Plasma-assisted oxidation of binder-mixed micron iron particles and their field emission applications

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Abstract: This work compares traditional, rapid, and plasma-assisted rapid Thermal Oxidation (TO) processes of iron (micron size) mixed with ethyl cellulose (M-Fe film) to achieve surface morphologies suitable for field emission applications. The effects of oxygen pressure, processing time, and heating rate were evaluated against the traditional TO process. The results indicate that the plasma-assisted rapid thermal oxidation process exhibits superior field emission performance.

1. Introduction

Iron oxide polymorphs (α, β, γ, and δ) are widely explored for applications in catalysis, energy storage, medical devices, data storage, and environmental remediation. Hematite (α-Fe_2O_3), a stable n-type semiconductor with a ~2.2 eV band gap, is particularly promising due to its stability and abundance [1]. Surface morphology plays a critical role in determining material performance across various fields [2]. This study focuses on tailoring iron oxide surface properties using binder incorporation (ethyl cellulose) and rapid heating, to achieve optimized surface morphologies for enhanced functionality.

2. Methods

In this work, three different thermal oxidation processes are applied to a M-Fe film to monitor the final surface phase and morphology. The M-Fe film was made of a mixture of iron powder, ethanol and ethyl cellulose. Different TO processes are applied: The traditional TO process involves heating the M-Fe film from room temperature to 750°C over 5 hours at a ramp rate of 2.5°C/min, followed by natural cooling. The rapid TO process incorporates controlled oxygen flow and uses a radiation heater with a fast heating rate of 12°C/sec for 10 minutes in a closed chamber. The addition of plasma to the rapid TO setup results in a plasma-assisted rapid TO process, maintaining the fastest heating rate of 12°C/sec with controlled oxygen flow. [3]

3. Results and Discussion

Figure 1 compares thermal oxidation (TO) routes for M-Fe films, highlighting the influence of processing time and environment on morphology. Traditional TO in ambient air forms 1D morphologies and stabilizes to hematite. Rapid TO with 100 sccm oxygen flow produced pyramidal morphologies, leaving bulk iron unreacted. Plasma-assisted rapid TO at 200 sccm generated whisker-like morphologies. The oxidation is responsible for the volume expansion, diffusion and stress gradient leading to layered Fe2O3/Fe3O4/Feo/Fe or Fe2O3/Fe3O4/Fe structures [4].

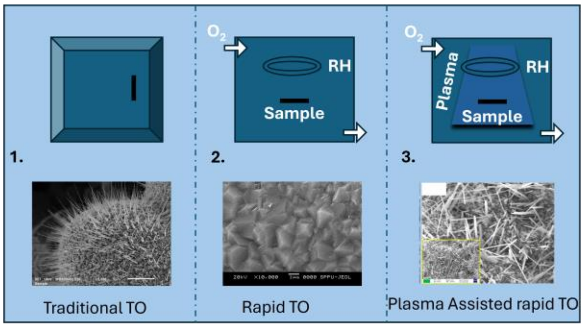

Fig. 1. Comparison between different Thermal Oxidation (TO) processes and achieve surface morphologies.

Moreover, the binder effects during oxidation were studied using TG-DSC, Raman, and XRD. All methods stabilized to hematite, with plasma-assisted rapid TO showing superior field emission performance.[3]

4. Conclusion

Whisker-like morphologies were achieved with minimal exposure time by optimizing oxygen flow and using plasma to generate reactive atomic oxygen. Plasma-assisted rapid TO produced a core-shell structure with superior field emission properties, outperforming traditional methods.

References

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