EFFECT OF RHEOLOGICAL PROPERTIES OF TiO2 SLURRY ON THE TRANSFER RATIO IN GRAVURE PRINTING

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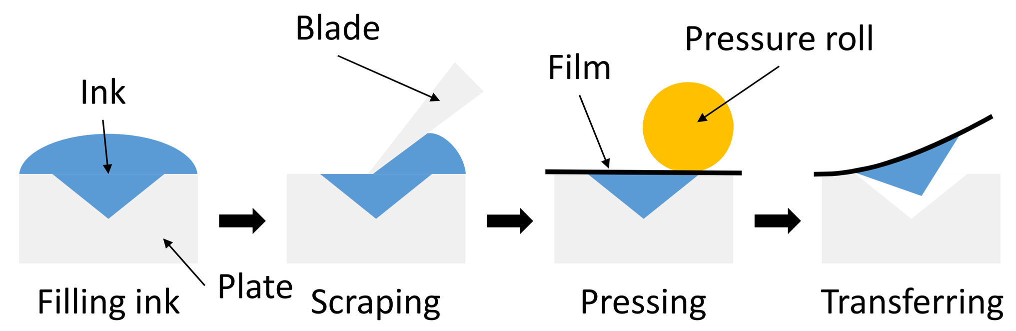
Introduction

Gravure printing has many advantages, such as good printability on thin films, good image quality, high-speed coating. TiO_2 ink is a common white ink and is frequently printed by a gravure printing. However, depending on the ink composition, the printed pattern may be inaccurate, resulting in the discrepancies from the engraved pattern.

The procedure of gravure printing is as follows. Fill the cell graved on the flat plate with ink, scrape off an excess ink, and transferring the residual ink to the film. It was assumed that inadequate scraping of ink was the mechanism of inaccurate print pattern because the normal stress of the ink under shear flow pushed up the blade.



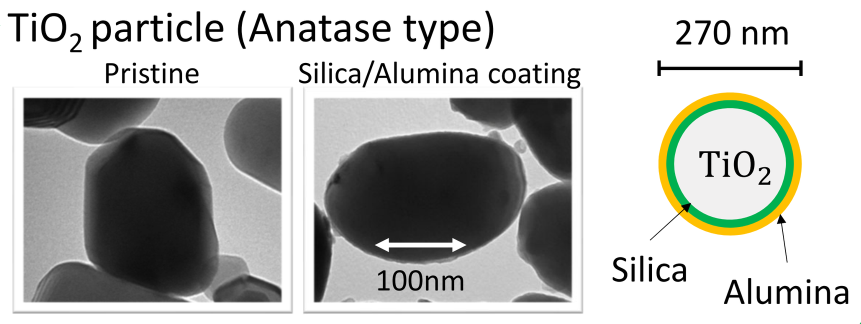
In this study, we investigated the effect of rheological properties of ink, printing speed and cell volume on the structure of the ink on the flat plate with graved cell. The dominant factor for appropriate gravure printing was clarified from the view point of rheological properties of TiO_2 ink.

Experiments

Composition of ink

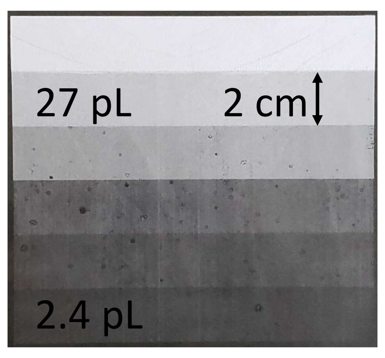
- Particle TiO_2 C_P = 40wt%
- Binder Polyurethane C_B = 10～30wt%
- Solvent EA : IPA = 3 : 1

TiO_2 particle (Anatase type)



Printing (Table-top gravure coater)

