High-Bendable 3D Corrugated Interconnections for Chiplet-Embedded Flexible Hybrid Electronics (FHE) Using Wafer-Level Packaging

Chang Liu, Tadaaki Hoshi, Jiayi Shen, Atsushi Shinoda, Zehua Du, Hisashi Kino, Tetsu Tanaka, and Takafumi Fukushima | Tohoku University

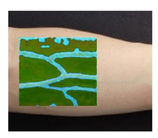
Background and Motivation

Smart Skin Display's function
- Pulse wave monitoring
- SpO_2, detection
- Vessel visualization
- Blocked blood vessel prevention etc.

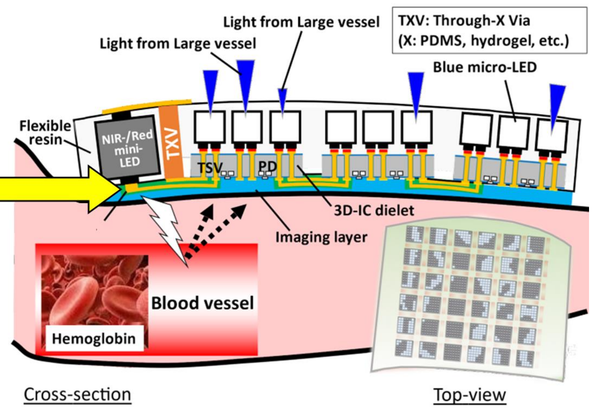
Components:
- 3D-IC chiplets
- Mini-LEDs
- Micro-LEDs

Device photo

Expected image

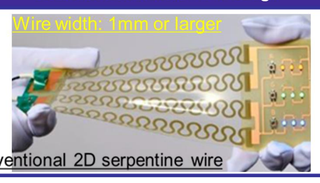


Multi-level flexible-wire formation

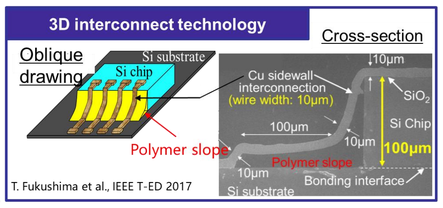


3D wire formation

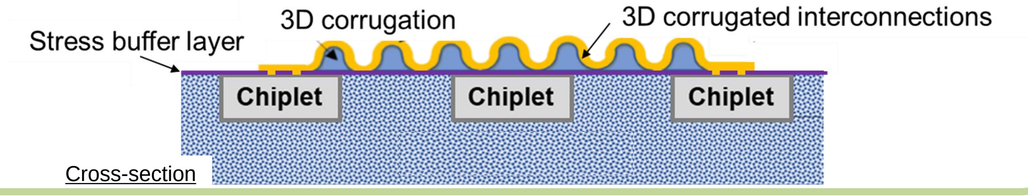
Excellent bendable wire design



3D interconnect technology Cross-section

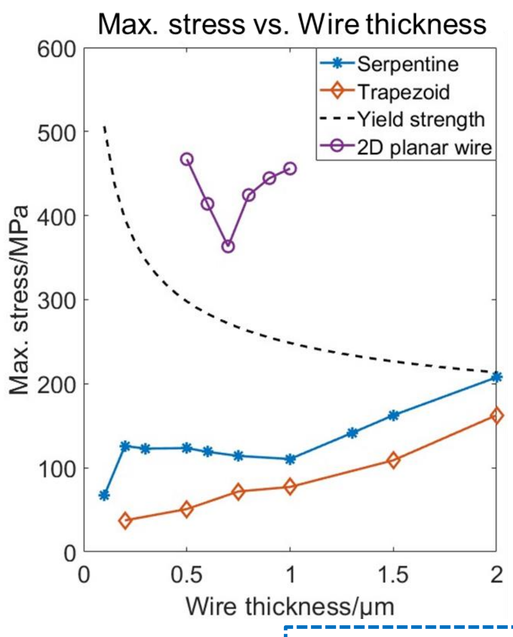


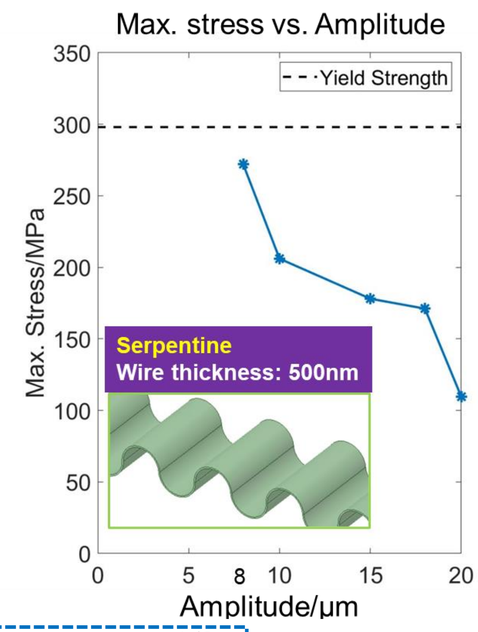
3D corrugated interconnections based on WLP



