MMC development for the AMoRE project

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Abstract

We present the progress on the MMC development to be used in the AMoRE project. AMoRE used MMCs as the main readout technology for heat and light detection. The MMCs sensors was first developed based on a gold alloy with 1000 ppm Er. The size of the AuEr sensor material was determined to optimize signal size in the heat channel having a large crystal absorber of about 100 cm^3. Since the measurement is carried out in 10-20 mK, silver based MMC is advantageous in terms of heat capacity in the temperature region. We compared the signal amplitudes of two detector setups with gold foil absorbers in the same size but different sensor materials of a AuEr (1000 ppm) and AgEr (400 ppm).The AgEr sensor resulted in larger signals below 30 mK. Moreover, in the light channel, the size of the AgEr sensor was varied to optimize the light channel with 2 inch Ge r Si wafers. We will summarize the test results with tour different sizes of AgEr sensors together with Ge wafer in the same size.

Introduction

- **Low-temperature detector**

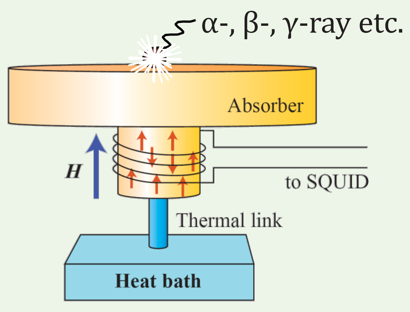
  Energy absorption Heat (Temperature)

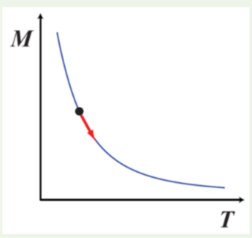
  o Measure the temperature changes of the absorber

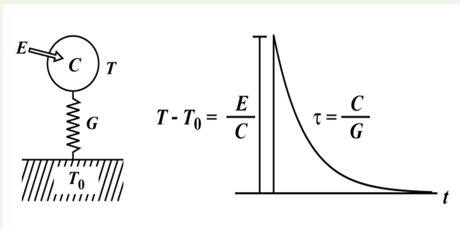
  o Temperature changes: $\delta T = E/C$

  o Relaxation time to bath temperature: $\tau = C/G$

- **Metallic Magnetic Calorimeters (MMCs)**







G : Thermal conductance

C : Heat capacity

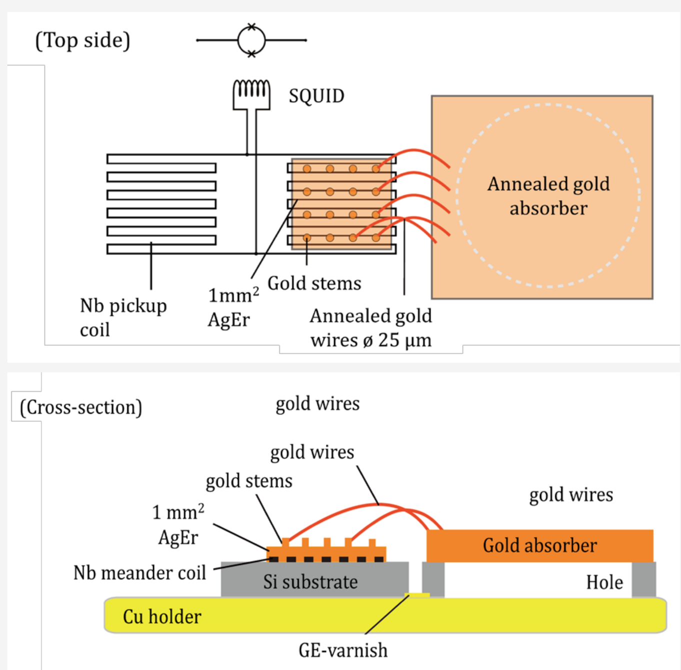
Energy (ΔE) → **Temperature (ΔT)** → **Magnetization (ΔM)** → Magnetic flux (ΔΦ) → Voltage(ΔV)

