

Identification of Extracted Ion Current Spectrum in Synthesising Fe@C₆₀ on ECRIS

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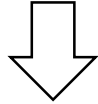
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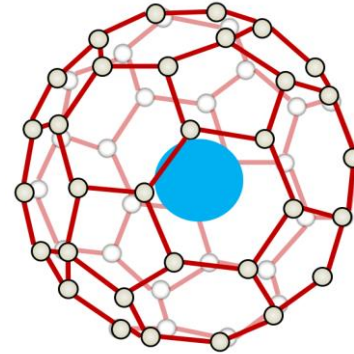
ECRIS 2020

Application of Electron cyclotron resonance ion source (ECRIS)



Atom endhedral fullerene ($M@C_{60}$)

- $Ar@C_{60}$: Super conducting materials
- $Li@C_{60}$: Solar cell
- $N@C_{60}$: Quantum computing



Generating $Fe@C_{60}^{\pm}$

- for contrast agents with highly sensibility for MRI
- for quantum computing
- 40~60eV of synthesis energy
- There is no stable method generating them


In ECRIS...

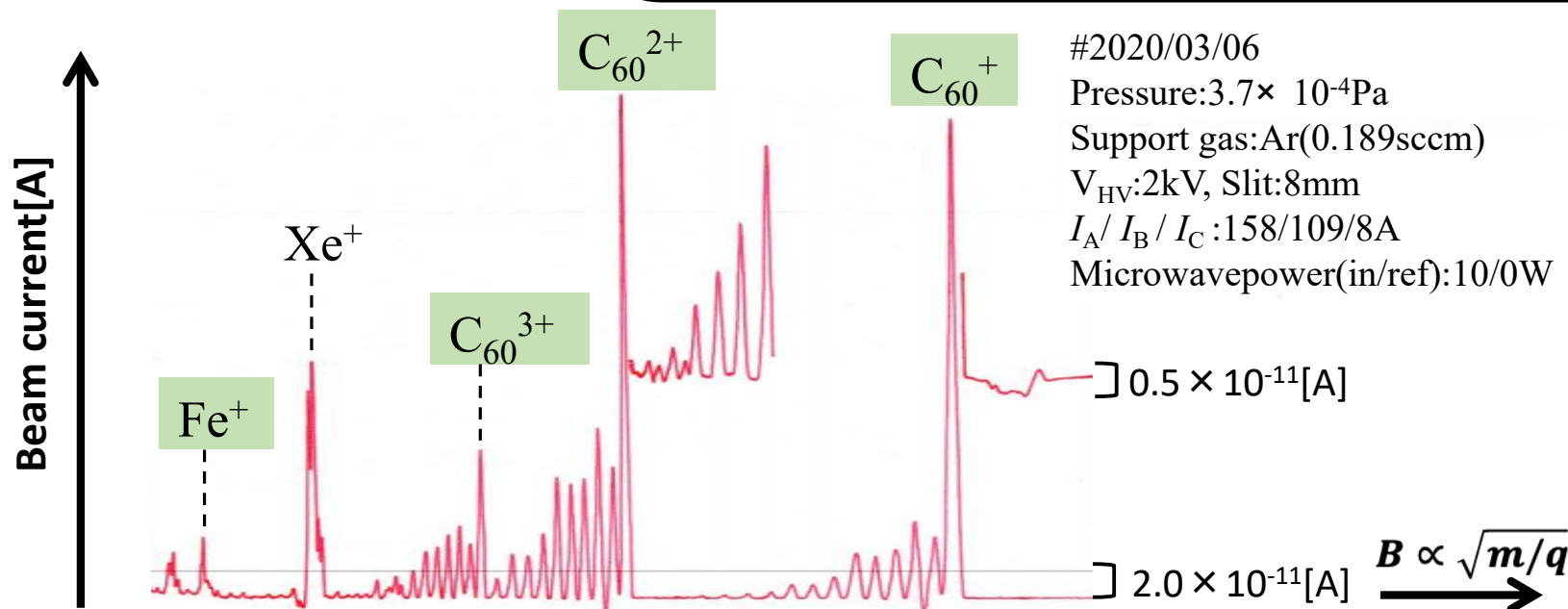
- **Synthesis in gas phase**
- **High yield generation**

