Design of 385 x 385 μm^2 0.165V 270pW Fully-Integrated Supply-Modulated OOK Transmitter in 65nm CMOS for Glasses-Free, Self-Powered, and Fuel-Cell-Embedded Continuous Glucose Monitoring Contact Lens

Kenya Hayashi[1], Shigeki Arata[1], Ge Xu[1], Shunya Murakami[1], Cong Dang Bui[1], Takuyoshi Doike[1], Maya Matsunaga[1], Atsuki Kobayashi[1] and Kiichi Niitsu[1, 2]

[1]Nagoya University, [2]PRESTO/JST, Japan

This research was financially supported by JST, PRESTO (No. JPMJPR15D5), by Council for Science. Technology and Innovation(CSTI), Cross-ministerial Strategic Innovation Promotion Program(SIP), "Energy systems toward a decarbonized society" (Funding agency:JST), by a Grant-in-Aid for Scientific Research (S) (No. 25220906), Grant-in-Aid for Young Scientists (A) (No. 16H06088) from the Ministry of Education, Culture, Sports, Science and Technology of Japan, and by MIC/SCOPE # 152106004 and # 185106001.

Motivation

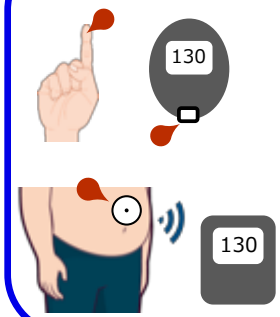
Diabetes

- Many complications
- Enormous cost of care
- 400 million people are involved

➡ **Need for preventive care**

➢ Continuous Glucose Monitoring (CGM)

Conventional Product



Needle type CGM

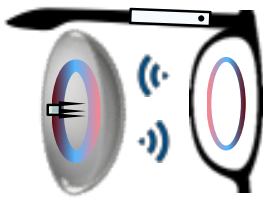
◎ Widely diffused

✘ High-Invasive

✘ High cost

→ Cannot be provided widely for prevention

Conventional Research



Smart contact lens *

◎ Non-invasive

✘ High cost

✘ Requirement of external power

→ Cannot be provided widely for prevention

This Work

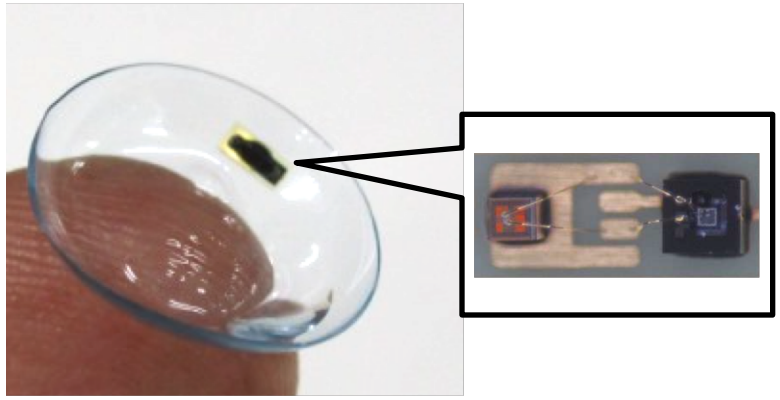
Proposed self-powered CGM

◎ Non-invasive

◎ Self-powered operation

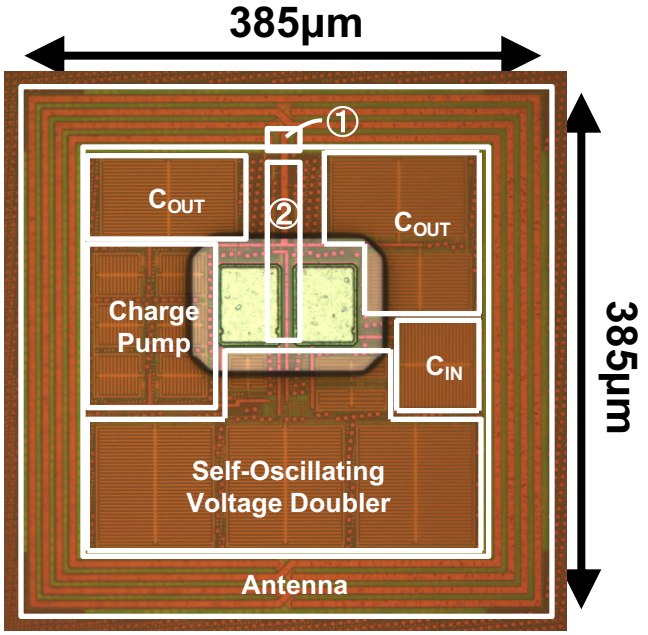
◎ Small size (2mm^2)

