Discovery of high functional sub-nano catalysts for electrochemical oxygen reduction reaction
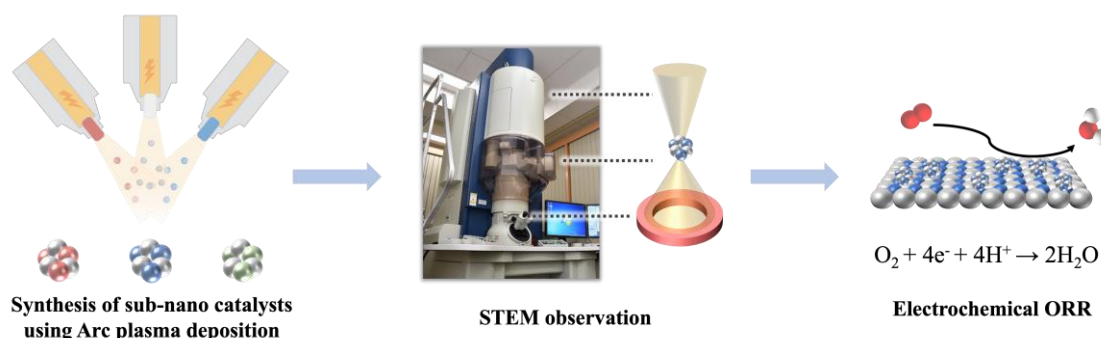
([1]*Lab. for Chemistry and Life Science, Science Tokyo*) ○YangYao Chen,[1] Tatsuya Moriai,[1] Masataka Yoshida,[1] Takane Imaoka,[1] Kimihisa Yamamoto[1]
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The development of clean and renewable energy sources is essential to achieve a sustainable future. An ongoing challenge in fuel cell research is identifying efficient catalysts for the Oxygen Reduction Reaction (ORR). Based on the previous research in our lab, Pt subnano particles (SNPs) with the size less than 1 nm are considered as promising catalysts for ORR.[1] By taking advantage of the synergy effect between Pt elements and other support elements,[2] this research aims to discover Pt based SNPs catalysts with both high catalytic performance and excellent durability with Arc Plasma Deposition method (APD); Using the confirmed APD parameters optimized by the QCM sensor, a series of Pt based binary SNPs with average diameters (around 1nm) were successfully prepared by APD method, characterized and applied to electrochemical testing methods.

The average diameters of the SNPs were analyzed by Annular Dark Field Scanning TEM (ADF-STEM) and the electronic states were determined by the X-ray photoelectron spectroscopy (XPS). The electrochemical properties of the SNPs were measured by directly preparing SNPs on the glassy carbon electrode. The durability of different alloying SNPs were further investigated through a detailed comparison of XPS and STEM analyses conducted before and after prolonged ORR processes. Using the aforementioned methods, a system for evaluating the catalytic performance of bimetallic Pt based SNPs was successfully established and the synergy effect of the alloying SNPs have been studied.

Synthesis of sub-nano catalysts using Arc plasma deposition — **STEM observation** — $O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$ **Electrochemical ORR**

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