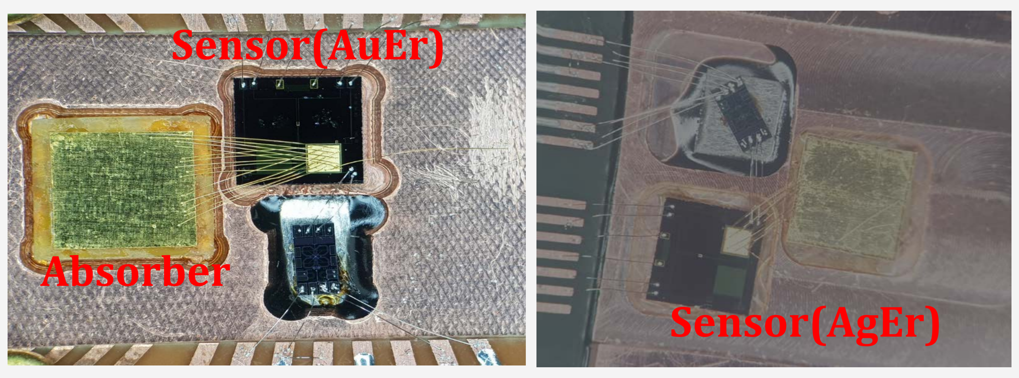
- Sensor material: AgEr, AuEr

  keeps its paramagnetic properties at tens of mK ranges

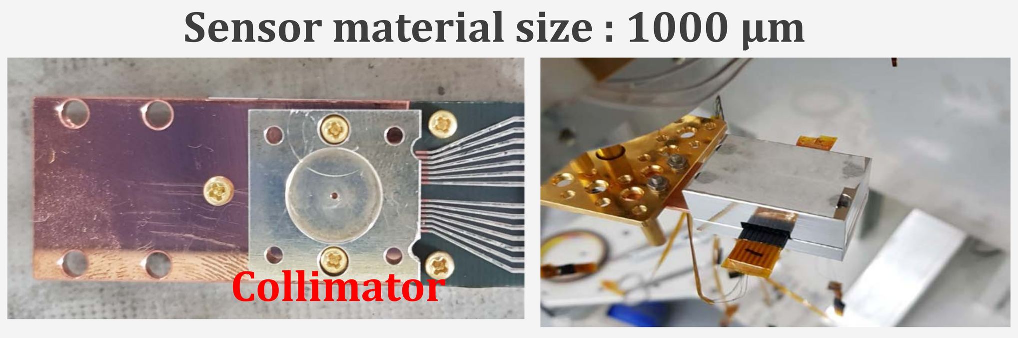
- SQUID: Superconducting Quantum Interference Device converts the change of magnetic flux into a measurable voltage signal

Schematic of experimental setup (AuEr (1000 ppm) vs AgEr (400 ppm))



