A chip-scale imprinter with integrated optical interference for calibrating models of NIL resists and resist-stamp boundary conditions

23 October 2013

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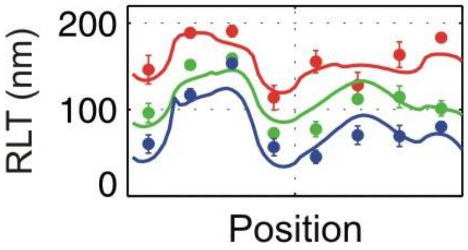
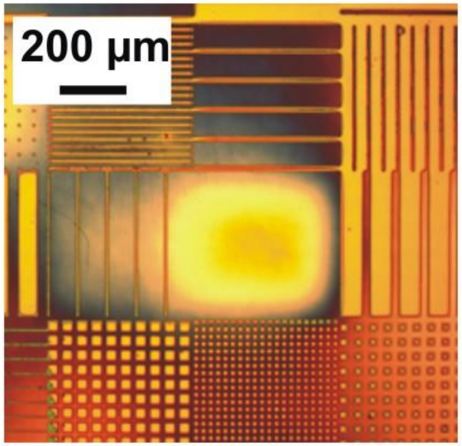
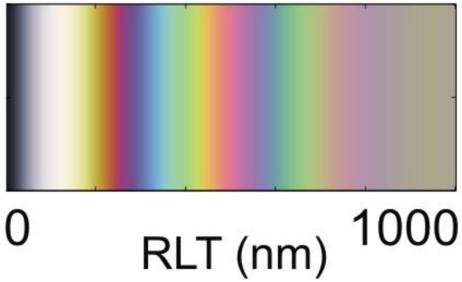
Outline

- **Resist model calibration by fitting simulations to imprint experiments**
- **The need for new tools to characterise resist–stamp material combinations**
- **Real-time optical monitoring of imprint**
- **Potential RLT sensing enhancements:**
  - Plasmonic
  - Ellipsometric
- **Potential applications of real-time optical imprint monitoring:**
  - Endpoint detection
  - Process control
  - Defect detection (including non-fill)



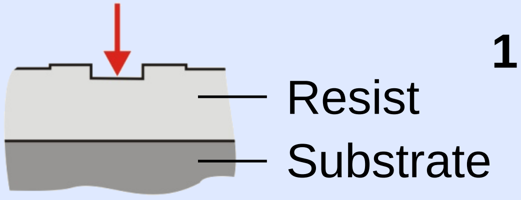




Our existing simulation technique quickly finds RLT and cavity-filling distributions

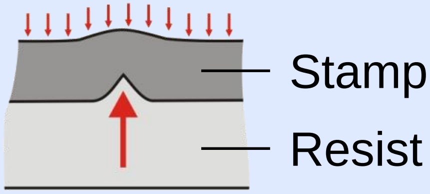
Resist surface's impulse response

1



Stamp's load response (bending, indentation)

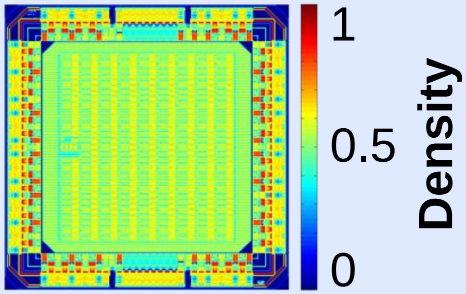
2



3

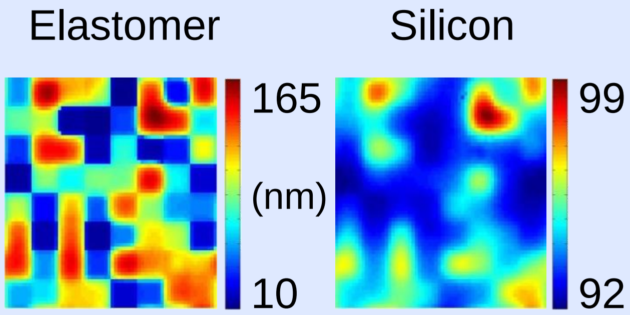
Pattern abstraction

4

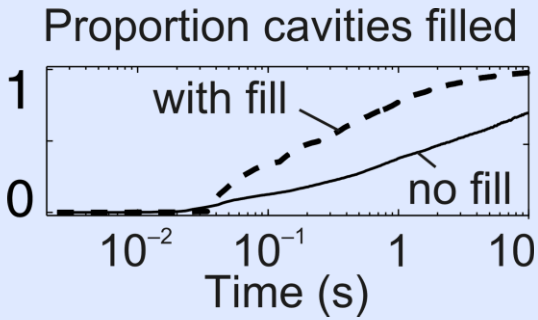


Example questions:

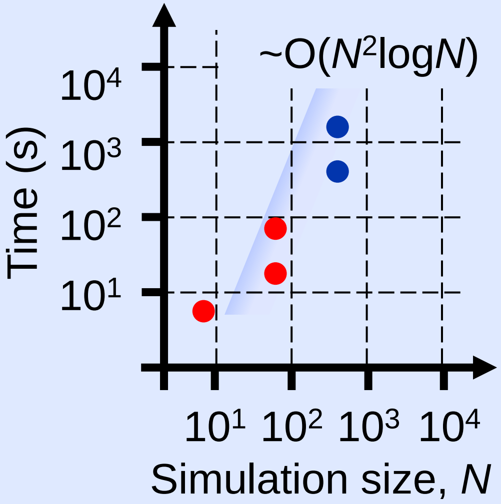
Does changing stamp material affect residual layer uniformity? [1,2]

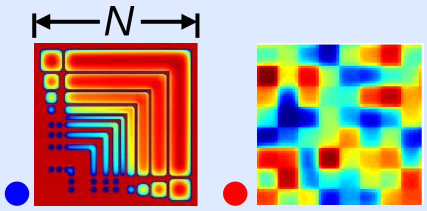


Can 'dummy fill' accelerate stamp cavity filling? [3]



Simulations need to be highly scalable



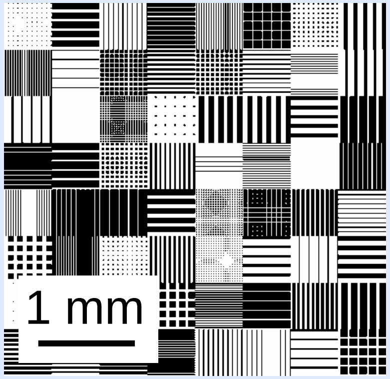


- At least 10^3 times faster than FEM
- Can trade off spatial resolution and speed

[1] Taylor *NNT* 2009, 2011; [2] Taylor *SPIE* 7641 2010; [3] Boning *et al.* *NNT* 2010

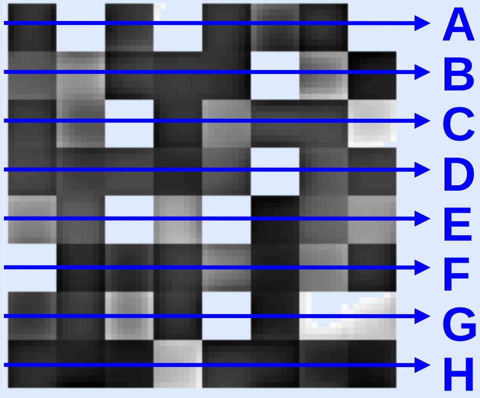
The NIL simulation technique has been experimentally validated

