

## Thin Film Deposition, Characterization, and Application of Polyimides by Vapor-Phase Polymerization.

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### Abstracts:

Thin-film polyimides were prepared by solvent-less vapor deposition polymerization (VDP) from pyromellitic dianhydride and 4,4'-oxydianiline at 200°C for liner dielectric formation of vertical interconnects called Through-Silicon Vias (TSVs) used in three-dimensionally stacked integrated circuit (3D-ICs). FT-IR, synchrotron XPS, and TDS were employed for determining the imidization ratio, and in addition, the mechanical properties, coefficient of thermal expansion (CTE) and Young's modulus, of the VDP polyimide were characterized on Si wafers. The VDP polyimide exhibited extremely high conformality, beyond 75%, toward high-aspect-ratio deep Si holes, compared with

conventional SiO<sub>2</sub> prepared by plasma-enhanced chemical vapor deposition. The adhesion between the VDP polyimide and Si wafer was enhanced by an Al-chelate promotor. Remarkably, the VDP polyimide TSV liner dielectrics showed much less thermomechanical stresses applied to the Si surrounding the TSVs than the plasma-CVD SiO<sub>2</sub>. The small Keep-Out Zone (KOZ) is expected for scaling down highly reliable 3D ICs for the upcoming real artificial intelligence society.

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### Conclusions

We proposed a TFET based MONOS memory device to reduce the power consumption of neural net-

work circuits composed by flash memory. Then, we fabricated a TFETbased MONOS memory cell. The fabricated devices indicated both symmetric STDP characteristics. We also obtained the asymmetric STDP characteristics of a biological synapse using triple-level rectangular wave pair. These results indicate that the proposed devices have the potential to be a synaptic device.

### Acknowledgments

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### References

- Two papers on flexible device technology submitted to our laboratory's IEEE Trans. CPMT are ranked in The 50 most frequently accessed documents for this publication T. Fukushima et al., IEEE Trans. CPMT, vol. 8 (2018), 1738-1746  
□ T. Fukushima et al., IEEE Trans. CPMT, vol. 10 (2020), 1419-1422
- The 52nd International Conference on Solid State Devices and Materials ( SSDM2020 ) will be held virtually on 9 / 27-30. We will present a total of 6 research presentations on 3D integration technology, wiring technology, optogenetic radioneurological probe, and flexible hybrid electronics (FHE) from our laboratory.

- The 81st JSAP Autumn Meeting in 2020 will be held virtually on 9 / 8-11. We are planning to present two research presentations on Flexible Hybrid Electronics (FHE) and In-Mold Electronics (IME) from our laboratory.
  - Infection of the new coronavirus has spread to the online open campus of the Department of Mechanical Intelligence and Aeronautical Engineering in the 2nd year of Reiwa, which was scheduled for September 21st (Monday / holiday) and 22nd (Tuesday / holiday) in Reiwa. From the viewpoint of prevention, we decided to cancel the event as a result of putting the safety of visitors first. As an alternative event, we will publish video content that allows you to experience the atmosphere of lectures and laboratories on a special page ( scheduled to be released in late August ) that introduces various research fields in this department . You can also watch the introductory video of our laboratory.
  - Our laboratory paper was published in IEEE TRANSACTIONS ON COMPONENTS, PACKAGING AND MANUFACTURING TECHNOLOGY (Vol.10, No.8). "Significant Die-Shift Reduction and  $\mu$ LED Integration Based on Die-First Fan-Out Wafer-Level Packaging for Flexible Hybrid Electronics" (T. Fukushima et al.), DOI: 10.1109 / TCP-MT.2020.3009640
  - The 2020 IEEE 70th The Electronic Components and Technology Conference ( ECTC2020 ) was held at Virtual on 6 / 3-7 / 7. Our laboratory made a total of 5 presentations on 3D-IC technology and flexible device technology. In addition, M2 Noriyuki Takahashi received the 2020 ECTC Student Travel Award (the papers of 10 highly rated students among 499 submitted papers were awarded).
  - Our laboratory paper has been published in Journal of Polymer Science (Vol.58, No.16). "On-wafer thermomechanical characterization of a thin film polyimide formed by vapor deposition polymerization for through-silicon via applications: Comparison to plasma-enhanced chemical vapor deposition SiO<sub>2</sub>" (T. Fukushima et al.), DOI: 10.1002 / pol.20200094
  - The 4th IEEE Electron Devices Technology and Manufacturing Conference ( EDTM2020 ) was held in Virtual on 4 / 6-4 / 21. Associate Professor Fukushima gave an invited talk on self-organizing 3D-IC technology, and Assistant Professor Kino gave a lecture on non-volatile memory.
  - [The Tohoku University diploma awarding ceremony was canceled due to the influence of COVID-19 in the first year of Reiwa, but 1 doctor (engineering), 2 masters (engineering), 1 master (medical engineering), bachelor (engineering) A total of eight people, four of whom, were awarded diplomas. Four of them left our laboratory. (Details are here .)
- [2020.3.3] A birthday party for Dr. Toru Tanaka was held. The gifts and cakes were very exciting and the teacher was pleased. (Details are here .)
- [2020.2.28] Our laboratory paper has been published in Japanese Journal of Applied Physics (Vol.59, No.5G). "Symmetric and asymmetric spike-timing-dependent plasticity function realized in a tunnel-field-effect-transistor-based charge-trapping memory" (H. Kino et al.), DOI: 10.35848 / 1347-4065 / ab6867
- [2020.2.27] Associate Professor Fukushima's research was published in Impact magazine (Vol.2020, No.1, Publisher: Science Impact Ltd) in the United Kingdom. "A new DSA technological dawn: Directed Self-Assembly based Interconnect Technology for Next-Generation 2D / 3D LSI", DOI: <https://doi.org/10.21820/23987073.2020.1.6>
- [2020.2.17] Our laboratory's paper has been published in the Journal of the Institute of Electronics, Information and Communication Engineers C (Vol. J103-C, No. 3). "Wiring formation on hydrogel flexible substrates using RDL-First FOWLP technology" (Noriyuki Takahashi et al.).