Simulation Result

Simulation results of interconnect thickness/width vs max. stress

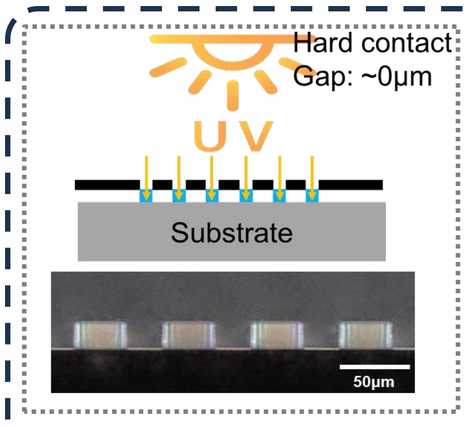


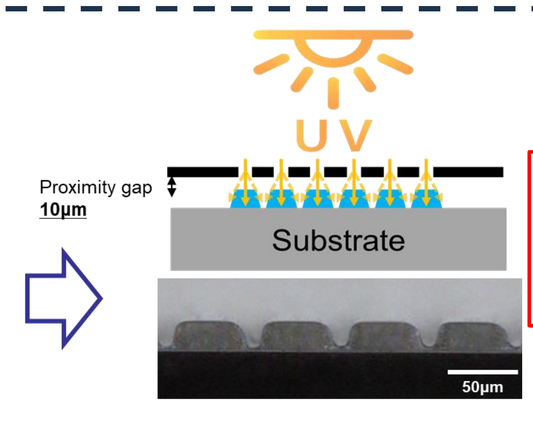


$$\sigma_{yeild\ strength} = 129.2 + 119.3t^{-1/2} *$$

Fabrication Target:
1)Wire thickness: 0.5-1μm. 2)Amplitude: ~20μm. 3)Wire width: ≤100μm

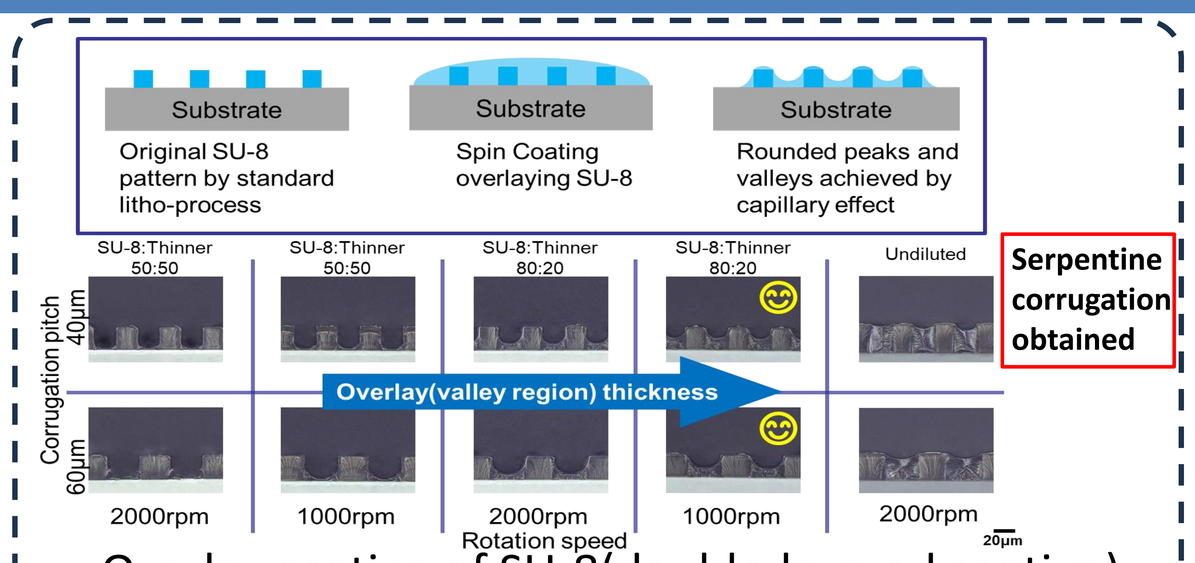
Strategies of corrugate interconnect fabrication