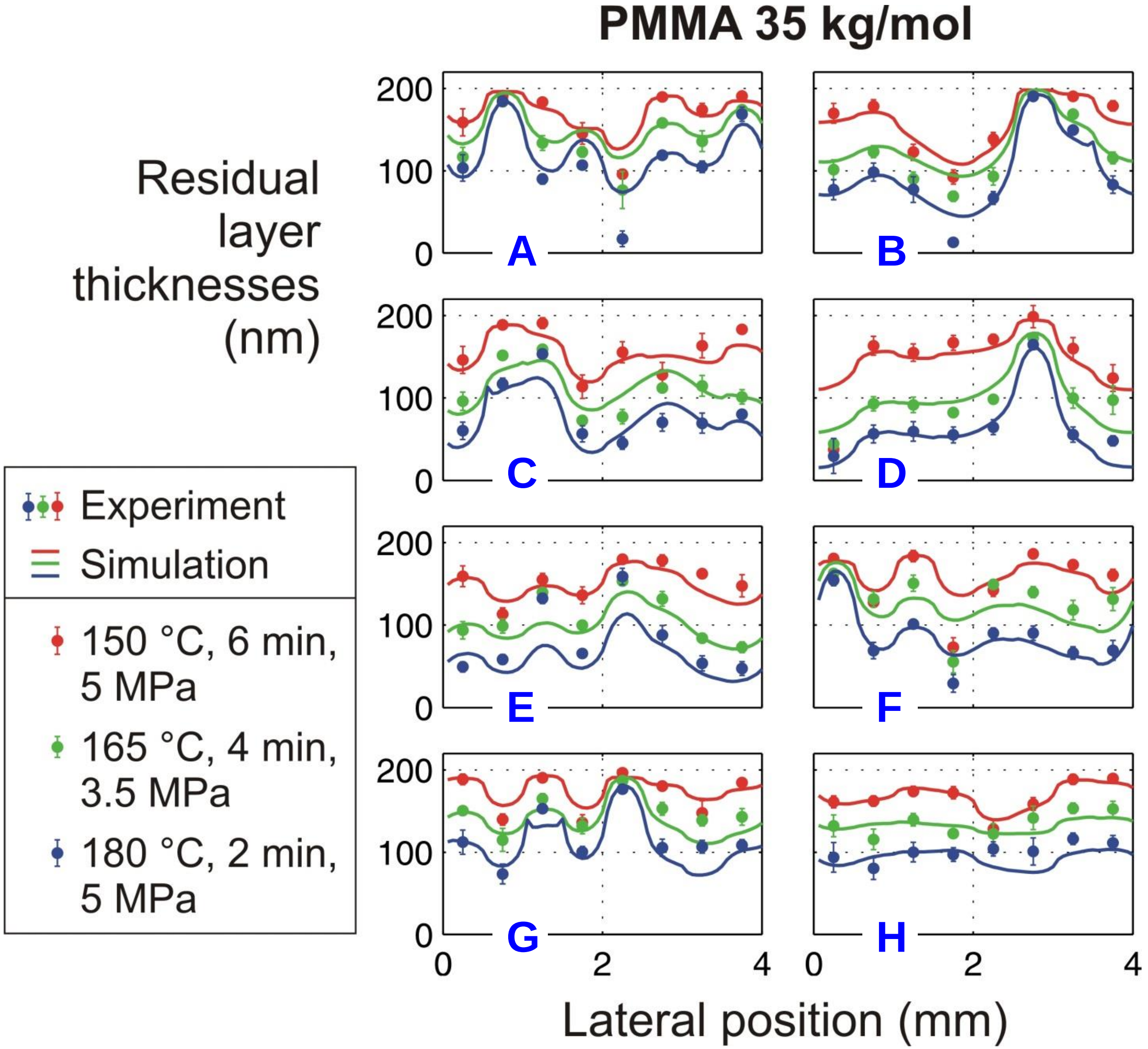
Silicon test stamp:



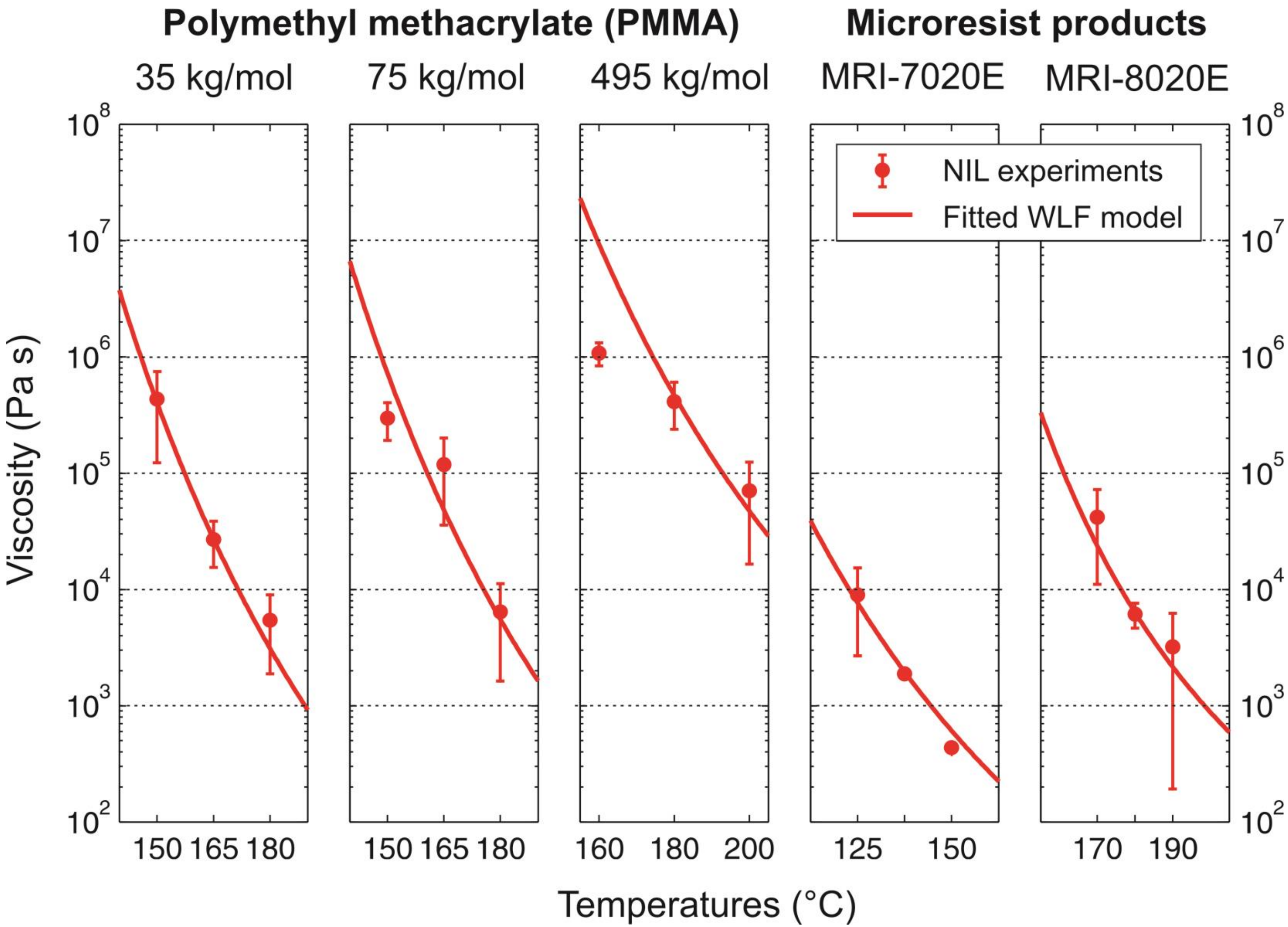
■ Cavities (~500 nm deep)