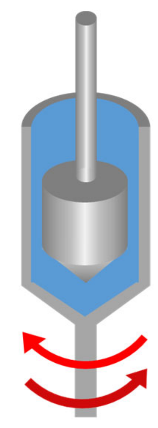
- ➢ Spread an ink over flat plate
- ➢ Scrape excessive ink
- ➢ Transfer to PET film

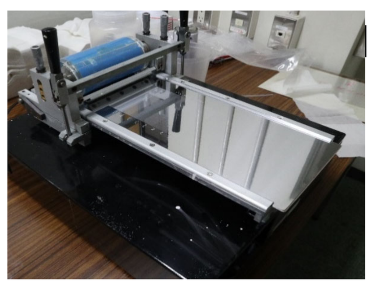


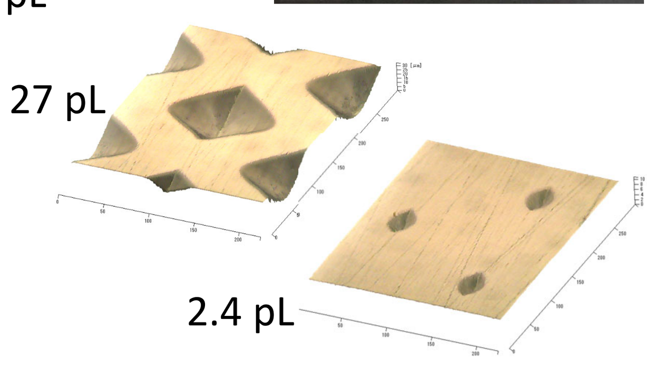
- ☐ Printing speed: 10 - 38 cm/s
- ☐ Cell size: 2.4 - 27 pL

Rheological characterization

- Stress-controlled Rheometer (Anton Paar MCR 701, Concentric cylinder)
  - Viscosity
  - Strain/Frequency sweep