Past studies

- Improvement of Iron ion evaporator
- Coexistence of Fe^{q+} and C_{60}^{q+} ions^[1]

Purpose

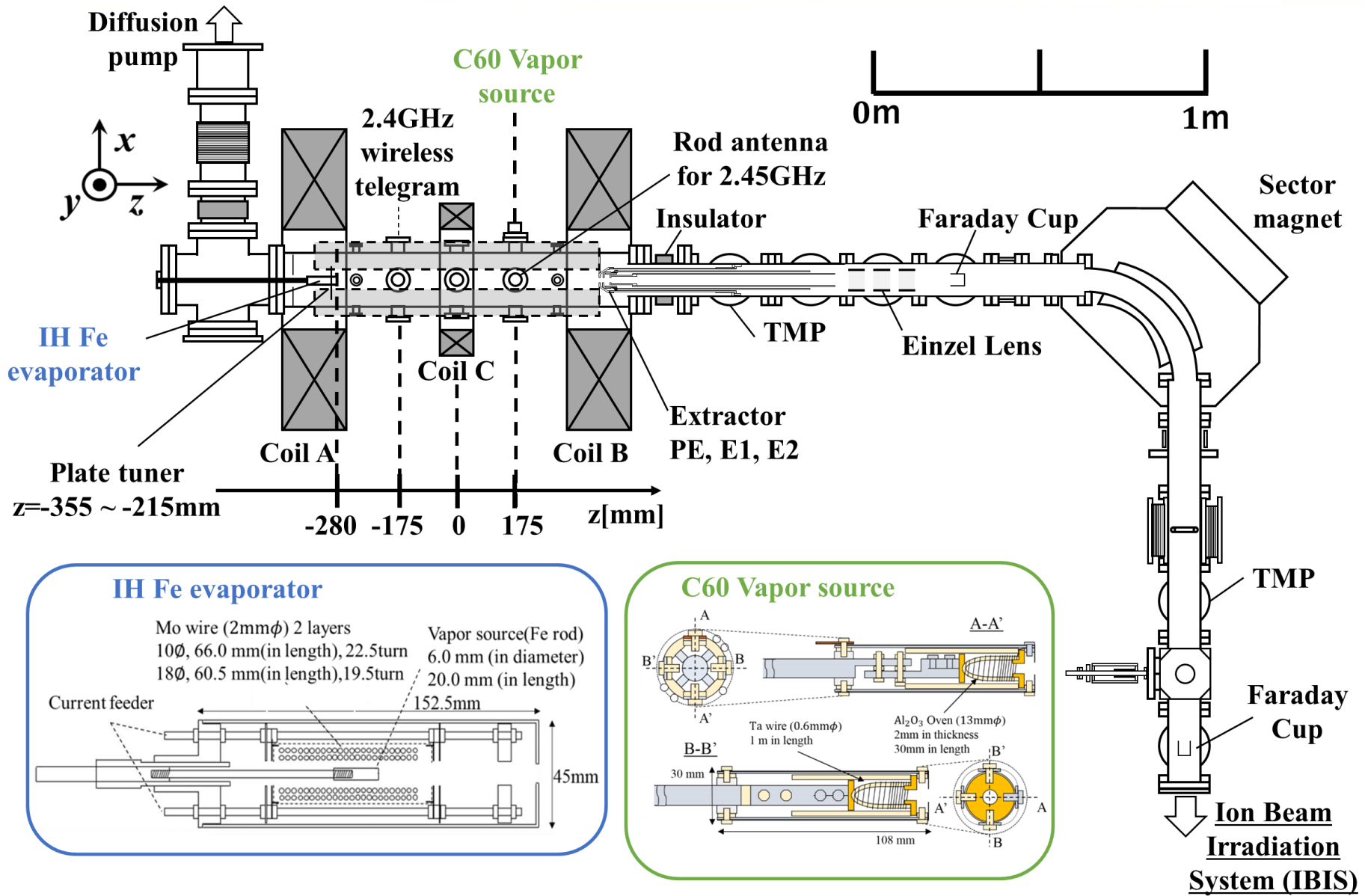
- Investigation of the formation possibility of iron endohedral fullerene
- 
 ▪ Detail identification of charge state distribution (CSD)