☐ Protrusions

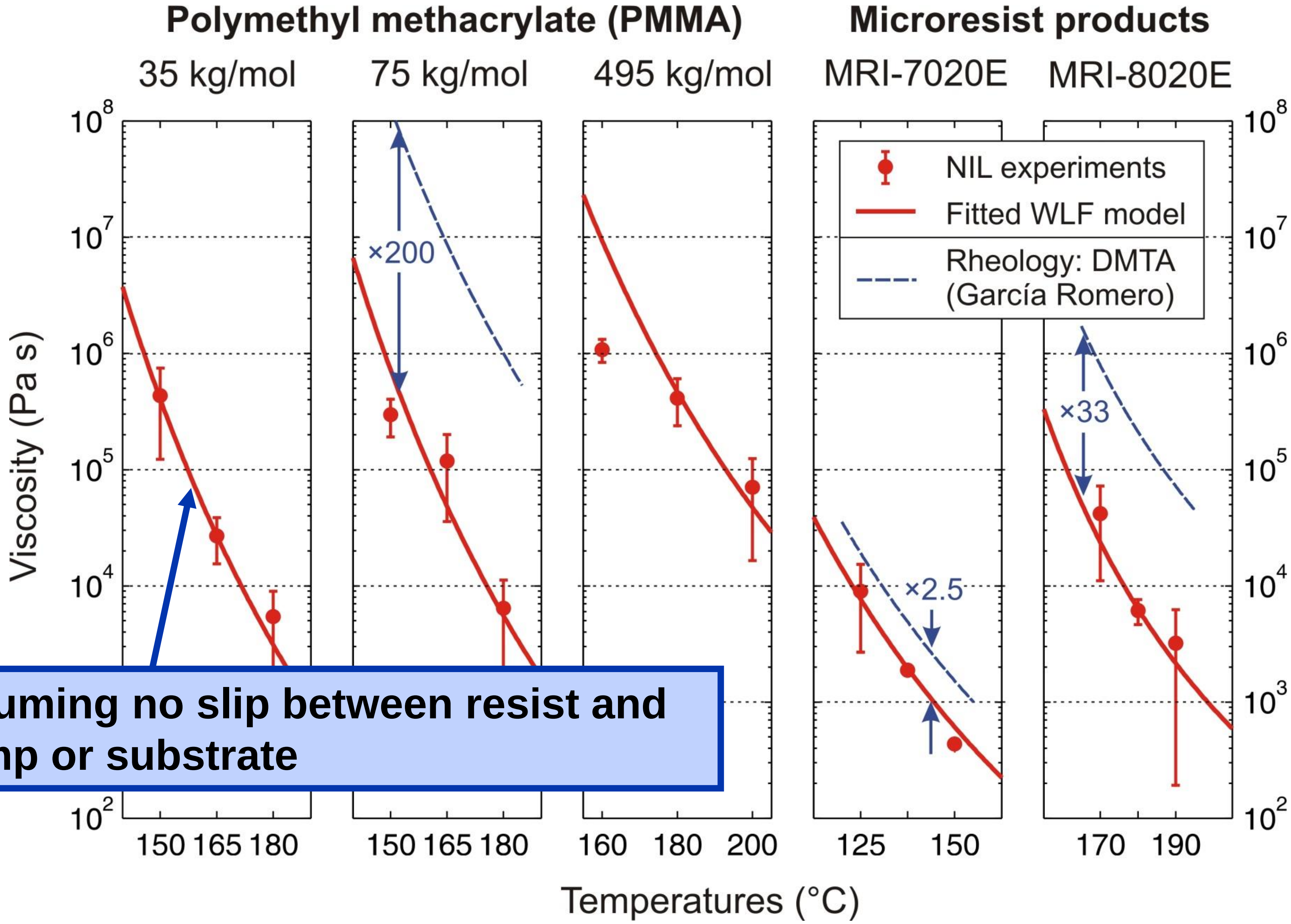




The technique has been validated for five thermoplastic materials



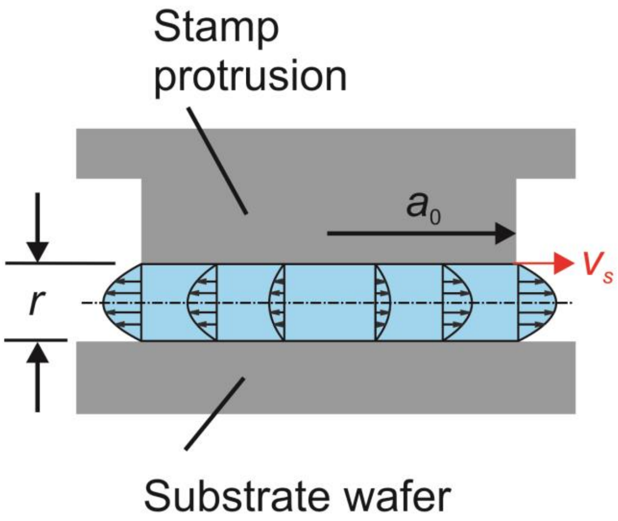
Nanoscale experiments may involve substantial slip between resist and stamp