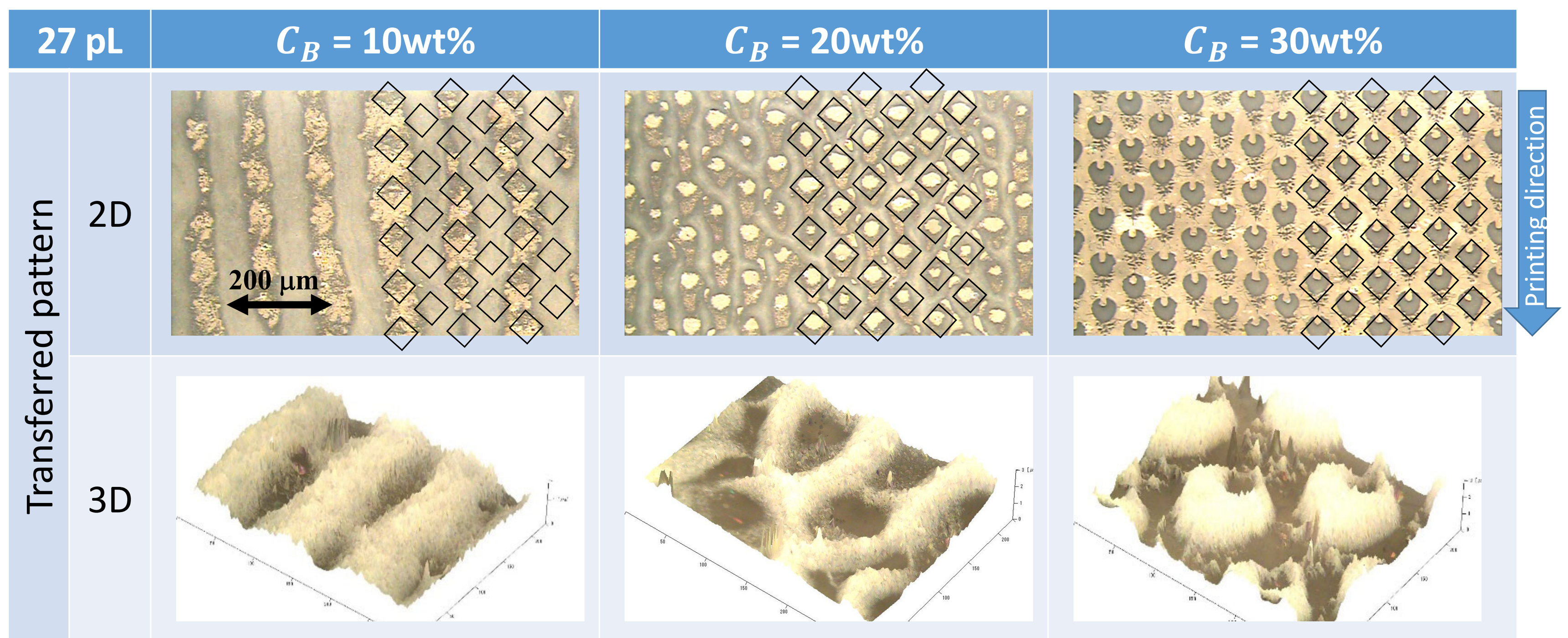


3D pattern characterization

- Laser confocal microscope (Keyence VK8500)
  - 3D geometry of transferred ink or scraped ink
  - Residual ink in a cell

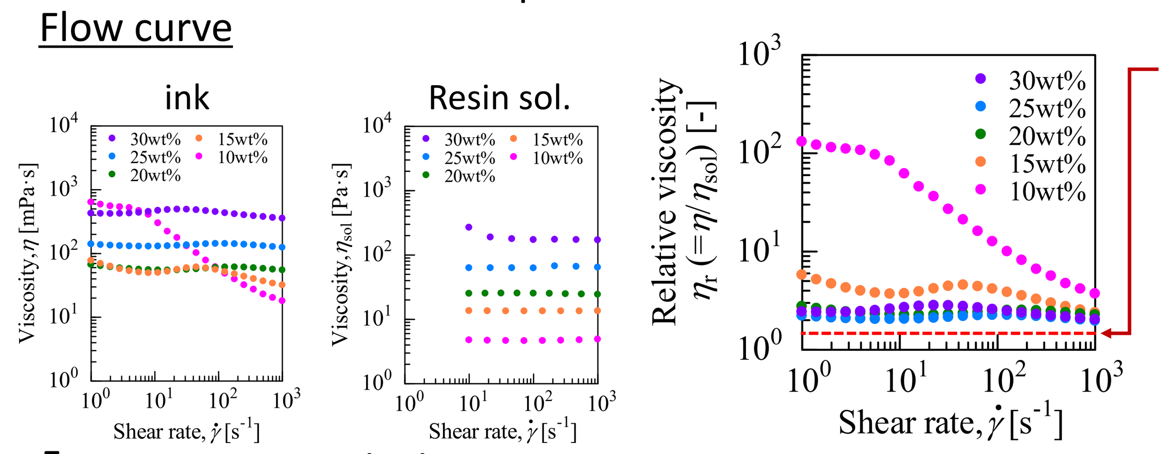
Results & Discussion

Effect of binder content on transferred pattern



Ink on the substrate is connected each other to form "Band-like" pattern | Combined pattern | The shape and position of transferred ink showed good agreement with cell

