolution,
- Resist C = Severe top loss / fast dissolution
- Appears to correlate well with hydrophobicity of alternating unit 2
  -i.e. structure is effecting interaction of resist with developer

Summary/Conclusions

- Synthesized a series of tertiary polycarbonates with ability to control T_g
- Outgassing levels are within specified limits
- Patterning down to cd of 29 nm demonstrated at 50 nm hp
- Structure of polymer affects interaction with developer

References

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