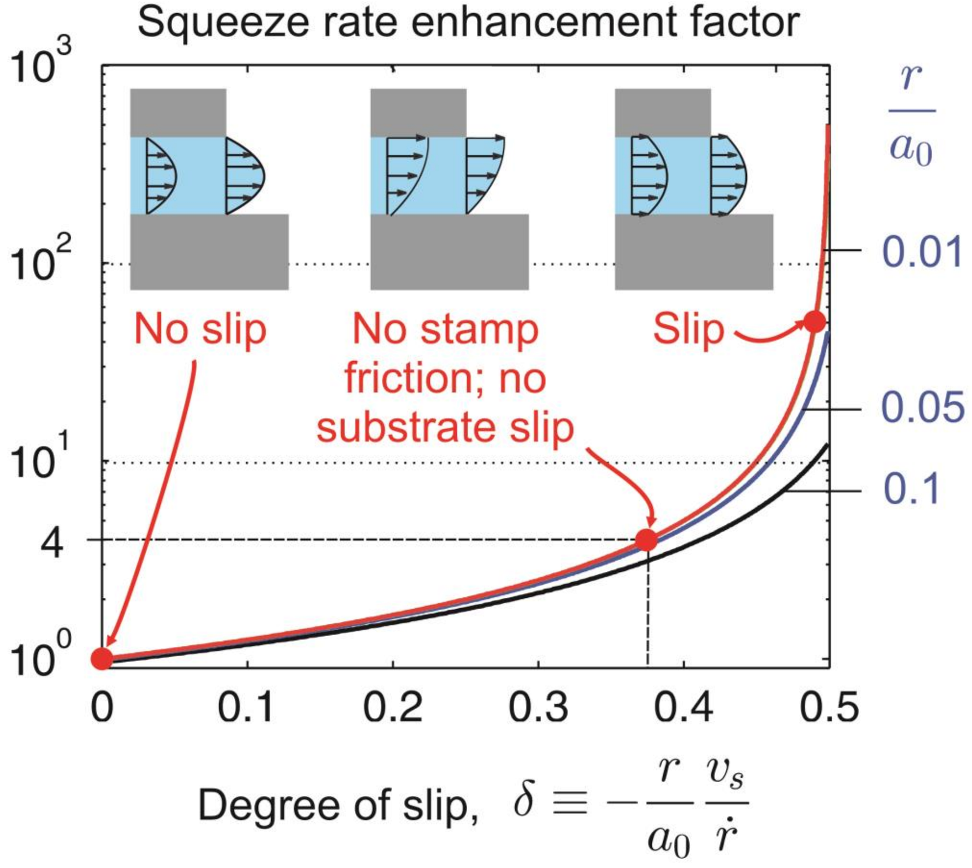


Assuming no slip between resist and stamp or substrate

The imprinting rate will depend strongly on any slip between resist and stamp/substrate

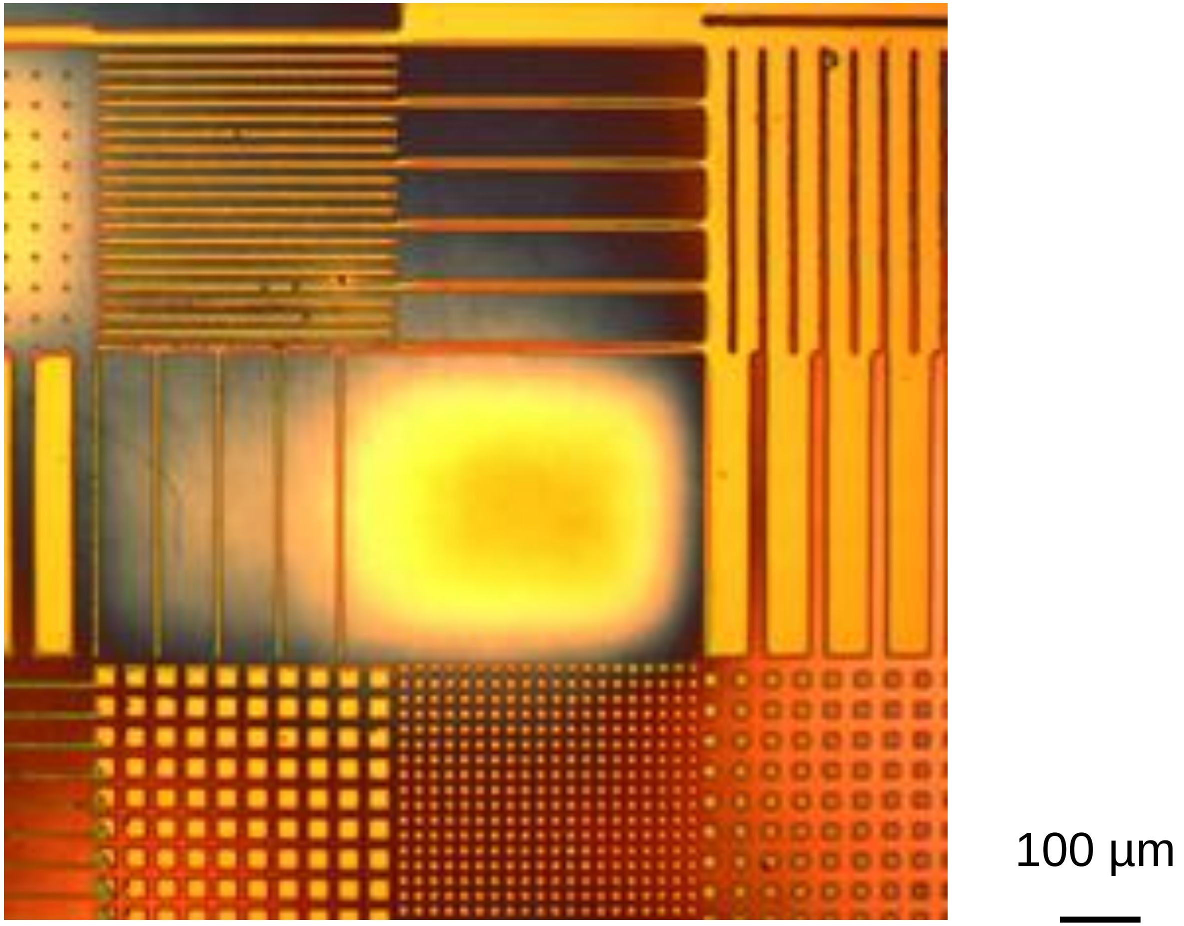
$$\frac{\mathrm{d}r}{\mathrm{d}t} = -\frac{r^3 p_0}{4k\eta_0 a_0^2}\underbrace{\left[(1-2\delta) + \left(\frac{r}{a_0}\right)^2 (1+2\delta)\right]^{-1}}$$



