Supporting information

Laser Sweeping Lithography: Parallel Bottom-up Growth Sintering of Nanoseed-organometallic Hybrid Suspension for Eco-friendly Mass Production of Electronics

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Number of tables: 1

Number of equations: 2

Calculation of penetration depth of laser incident in silver mask layer

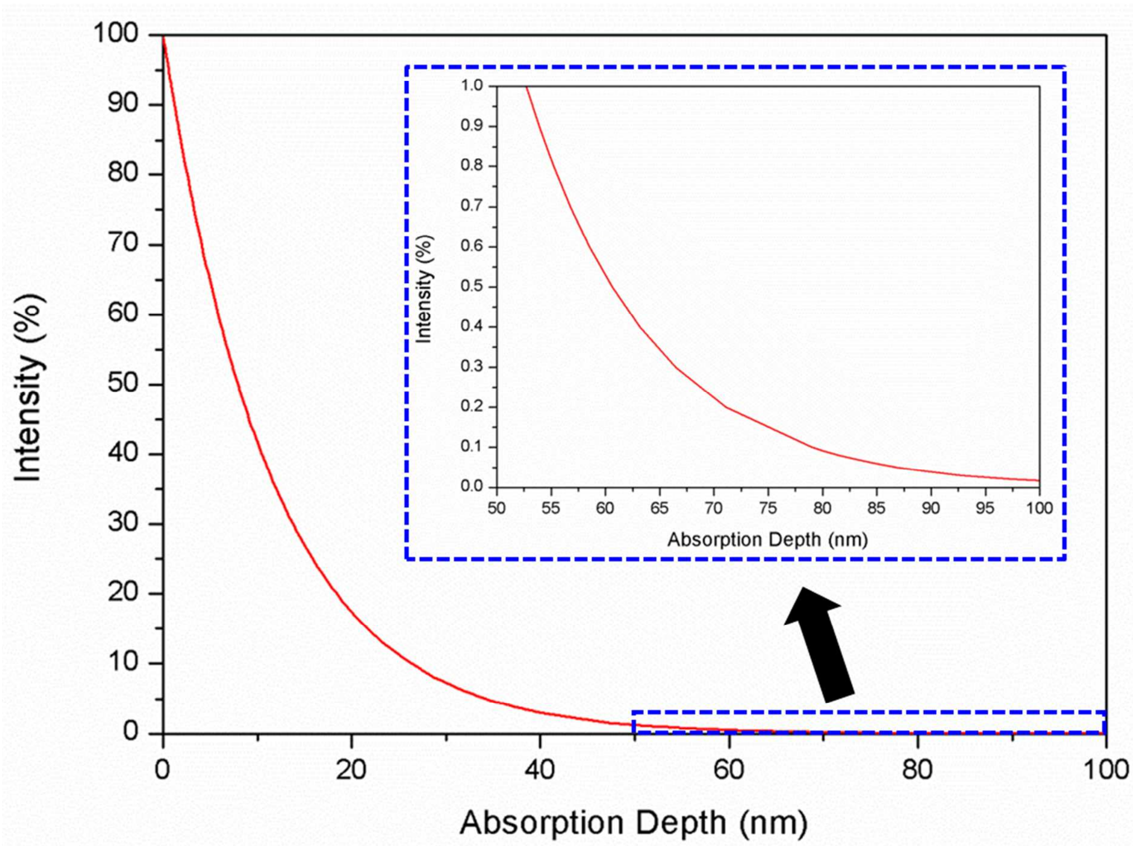

Figure S1. Calculated intensity variation of a 980 nm laser incident passing through silver layer.

According to the calculation of laser absorption depth, shown in Fig. S1, the absorption depth requiring for reaching 1 % of total incident power of laser is approximately 53 nm. Because this calculated depth is lower than the practical deposition thickness of silver (200 nm), it is reasonable that the thermal energy induced by absorption on silver layer does not affect to the substrate and the hybrid solution.