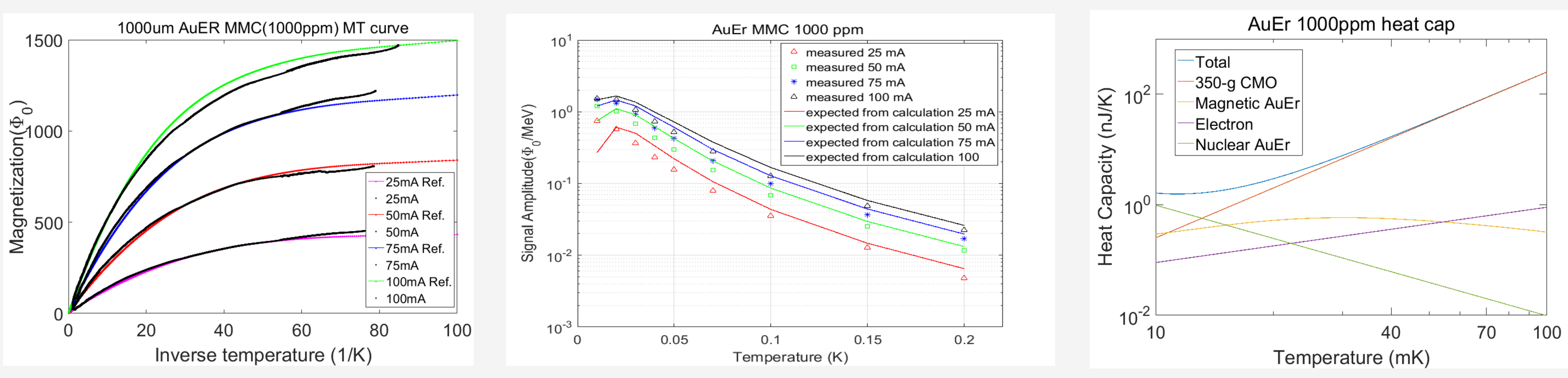


Sensor material size : 1000 µm

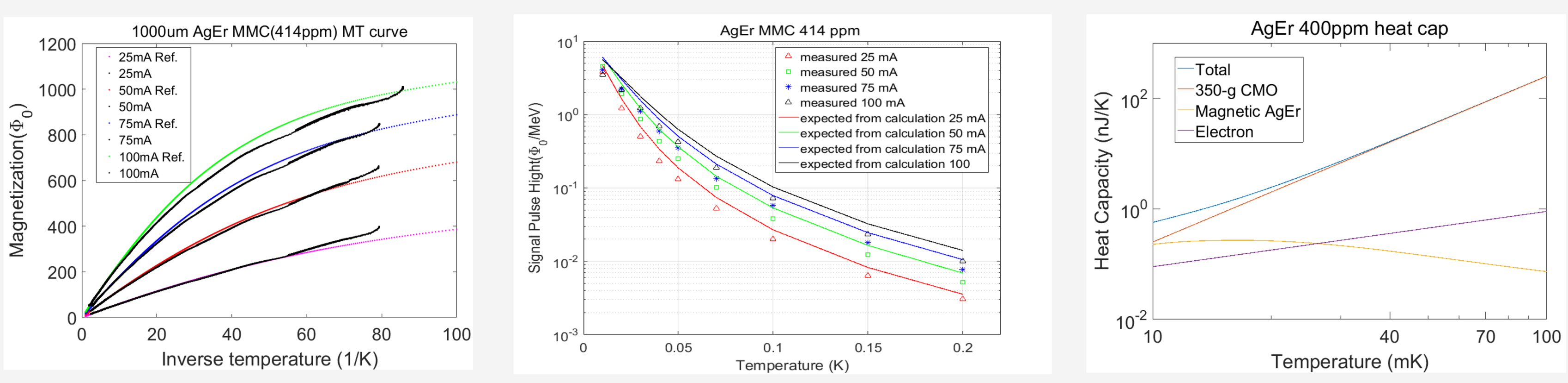


Signal analysis : AuEr and AgEr

AuEr MT curve — Signal Amplitude — Heat capacity (low temp.)



AgEr MT curve — Signal Amplitude — Heat capacity (low temp.)

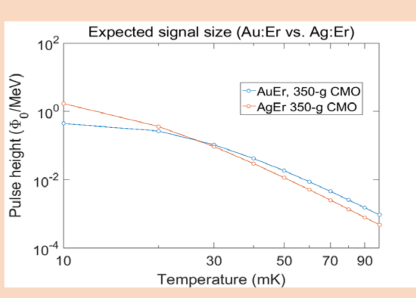


Summary : AuEr vs AgEr alloy sensor

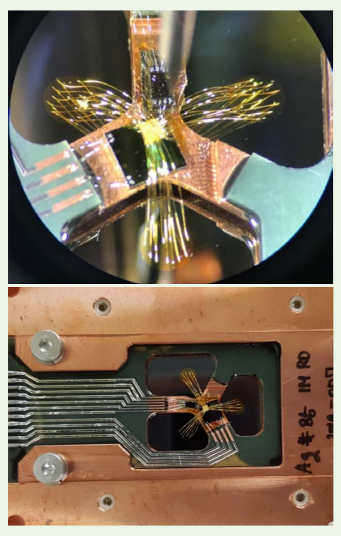
o Compared the signal amplitudes of two detector setups with gold foil absorbers in the same size but different sensor materials of an AuEr (1000 ppm) and AgEr (400 ppm).

o Since the measurement is carried out in 10-20 mK, silver based MMC is advantageous in terms of heat capacity in the temperature region.

o The AgEr sensor resulted in better signals below 30 mK than AuEr. And near at 10 mK, signal height of AgEr is more sensitive about 3 times than AuEr.