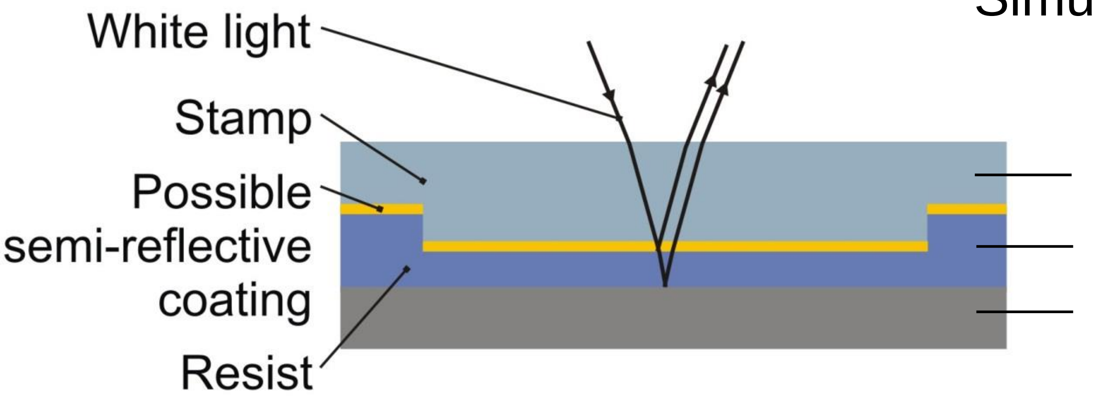


Laun, *J. Non-Newtonian Fluid Mechanics* **81** (1999) 1-15

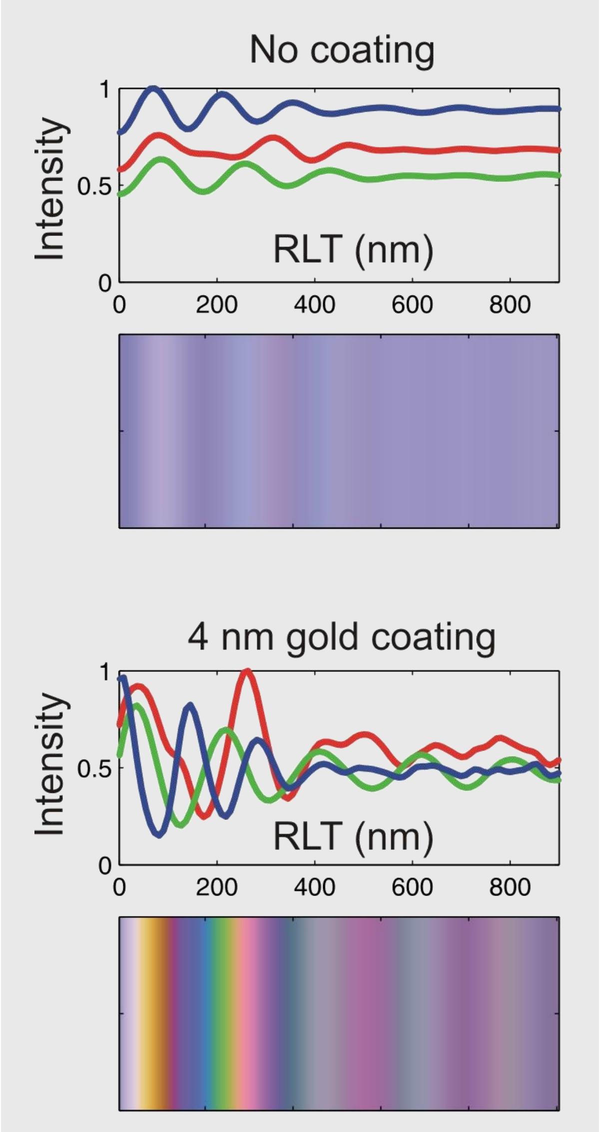
Real-time observation of evolving RLT could accelerate material/stamp characterisation

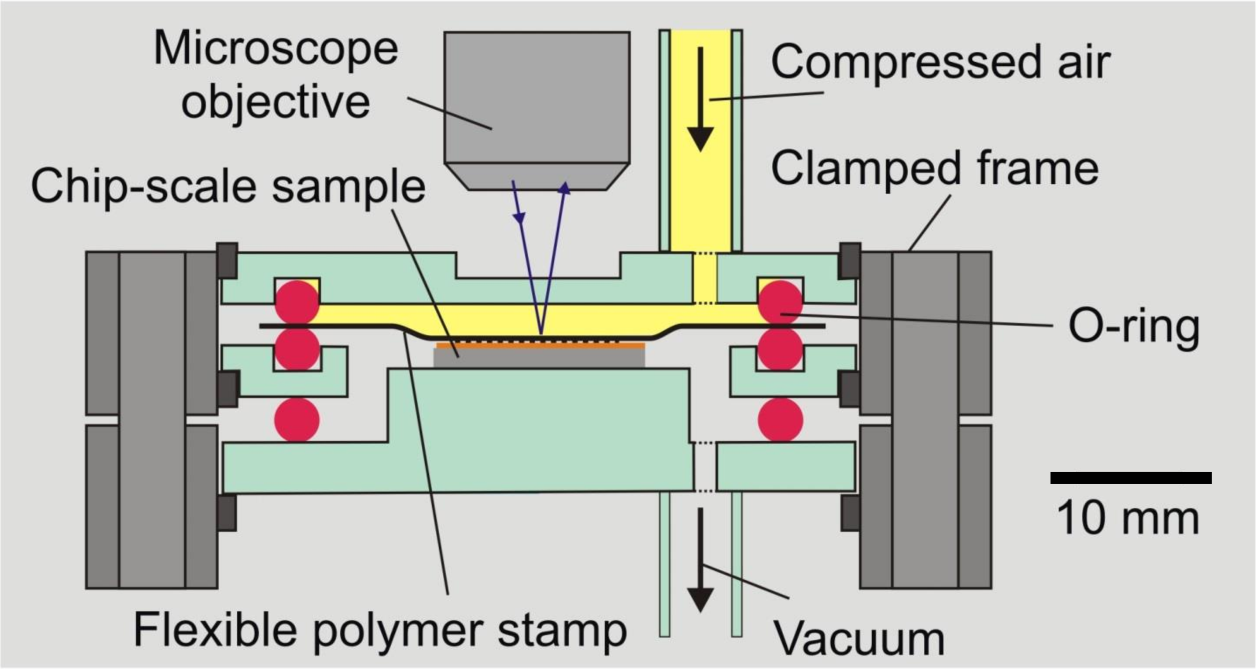


Real-time observation of evolving RLT could accelerate material/stamp characterisation