◎ Low cost (less than 1$)

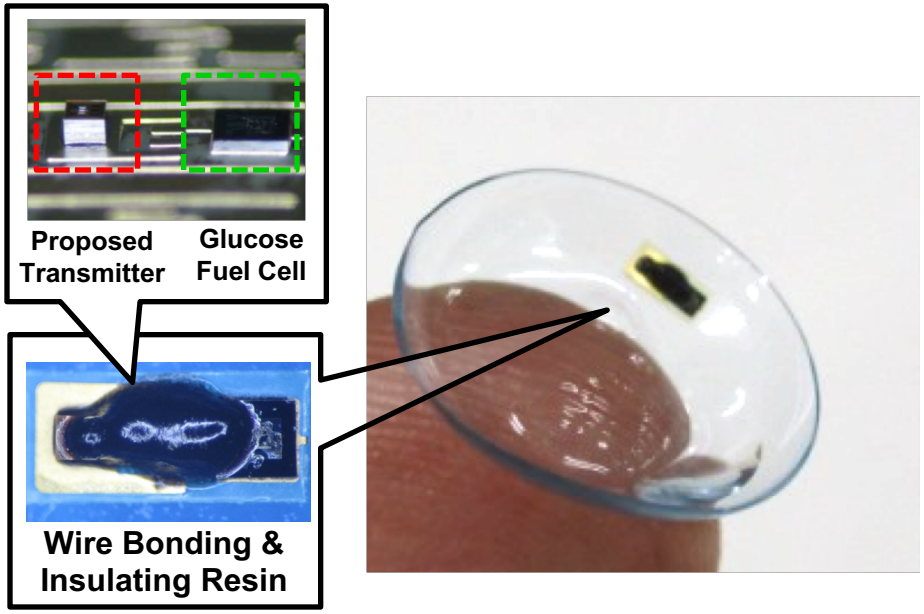


* Y. T. Liao et al., IEEE JSSC, vol. 36, no. 2, pp. 335-344, Apr. 2012.

Proposed Architecture



① : LC Power Oscillator ② : Switching Circuit



Proposed Transmitter

- 65nm standard CMOS process
- Low power (270 pW at 0.165 V)
- No off-chip components
- Small area (385 x 385 um^2)
  - ➢ Low cost

Proposed Glucose Sensor

- Self-Powered CGM contact lens
  - ➢ Non-invasive → Pain-Free
  - ➢ Low cost → Widely spread
  - ➢ Good usability
- Small area (1 x 2 mm^2)

Comparison Table

- 1/10000 power reduction compared to conventional CGM research.
- Can be fully-integrated. Cost of glucose sensing can be less than 1$.
- 1/10 power reduction compared to conventional sub-mm² transmitter.

	JSSC 2012[1]	TCAS-I 2015[2]	This Work
CMOS Process	130 nm	32 nm	65 nm
Architecture	Glucose Sensor & Transmitter	Transmitter	Glucose Sensor & Transmitter
Minimum Power Consumption	3 μW	3 nW	270 pW
Operating Voltage	1.2 V	0.1 – 0.19 V	0.165 – 0.39 V
Off-Chip Components	Antenna, Electrode, Wireless Power Delivery	None	CMOS compatible glucose fuel cell (Can be on-chip)
Specific Process Characteristic	None	Deep-trench capacitors (250 fF/μm²)	None
Kick Start	Needed	None	None
Area	Circuits: 0.6 × 0.6 mm² All of the Glucose Sensor: 10 × 10 mm² (+ External Wireless Power Delivery Device)	0.3 × 0.3 mm²	Circuits: 0.385 × 0.385 mm² All of the Glucose Sensor: 1 × 2 mm²

[1] Y. T. Liao et al., IEEE JSSC, vol. 36, no. 2, pp. 335-344, Apr. 2012. [2] J. Choi et al., IEEE TCAS-I, vol. 62, no. 8, pp.1950-1958, Aug. 2015.