Set up of the light detector various the AgEr size

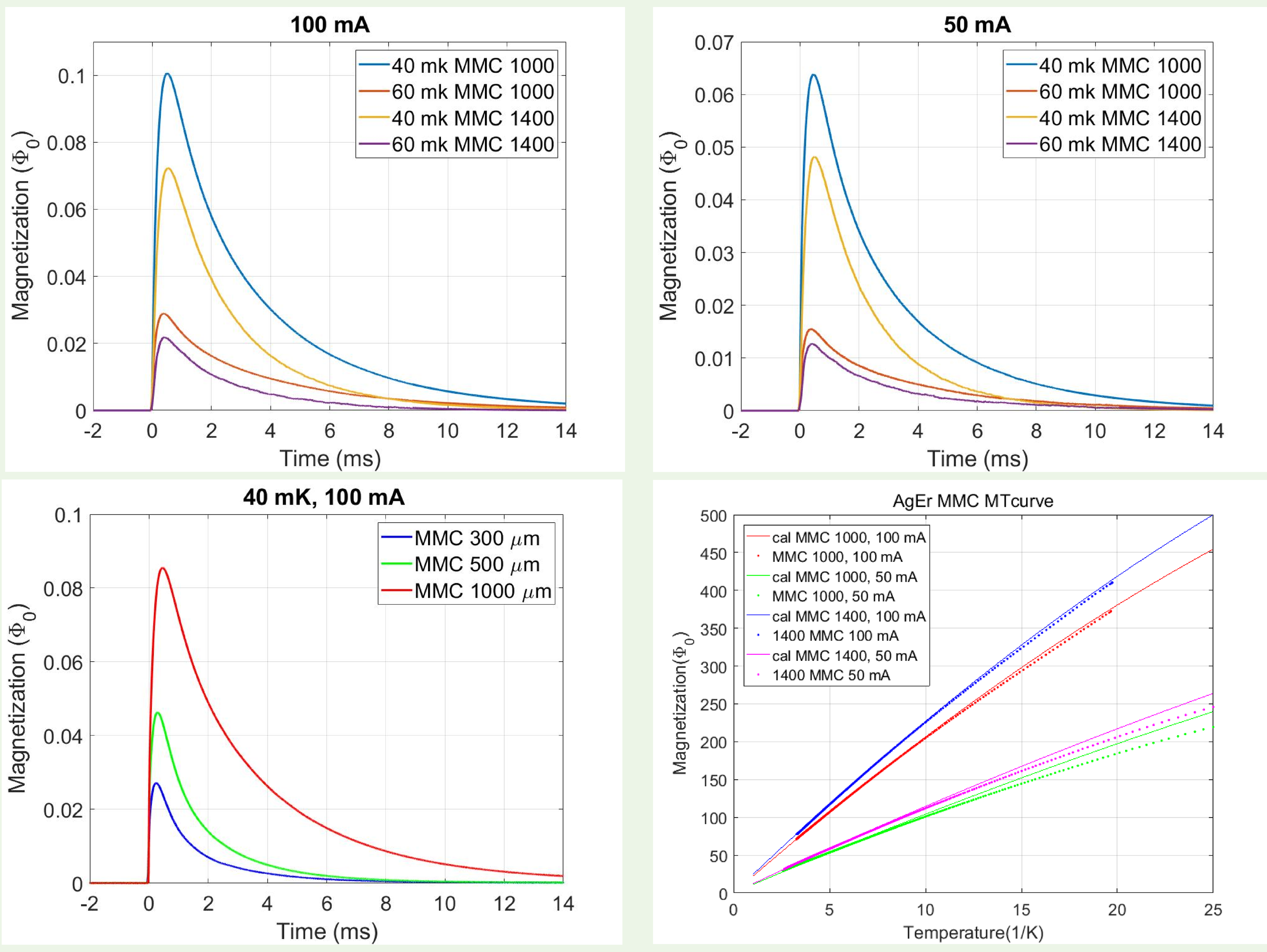


Photon absorption in the wafer → Phonon collector →MMC

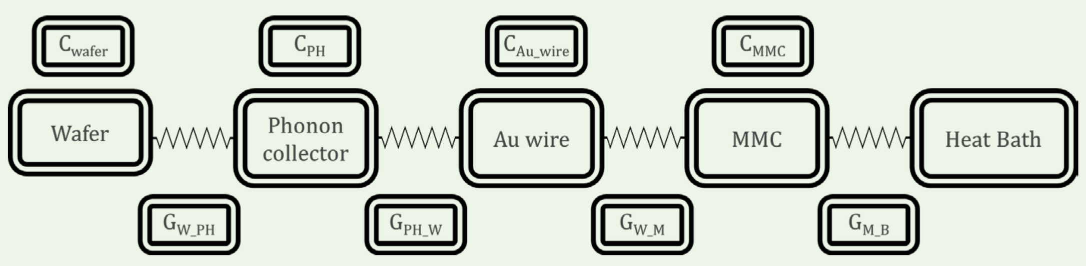
- MMC : works as a temperature sensor
  - (Experiment of MMC sensor area 9 ×10^{-2} ~1.8 µm^2)
- Photon absorber : 2″ Ge wafer absorber
- Phonon Collector : 3 circle shaped Au films (3 mm in diameter, 300 nm thick)
- Au wires : Thermal connection between the phonon collector and the MMC
- SQUID : Read out the MMC signal