Calculation of heat diffusion length in silver mask layer

Mathematical formulation of heat diffusion length (l) is calculated from the following thermal diffusivity (D) given as follow,

$$D = \kappa/(\rho \cdot C_\rho) \tag{S1}$$

where, κ (W/m·K) is the thermal conductivity of silica, ρ (kg/m^3) is the density of silica, and C_ρ (J/kg·K) is the specific heat capacity of silica. By substituting the parameters of silica into the formula, the thermal diffusivity of 0.34 mm^2/s is calculated. And we assumed that the heat transfer in the silver layer does not depend on time and the time duration of laser irradiation including rising and drop time is 2 μs in spite of the use of CW laser. Based on above assumption and the following equation showing relationship between a heat diffusion length and thermal diffusivity, the heat diffusion length of 825 nm was calculated.

$$l(t) = (D \cdot \tau)^{0.5} \tag{S2}$$

Because this value implies the minimum thcikness to prevent thermal diffusion in silica layer which is used as a prothection layer, the thcikness should be larger than this calculated diffusion length.

Two dimensional intensity distribution of a line-modulated laser diode in a focusing zone

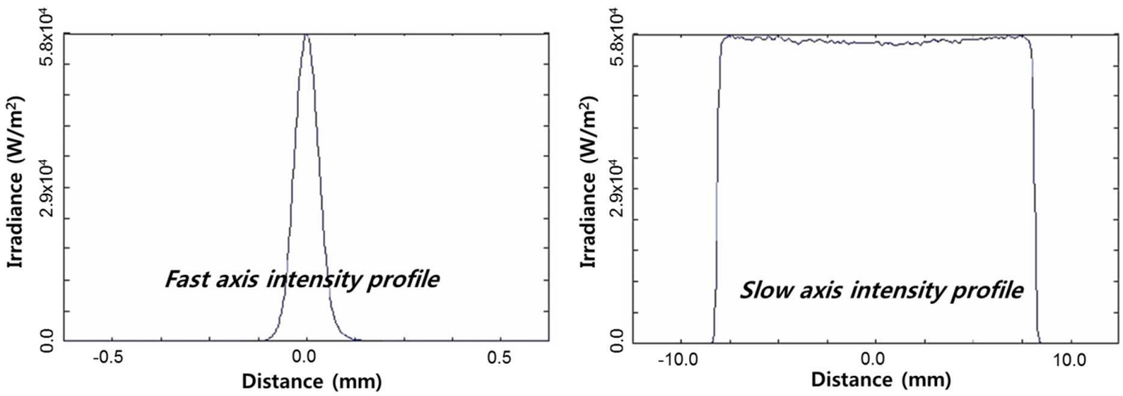

Figure S2. Spatial intensity distribution of a line-modulated diode laser of 500 W (left: on fast axis and right: on slow axis)

Effect of thickness of SiO_2 protective layer on pattern formation.

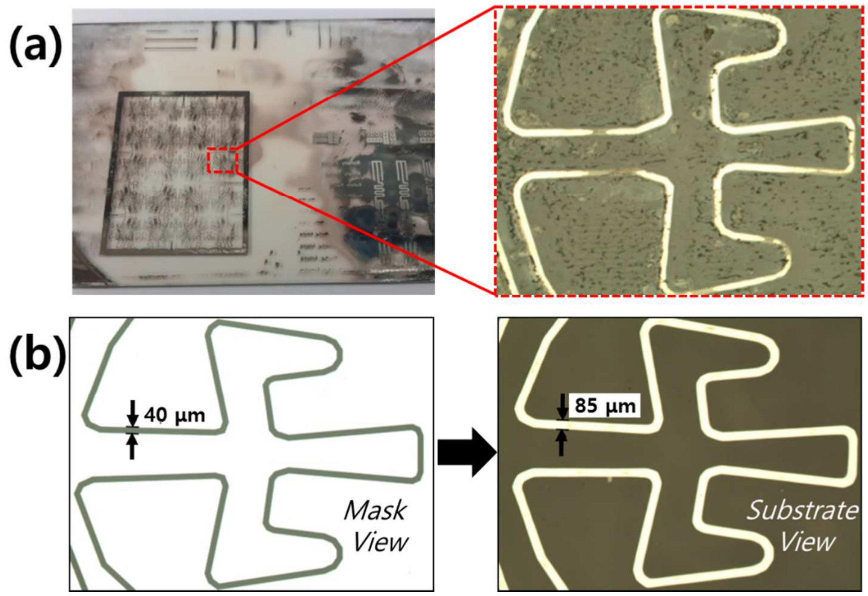

Figure S3. (a) Photograph and microscope image of patterns fabricated by using a photomask without a protective layer. (b) Microscope image of a photomask with a protective layer of 4 µm and corresponding printed patterns.