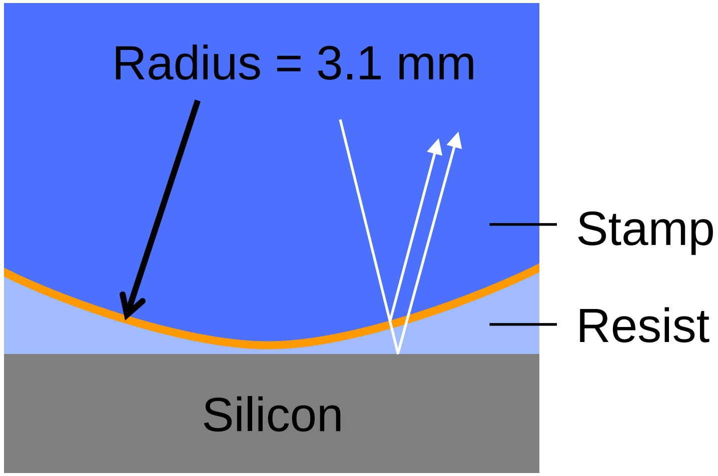


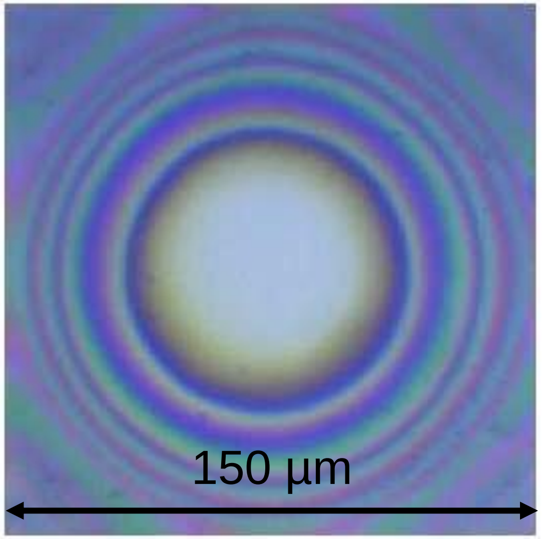
Simulations

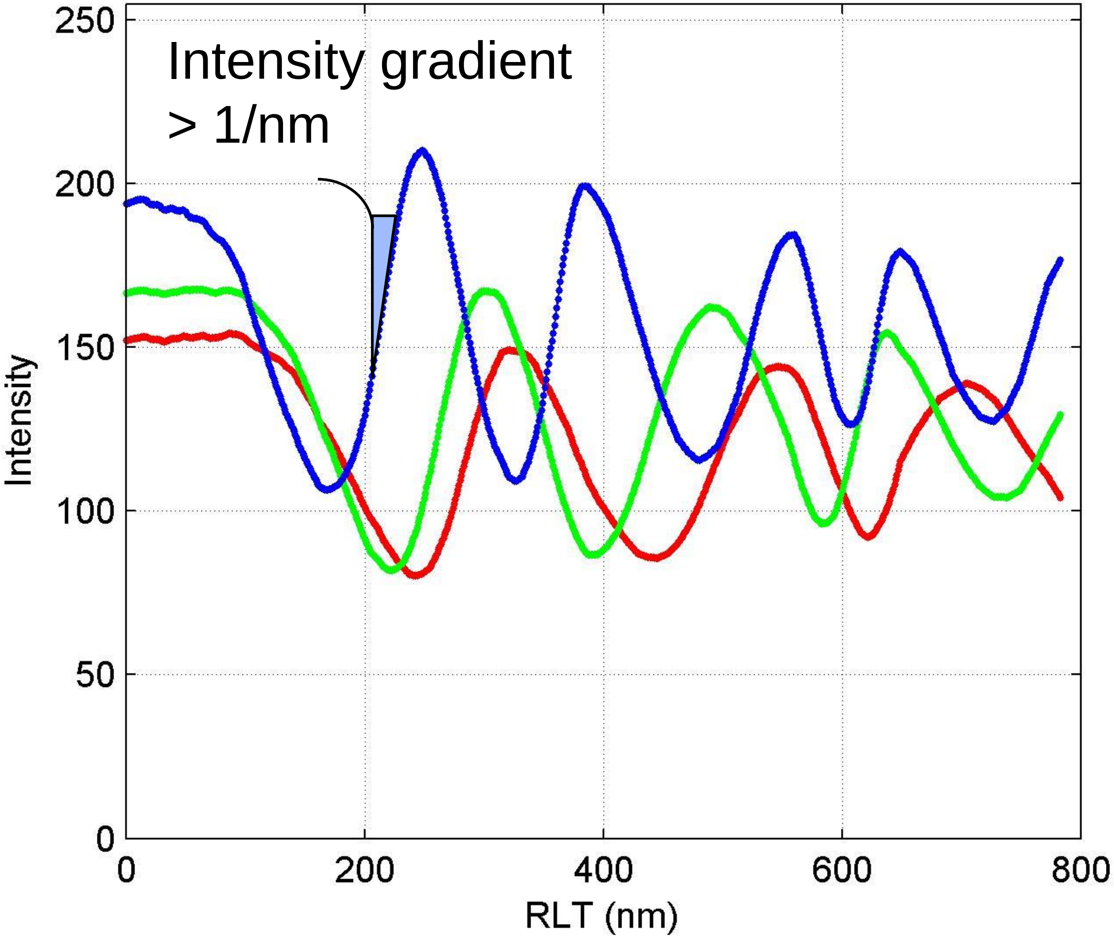




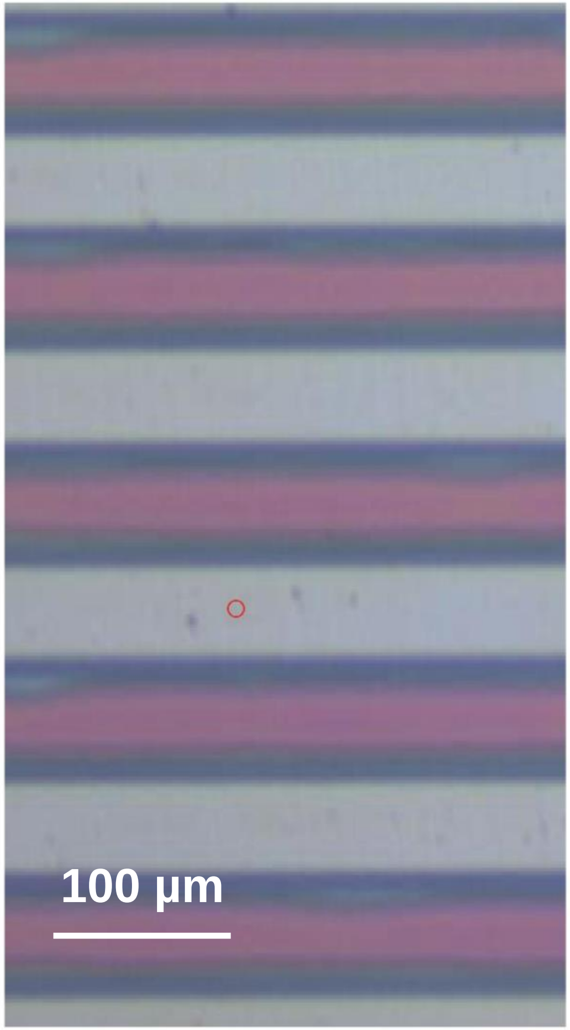
RLT–colour relationships are calibrated using a known stamp topography

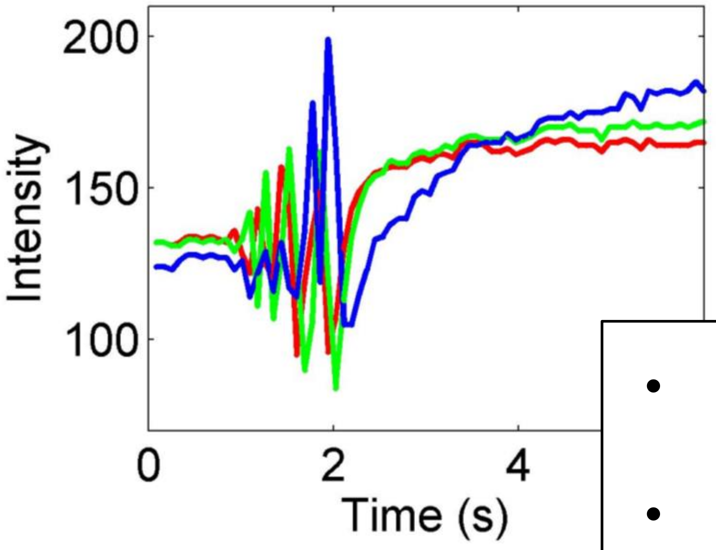


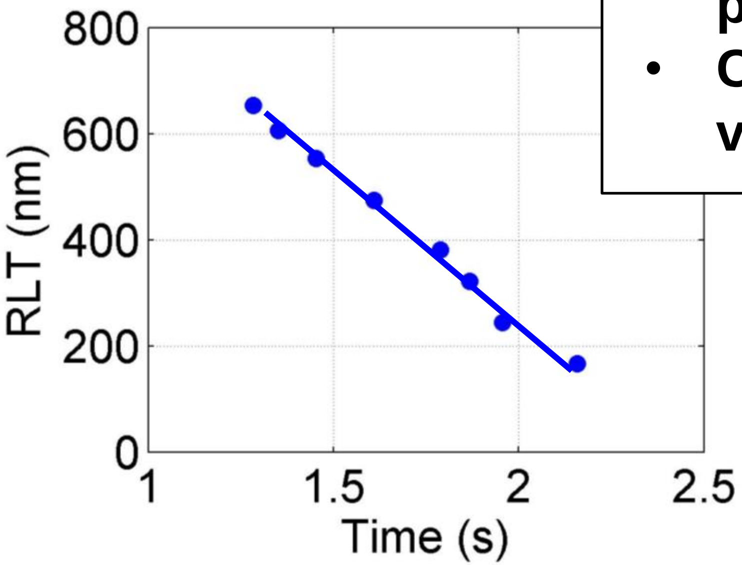




Videos of the imprinting process allow the temporal response of resist to be extracted



