Direct Imprinting and Electrical Properties of ITO Precursor Gel School of Materials Science, Japan Adv. Ins. Sci & Tech. (JAIST) °Puneet Jain, Ken-ichi Haga, Eisuke Tokumitsu E-mail: s1620011@jaist.ac.jp

Introduction: Printing electronics has gained a conventional great attention over the photolithography process due to their inexpensive fabrication cost. However, the obtainable pattern size using conventional printing technologies is usually greater than 10 µm. On the other hand, a new printing method namely nano-rheology printing (n-RP) has been developed [1, 2]. n-RP is a direct thermal imprinting technique and deforms oxide precursor gel without photoresist. n-RP enables the deformation of sub-100 nm patterns by utilizing the rheological properties of an oxide precursor gel. In this work, we study how addition of tin (Sn) to pure indium oxide (In₂O₃), affects the direct imprinting and electrical properties of pure In₂O₃.

Experimental Procedure: First, we obtained a condition to get good patterns using direct imprinting for pure In_2O_3 , by dissolving indium(III) acetylacetonate [In(acac)₃] in propionic acid [C₂H₅COOH, hereinafter called PrA] at 120 °C. After this, indium tin oxide (ITO) source solutions, with Sn composition of 10 and 100 wt. %, were prepared by dissolving In(acac)₃ and SnCl₂ in PrA at same temperature of 120°C. The ITO solution was spin coated on SiO₂/Si wafer, to form a thin film of ITO. It was then dried at 100 °C on a hot plate for 3 min to evaporate the solvent from the film and to get an ITO gel (or precursor gel). This gelation step plays an important role in n-RP n-RP depends on the viscoelastic because transformation of precursor gel. A thermal imprinting machine was used for rheological imprinting, in which the sample was kept on a heated stage, after which the mold was properly aligned with respect to the sample, before the application of the required imprinting pressure and temperature. The optical microscope, scanning electron microscope (SEM), step profiler were used for characterization. Hall mobilities and carrier densities were measured using a Hall measurement set-up.

<u>Results and Discussion:</u> Figure 1 shows the optical images of direct imprinted (i.e. n-RP) pure In₂O₃ and 10 wt. % Sn-doped ITO films. Molds used in these experiments are PH-350 and SNP-02 patterned quartz mold (NTT-AT). 100 wt. % (with SnCl₂ and PrA) data is not shown, as SnCl₂ did not dissolve in PrA. In Fig. 1, both, 0 and 10 wt. % films, were imprinted with an imprinting pressure and temperature of ~ 15 MPa and ~ 175 °C, respectively. It is seen clearly that adding Sn, the imprinting properties degrade. When we imprint

pure In₂O₃ under pressure, there is a release of carbon content in the form of PrA and acac, by changing the viscoelastic properties (i.e. softening) of the precursor gel. On the other hand, it was found that the viscoelastic properties were affected by the addition of SnCl₂. The Hall mobilities and carrier densities of the imprinted films with 0, 10, and 100 wt. % ITO solution prepared by PrA, In(acac)₃, and SnCl₂ are shown in Table I. Before the measurement of Hall-parameters, the samples were annealed in O2 ambient for 1 hour at 600 °C. It is seen from Table I, that the Hall mobility of Sn composition of 0 wt. % is more than that of 10 wt. % because Sn in In₂O₃ acts as a donor impurity. We also examined a different precursor, tin(II) acetylacetonate $[Sn(acac)_2]$. The details will be presented at the meeting.



Fig. 1: Optical microscope images of In₂O₃ and ITO(Sn:10 wt. %) imprinted film with (a) and (b) PH-350 while, (c) and (d) SNP-02 mold

Table I	Hall	narameters	ofim	printe	d film
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Sn wt. %	Mobility (cm ² /V.s)	Carrier conc. (cm ⁻³)
0 (In(acac) ₃ in PrA)	1.52	2.8 x 10 ¹⁹
10 (In(acac) ₃ and SnCl ₂ in PrA)	0.48	7.8 x 10 ¹⁹
100 (SnCl ₂ in PrA)	SnCl ₂ did no	t dissolve in PrA

<u>Summary:</u> We have successfully formed the patterns of ITO using n-RP with 0 and 10 wt. % with $In(acac)_3$ and $SnCl_2$. However, with the addition of $SnCl_2$, the patterning properties degrades.

<u>References:</u> [1] T. Kaneda *et al.* J. Mater. Chem. C 2(2014) 40-49. [2] K. Haga *et. al.*, Jpn. J. Appl. Phys. 57 (2018) (under publication).