Measured data of AgEr MMC

Pulse Height : MMC size & Injected permanent current



Analysis of the simple heat input model



Energy (ΔE) → Voltage(ΔV) → Magnetic flux (ΔΦ) → Magnetization (ΔM) → Temperature (ΔT)

$$\dot{T}_{wafer} = {G_{w\_PH}}/{C_{wafer}} \times (T_{wafer} - T_{PH}) + (1-\epsilon) \times {\dot{Q}_{wafer}}/{\tau} \times e^{-t/\tau}$$

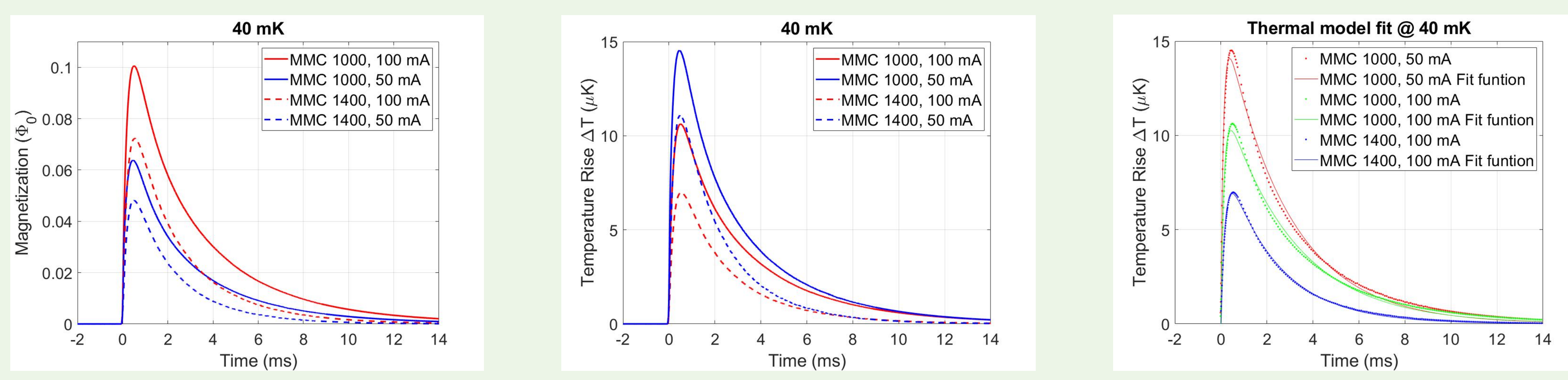
$$\dot{T}_{PH} = {G_{w\_PH}}/{C_{PH}} \times (T_{PH} - T_{wafer}) + {G_{w\_ph}}/{C_{PH}} \times (T_{PH} - T_{Au\_wire}) + \epsilon \times {\dot{Q}_{wafer}}/{\tau} \times e^{-t/\tau}$$

$$\dot{T}_{Au\_wire} = {G_{PH\_W}}/{C_{Au\_wire}} \times (T_{Au\_wire} - T_{PH}) + {G_{W\_M}}/{C_{Au\_wire}} \times (T_{Au\_wire} - T_{MMC})$$

$$\dot{T}_{MMC} = {G_{W\_M}}/{C_{MMC}} \times (T_{MMC} - T_{Au\_wire}) + {G_{M\_B}}/{C_{MMC}} \times (T_{MMC} - Heat - Bath)$$

$$\dot{Q}_1 = {E}/{\tau_1} \times e^{-t/\tau}$$

$$\dot{Q}_2 = {E}/{\tau_2} \times e^{-t/\tau}$$



Discussion and Conclusion

o The silver based MMC is advantageous in the of heat capacity under 30 mK, and near at 10 mK, signal height of AgEr is more sensitive about 3 times than AuEr.

o Experiments were performed to optimize the variation size of AgEr alloy and injected permanent current that the pulse height were compared.

o From the comparison of changes in temperature and magnetization, we optimized signal in MMC with appropriate heat capacity. In this experiment, the best performance shows when the persistent current of 100 mA applied for 1000 µm size.