Experimental equipment



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Experimental procedure (Fe^{q+} & C_{60}^{q+} coexistence)

Suitable Extraction voltage & Microwave power

	Ext. voltage	μw pow.
Fe^{q+}	10kV	5~20W
C_{60}^{q+}	2kV	~1W

#2020/03/06

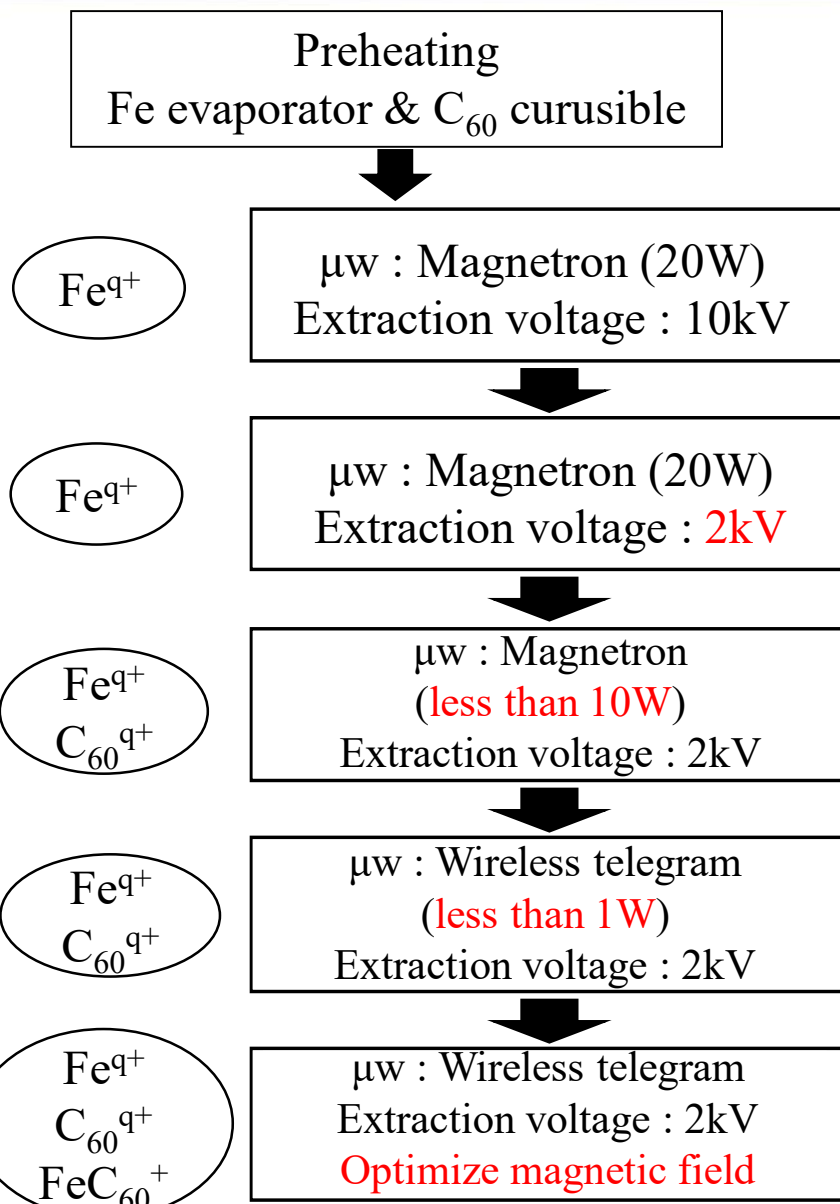
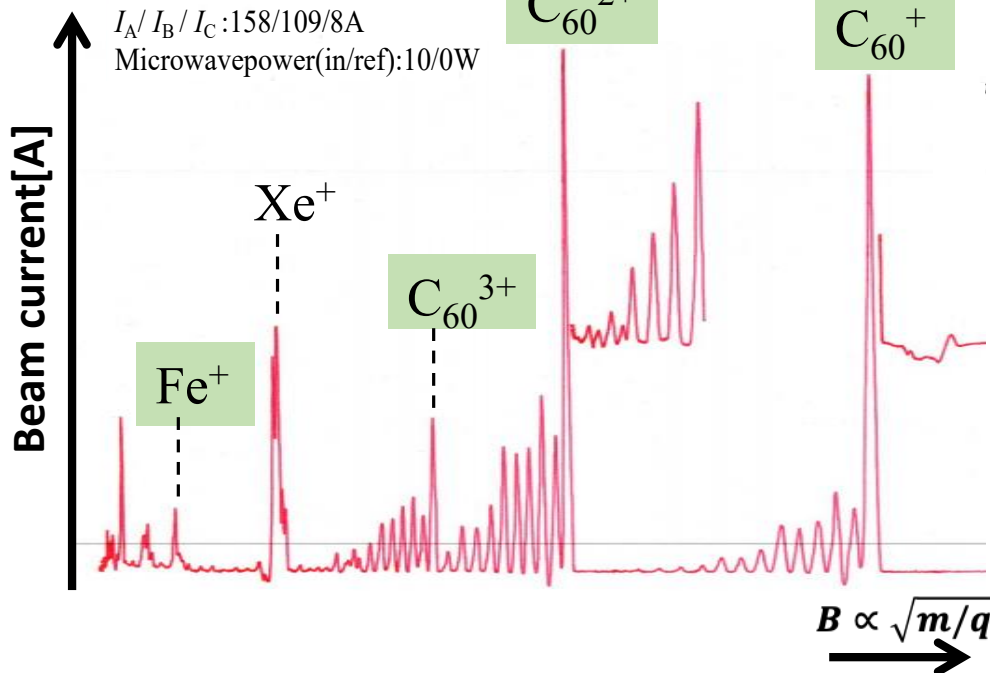
Pressure: $3.7 \times 10^{-4} \text{Pa}$