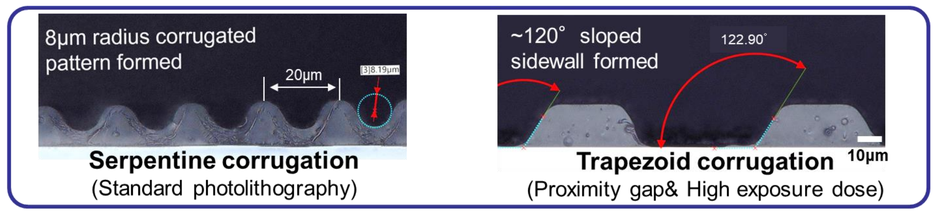


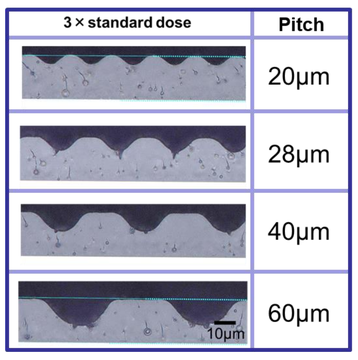
One-step litho; not feasible for fine-pitch

Proximity gap and high dose exposure (SU-8)



Overlay coating of SU-8(double-layered coating)





	SU-8	PSR
Young's modulus	2.0GPa	1.0~1.2GPa
Curing temp.	150-200℃	130℃
Developer	Organic	2.38% TMAH : H_2O 1 : 15 vol%

Solubility of PSR against alkaline is much higher than SU-8 to organic developer

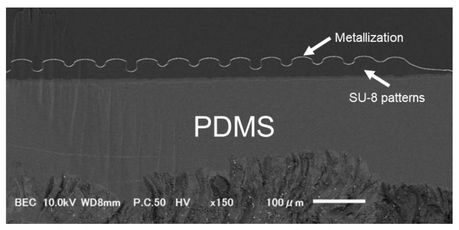
Processing temp. involved with PDMS < 120℃ (CET mismatch)

Both serpentine and trapezoid corrugation can be formed by 1-step photolithography process

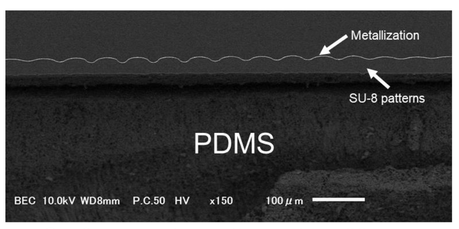
The use of pliable solder resist (PSR)

Fabrication Result and Bending Test

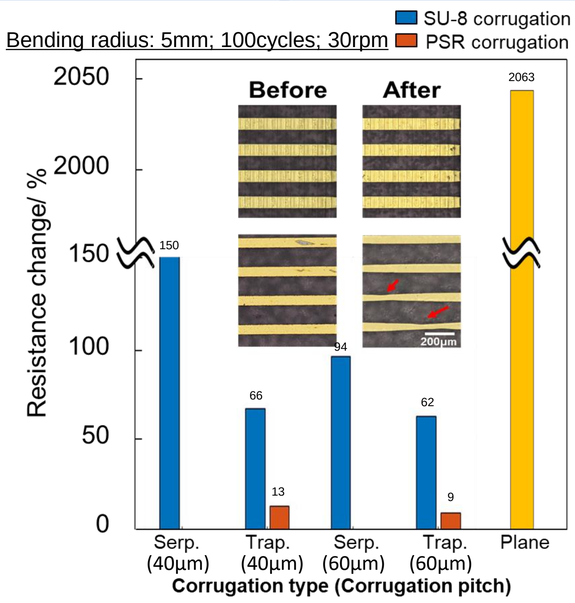
Interconnect formation



SU-8 corrugated patterns Pitch 40μm



SU-8 corrugated patterns Pitch 60μm



Conclusion

- To address the interconnect bending stress concentration issue, three strategies were proposed to form 3D corrugated structures.
- Two photosensitive materials, brittle SU-8 and flexible PSR, are employed for the fabrication of corrugations. PSR costs less effort but requires more exploration.
- The resistance changes are drastically reduced when using the 3D corrugated wires compared to the wires without the 3D corrugation.
- PSR trapezoid corrugation further reduced the resistance change due to its lower Young's Modulus.

Acknowledgement

This work was performed in the Micro/Nano-machining research and education Center (MNC) and Jun-ichi Nishizawa Research Center at Tohoku University. This work was supported by JSPS KAKENHI Grant Number 19KK0101, 21H04545, and 22K18291. This work was supported by JST SPRING, Grant Number JPMJSP2114. This work was supported by Graduate Program for Integration of Mechanical Systems of Tohoku University. This work was also supported through the activities of VDEC, The University of Tokyo, in collaboration with Cadence Design Systems.

2023 UCLA CHIPS Workshop
Poster Session

UCLA CHIPS CENTER FOR HETEROGENEOUS INTEGRATION AND PERFORMANCE SCALING