Flow curve

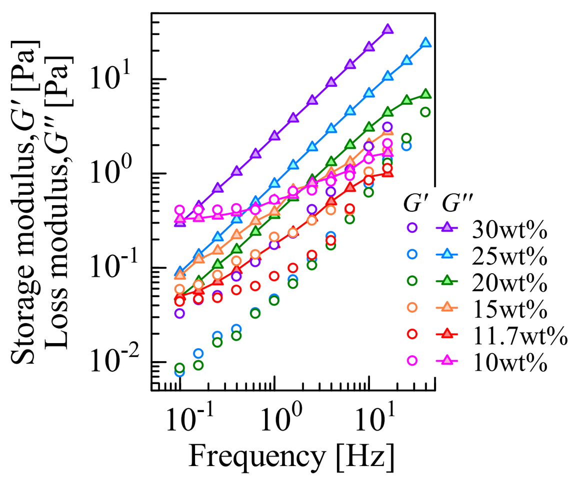


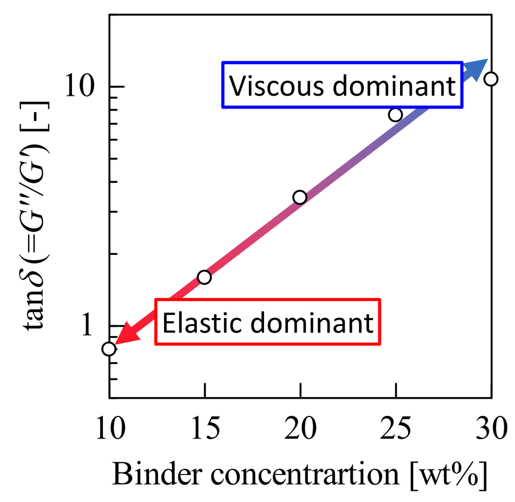
Complete dispersion (η_r = 1.4)

$$\eta_r = \left(1-\frac{\phi}{\phi_m}\right)^{-2.5\phi_m}$$ (Krieger-Dougherty Eq.)

- Aggregation at low resin content
- No difference above 20wt%

Frequency sweep test

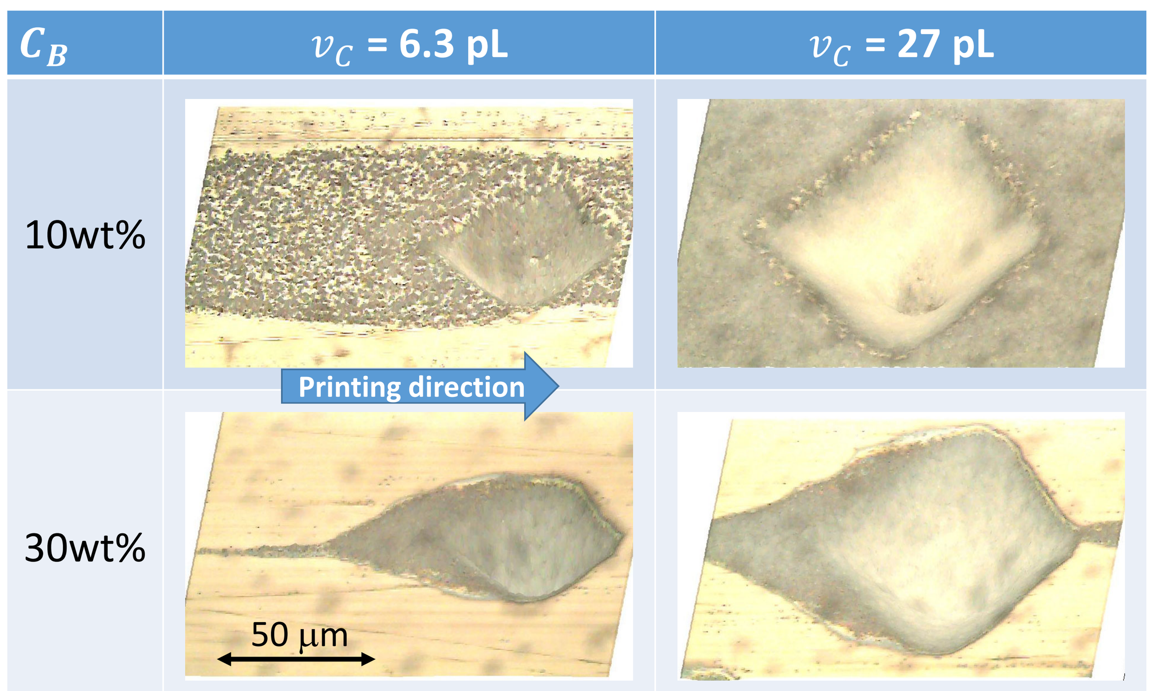




- At 10wt%, 2nd plateau and small tanδ indicates the formation of network of titanium particles in the ink
- Minimum G' at 15-20wt% determined by the balance between particle dispersion and resin sol. viscosity