Support gas: Ar(0.189sccm)

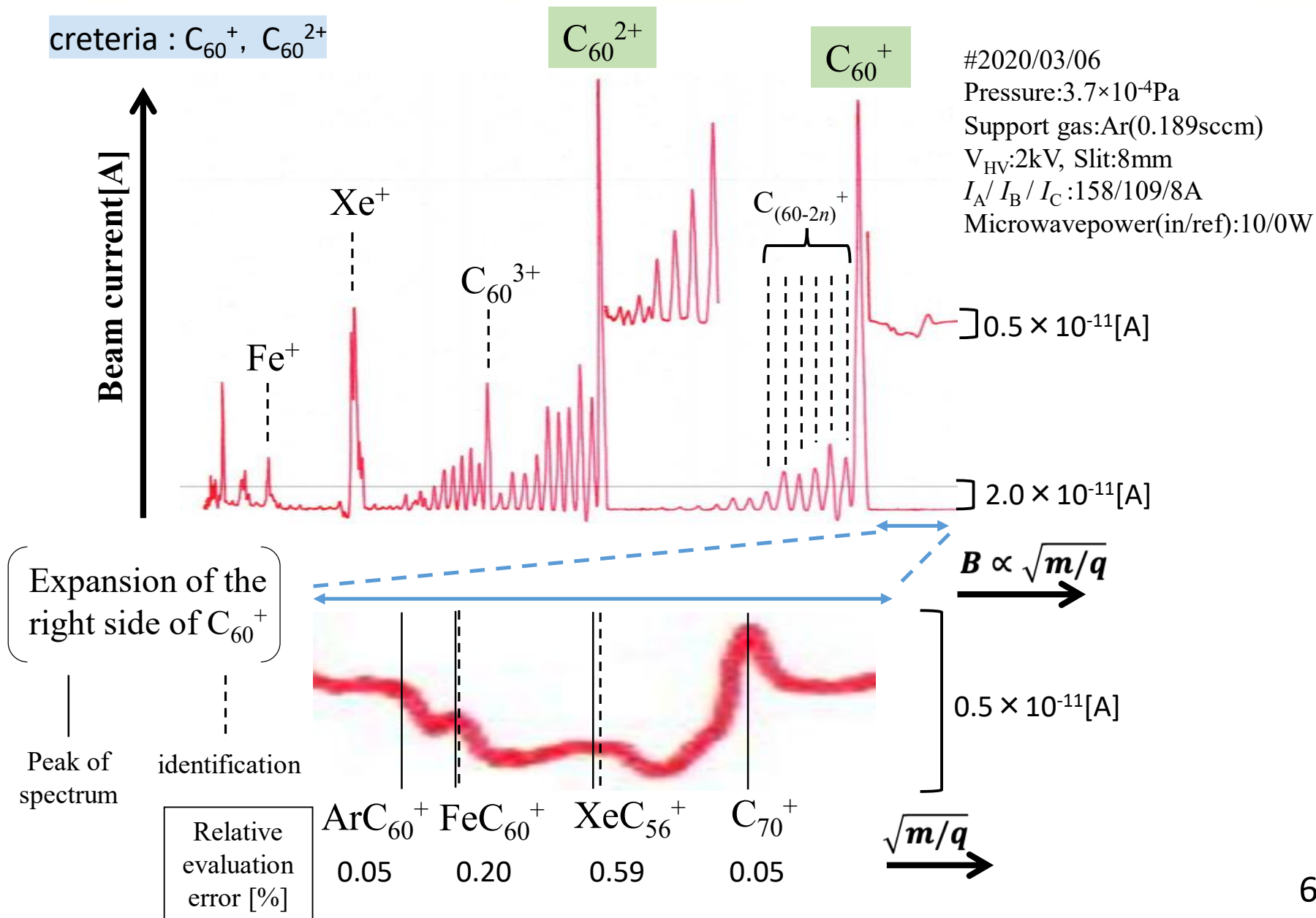
V_{HV} : 2kV, Slit: 8mm

$I_A / I_B / I_C$: 158/109/8A

Microwavepower(in/ref): 10/0W



Error evaluation with different criteria



$$\text{Relative error}[\%] = \left| \frac{\alpha_1 - \alpha_2}{\alpha_1} \right| \times 100$$

α_1 : theoretical mass/charge (m/q) value

α_2 : mass/charge (m/q) value measured by CSD

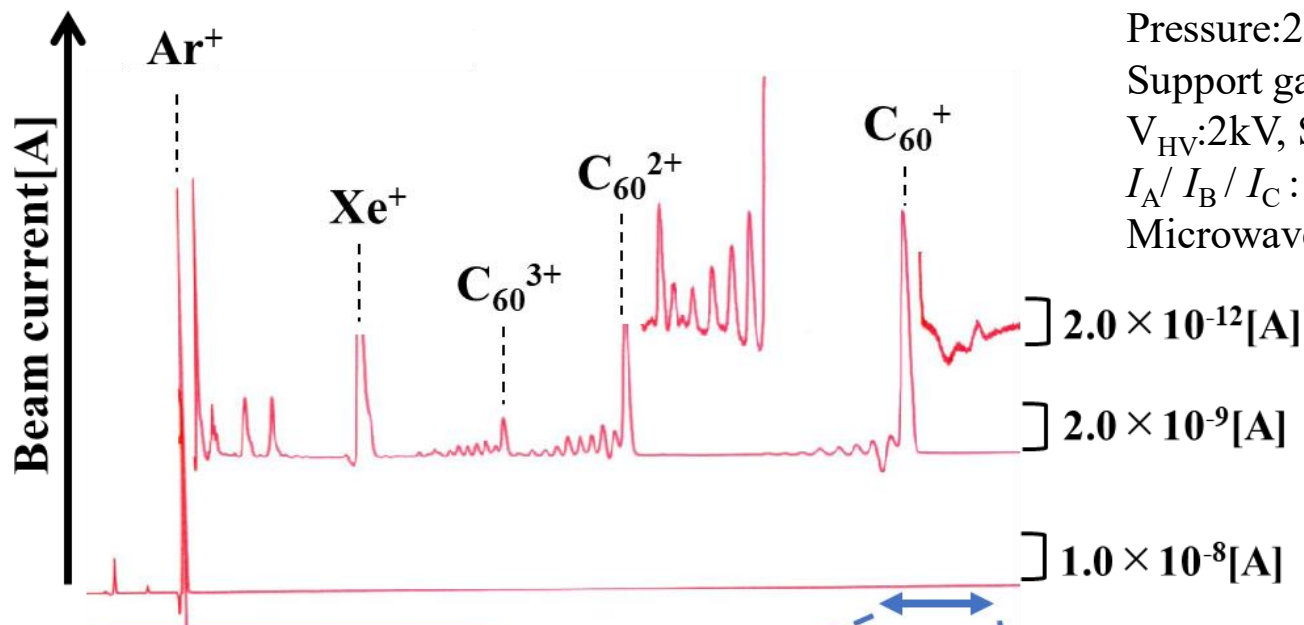
Relative error evaluation in each of the identification criteria [%]