Variation of pattern width depending on laser power

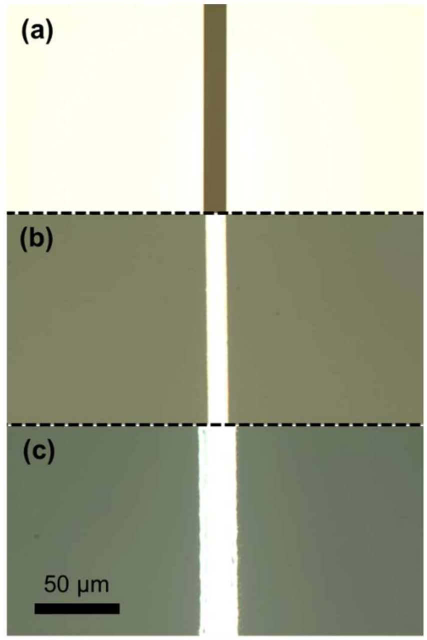

Figure S4. Variation of pattern width depending on laser power. (a) Microscopy of mask pattern and corresponding patterns printed at different laser powers ((b) 115W and (c) 125 W) under a scanning rate of 50 mm/s.

Productivity of laser sweeping lithography (LSL) in comparison with a conventional laser-induced fabrication method using a focused laser spot

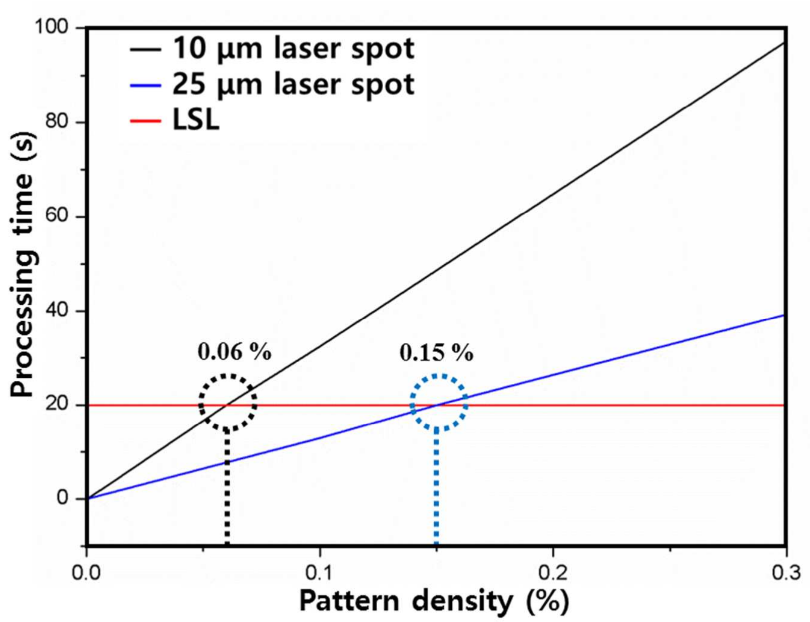

Figure S5. Comparison of processing time between conventional laser sintering method using single spots of 10 and 25 μm with respect to pattern density.

The processing time of LSL method is constant, regardless of the pattern density, while that of conventional single laser spot used method is proportionally increases with the required pattern density. For example, the processing time of LSL method begins to decrease from the very low pattern density of 0.06 % compared to that of conventional laser focused sintering (LFS) method using 10 μm laser spot. Even if the LSL requires more processing time to fabricate electrodes with very low density of less than 0.06 %, this case is not commonly occurred in the manufacturing of practical electronic devices. In addition, Table S1 shows the comprehensive productivity of LSL method in comparison with conventional approaches Therefore, it is obvious that the LSL is more effective and faster than conventional LFS method using single laser spot in most engineering situations.

Table S1 Evaluation of productivity of LSL method compared with a conventional laser focused sintering method

Productivity Evaluations	*Laser Focused Sintering (LFS) (Spot size: 25 μm/10 μm)*	*Laser Sweeping Lithography (LSL)*
Nominal maximum scanning rate (mm/s)	25/25	50
Patterning area per second (mm^2/s)	0.625/0.25	600
Expected process time (sec) for 4 in wafer	12,971/32,428 (99 % Density) 130/324 (1 % Density)	20