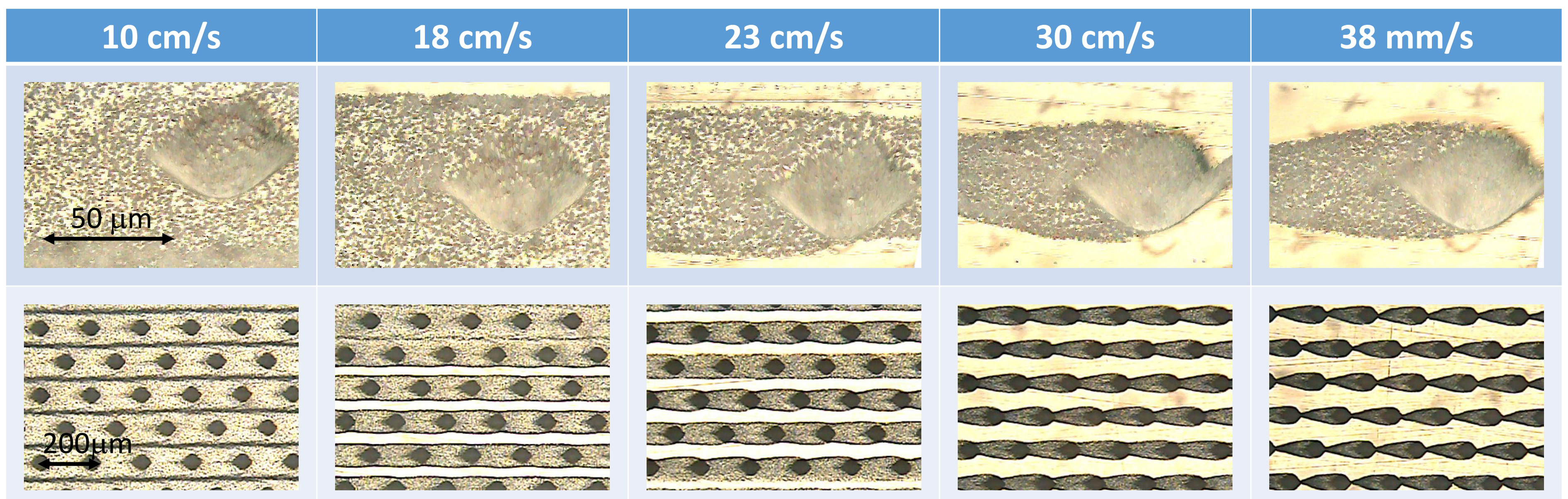
✓ When the band-like pattern was formed? After/During/Before transferring?