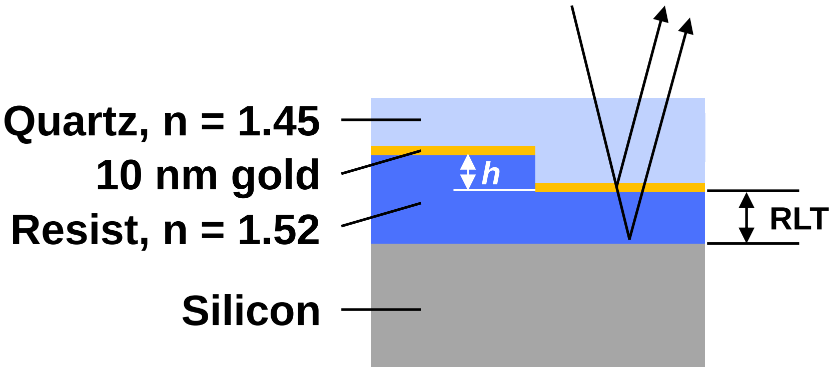


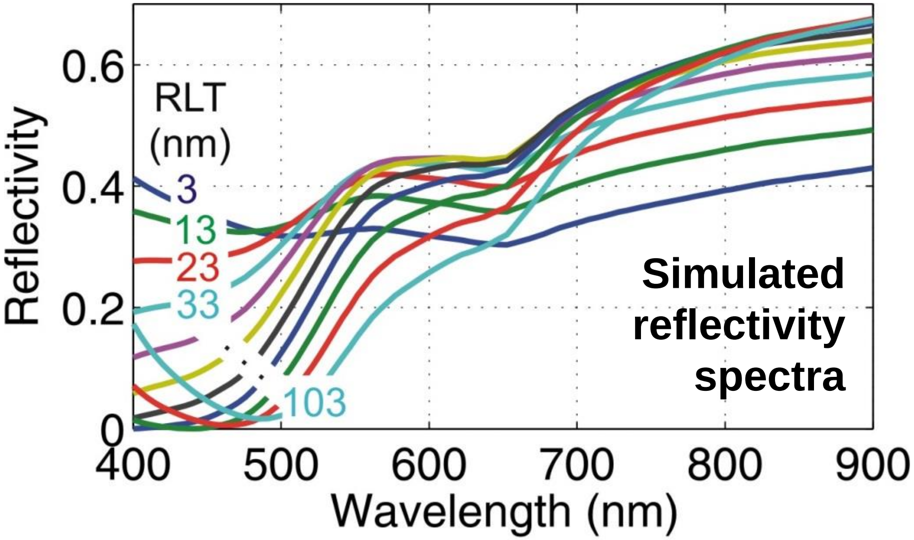


- **Material: MRT mr-UVCur-21**
- **Stamp-average pressure 20 kPa**
- **Consistent with viscosity ~ 7 Pa.s**

If features are sub-wavelength, plasmonic effects could enhance RLT detection

Large features





Simulated reflectivity spectra

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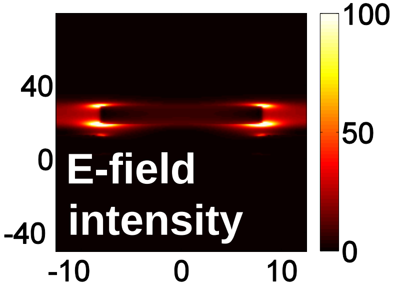
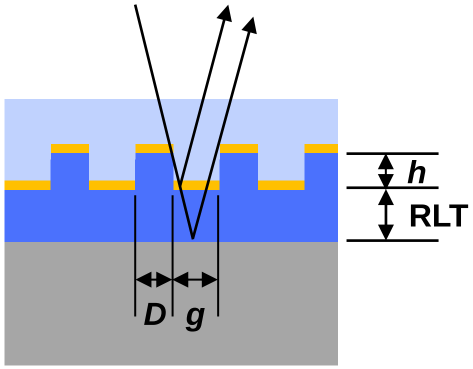
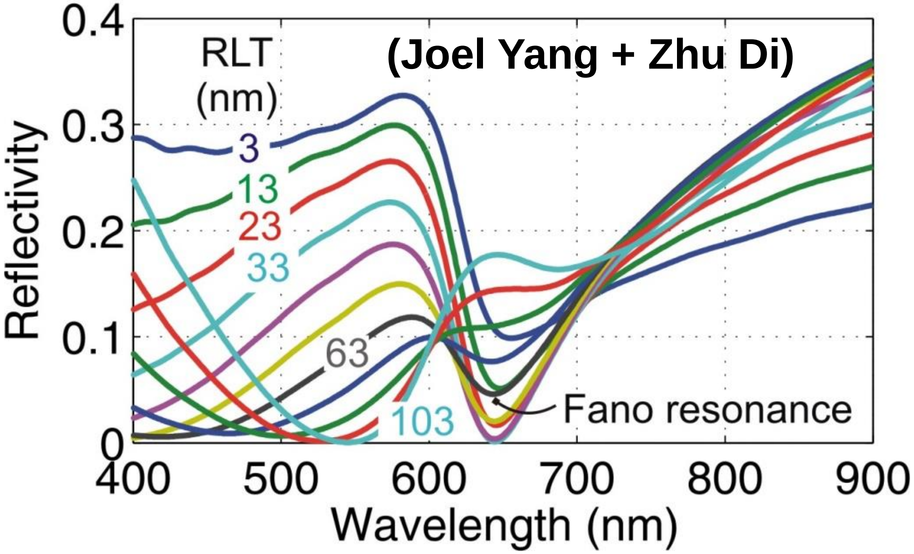
25 nm-pitch dot array