Identification creteria	ArC ₆₀ ⁺	FeC ₆₀ ⁺	XeC ₅₆ ⁺	C ₇₀ ⁺
C ₆₀ ⁺ & C ₆₀ ²⁺	0.10	0.50	0.34	0.24
C ₆₀ ⁺ & C ₆₀ ³⁺	0.05	0.44	2.08	0.19
C ₆₀ ⁺ & Fe ⁺	0.60	0.44	1.07	0.47
C ₆₀ ²⁺ & Fe ⁺	1.47	1.32	1.92	0.52
Ave. error	0.56	0.68	1.35	0.36

⇒ The spectrum of atom endohedral fullerene were identified with the average relative error of 0.36~1.35%.

Additional experiment (without iron ions)

(a) Typical CSD of without iron ions



#2020/07/28

Pressure: 2.0 × 10⁻⁴ Pa

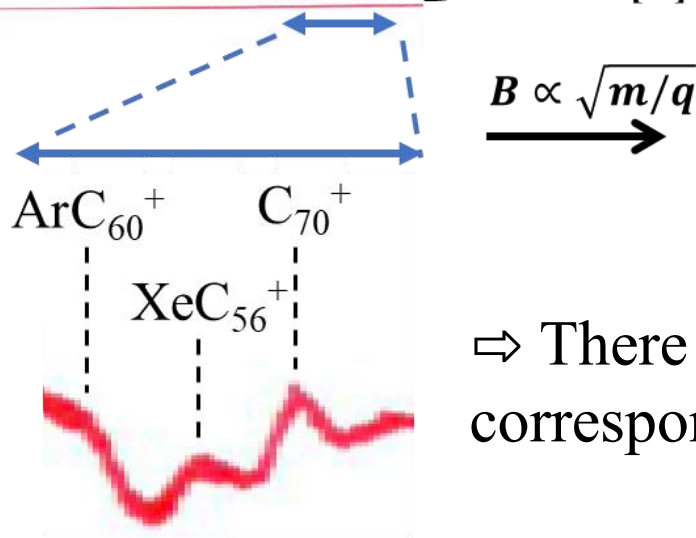
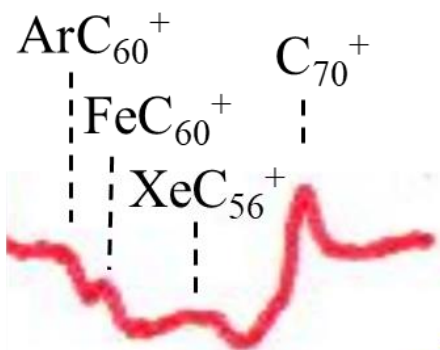
Support gas: Ar (0.183 sccm)

V_{HV}: 2 kV, Slit: 8 mm

I_A / I_B / I_C: 158 / 110 / 5 A

Microwave power (in/ref): 5/0 W

(c) Spectrum near C₆₀⁺ (with iron ions)



(b) Spectrum near C₆₀⁺

⇒ There is no spectrum corresponding to Fe@C₆₀⁺

Summary

- Synthesis of iron-endohedral fullerenes on ECRIS
- The spectrum corresponding to $\text{Fe}@C_{60}^+$ is identified with the average relative error of 0.68%
 - ⇒ The possibility of generating $\text{Fe}@C_{60}^+$ is suggested
- Additional experiment without iron ions introduction
 - ⇒ There is no spectrum corresponding to $\text{Fe}@C_{60}^+$

Future work

- Increase the beam current of the FeC_{60}^+
 - ⇒ Optimization of generation and extraction conditions
- Time-of-flight and chemical analyses of actual products