Effect of binder concentration on the shape of scraped ink



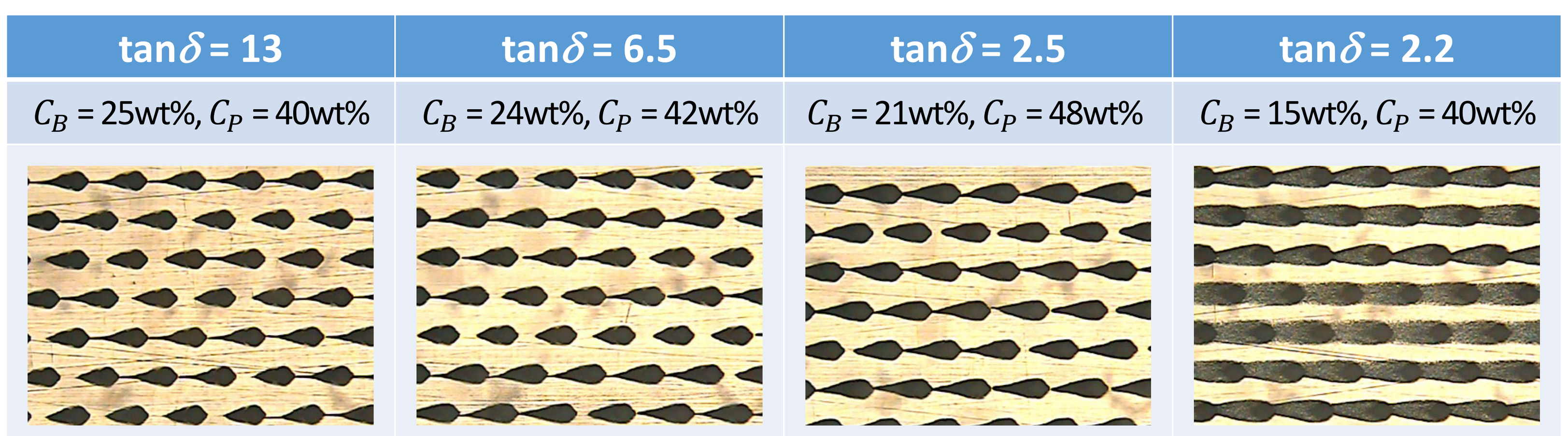
- ■ Elastic ink (10wt%):
  - Overflow
  - Preferentially spread in printing direction
  - Flat area was fully covered for large cells
- ■ Viscous ink (30wt%)
  - Tailing in printing direction
  - Flat area was rarely covered by the ink

Effect of coating speed on the shape of scraped ink (C_B=10wt%, 6.3 pL)

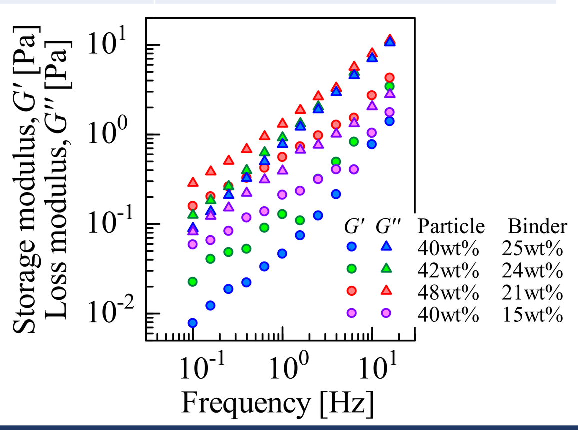


- Overflow could be suppressed even for elastic ink as increasing printing speed. This is because aggregates of particles were broken up, which reduced elasticity.

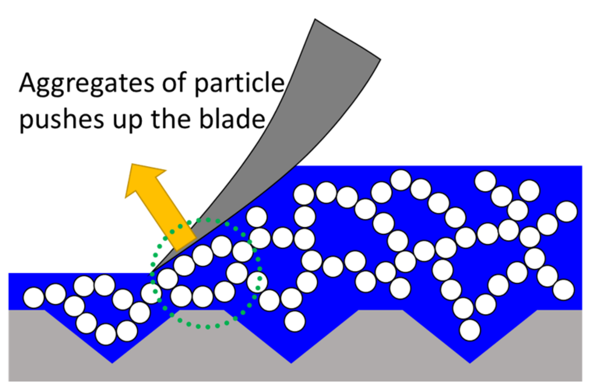
Effect of elasticity on the shape of scraped ink (6.3 pL, 18 cm/s)