h = *D* = 16 nm
g = 9 nm

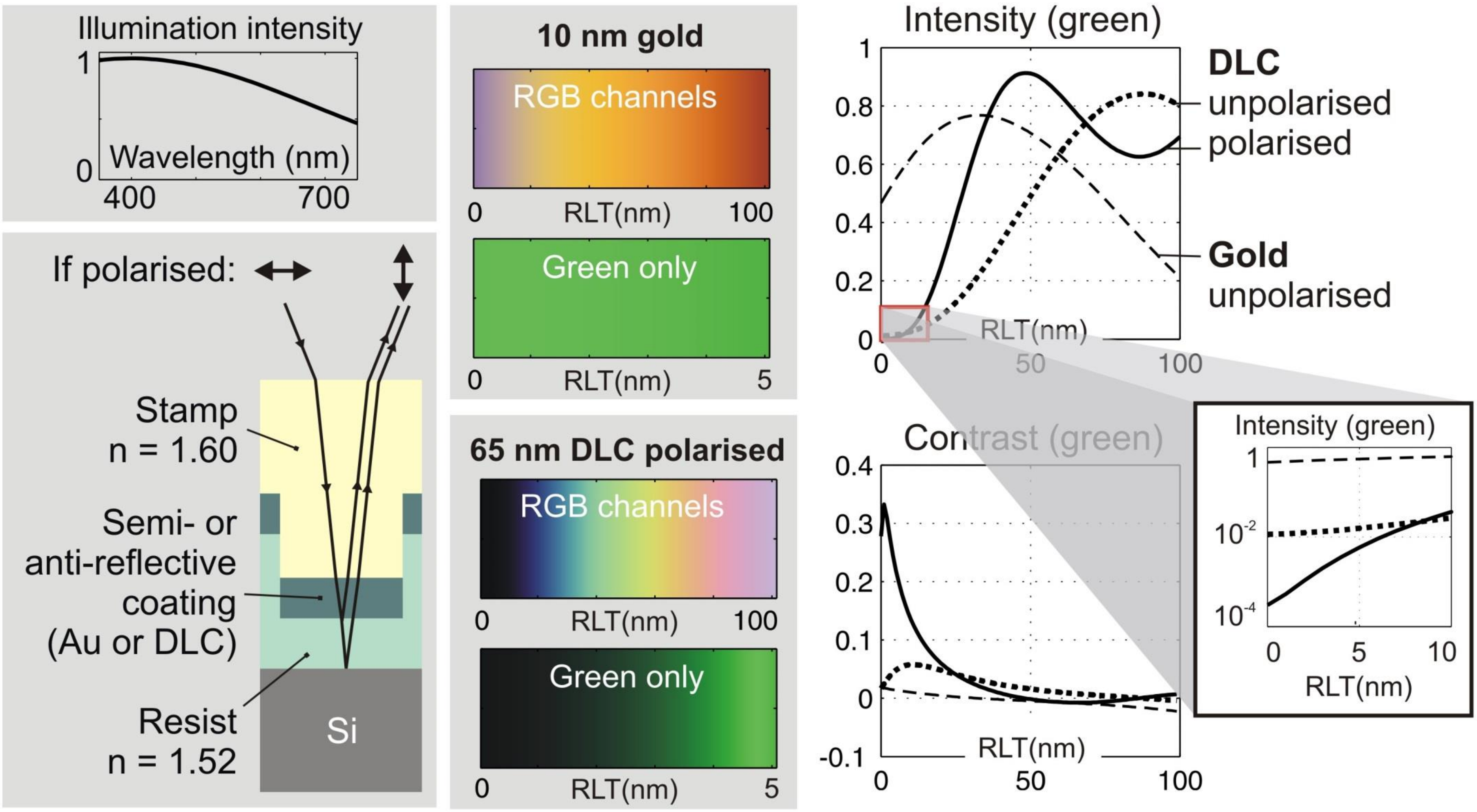






(Joel Yang + Zhu Di)

An anti-reflective stamp coating and light polarisation could enhance RLT contrast

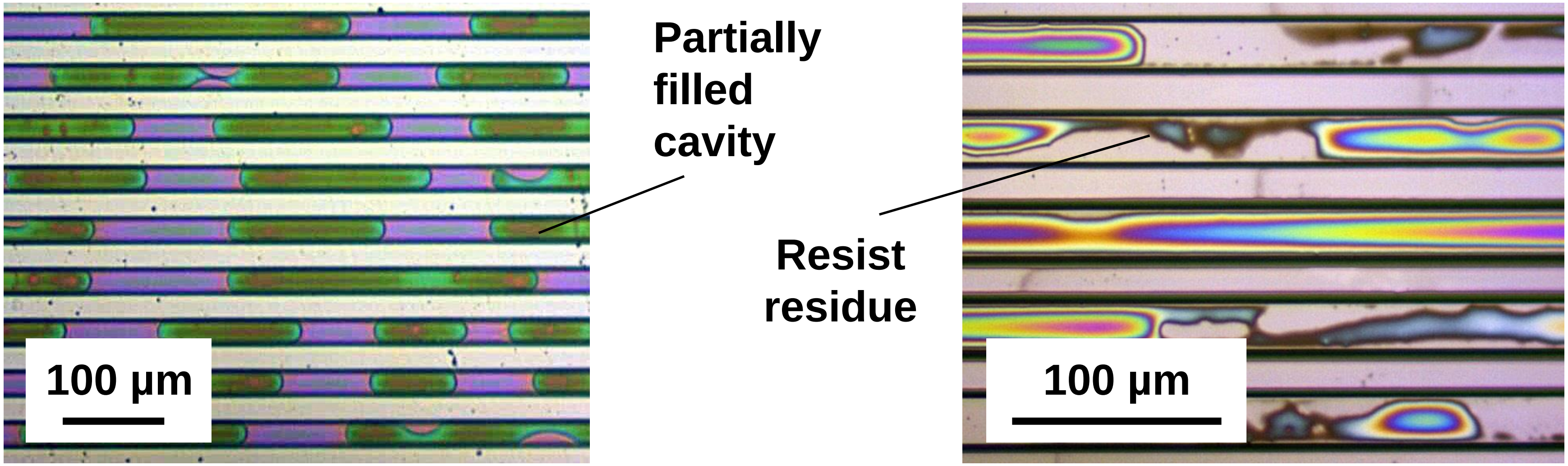


Contrast: relative change in intensity for a 1 nm change in RLT about a given RLT

Substrate-enhanced ellipsometric contrast: Ausserré, *Optics Express*, **15** 8329 (2007)

Potential applications include endpoint detection and cavity filling monitoring

- Endpoint detection
- Feedback control in R2R processing
- Cavity filling
- Stamp inspection/defect detection
- Probing of complex fluids (*e.g.* biological samples)



Conclusions and outlook

- **Resist rheological behaviour can be extracted from nanoscale imprint experiments**
- **Resist-stamp boundary conditions are critical and require characterising**
- **Real-time measurement of RLT can be accomplished interferometrically using simple white light microscopy**
- **Optical RLT measurement sensitivity can be tuned using plasmonic or ellipsometric approaches**
- **Real-time RLT measurement could be applied to improve NIL yield and throughput**

Collaborators and acknowledgements

- **AMO, Germany**
  - Christian Moormann
  - Ulrich Plachetka
- **Microresist Technology, Germany**
  - Arne Schleunitz
  - Marko Vogler
  - Freimut Reuther
- **IMRE, Singapore**
  - Goh Wei Peng
- **NTU, Singapore**
  - Tan Boon Hwee
- **IBN, Singapore**
  - Ciprian Iliescu
- **Trinity College Dublin**
  - Graham Cross