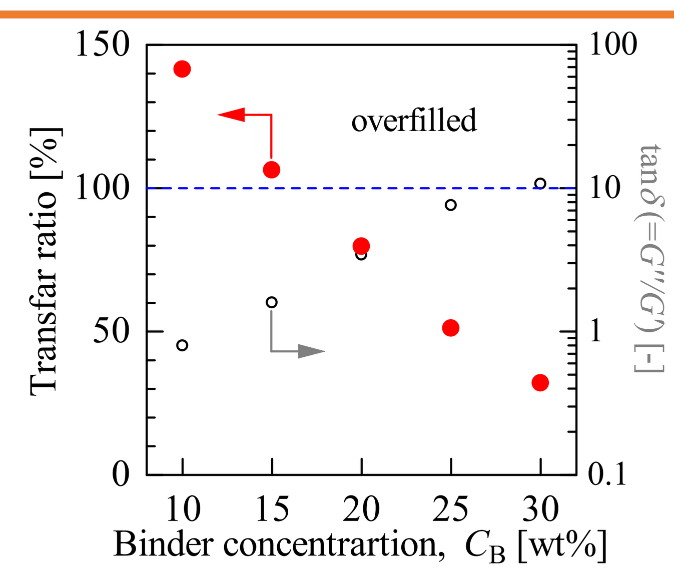


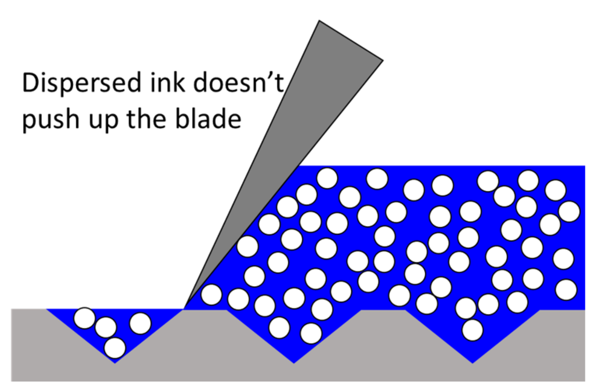
- tanδ being the ratio of viscous to elastic terms did not always affect the shape of ink after scraping.
- At the same tanδ, overflow was observed only for the ink with low elastic moduli.
- An ink showing low viscosity and relatively large elasticity tends to overflow when printing at low speed.



Transfer ratio and elasticity







✓ Aggregated structure of TiO_2 particles causes large elasticity. While the ink is sheared, the tip of doctor blade is pushed up due to large normal force. As a result, the ink overflowed from the cell. The ink can move on PET film after transferring, resulting in the band-like pattern.

✓ Dispersed ink exhibits small elasticity and can be scraped appropriately by a doctor blade. However, the transfer ratio was decreased with the increase in binder concentration. This is probably due to difficulty in transferring high viscosity ink from the cell plate to PET film.

Conclusion

- TiO_2 inks with different binder concentrations were coated on PET film by the gravure printing method. Inks containing sufficient amount of binder could print appropriately, whereas the ink with small binder concentration formed a band-like pattern on the PET film. Rheological measurement showed that band-like pattern can be obtained using elastic inks.
- The surface structure of the dried ink on the flat plate with graved cells was observed after the scraping process. It turns out that elastic ink overflowed from the cell. Increasing the coating speed will probably break up particle aggregates and then reduce elasticity, thus avoiding overflow. It was revealed that tanδ was not suitable parameter to check if ink overflows or not. Low viscosity is also the factor that induces overflow.
- At constant particle content (~12vol%), transfer ratio correlated well with tanδ. However, it is necessary to clarify the relationship between rheological properties and the amount of residual ink on the flat plate after scraping, and the ink transfer ratio from the flat plate to PET film.
- Normal force measurement need to be performed in future using a solvent trap or some special technique.

Acknowledgment

The authors thank to Mr. M. Katayama, Mr. T. Kato and Mr. A. Kitakoji for the preparation of TiO2 inks and fruitful discussion on the results

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