# Effect of Polyvinylpyrrolidone (PVP) Addition on the Morphology of Electrochemically Deposited Copper *in a Nitrate Medium*

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**ABSTRACT**

*Copper electrodeposition in nitrate electrolytes under direct current is a controllable route for producing copper deposits and powders with diverse morphologies. The resulting morphology directly affects the processing and functional performance of copper powder in emerging applications. In this study, morphological changes of copper deposits and powders in a nitrate-based system were investigated by varying key parameters, including current density, temperature, copper-ion concentration, and the polymeric additive polyvinylpyrrolidone (PVP). Finally, the morphology of copper electrodeposition in the nitrate medium was examined using SEM images.*

***Keywords:*** *polyvinylpyrrolidone (PVP); morphology of electrodeposited copper; copper electrodeposition in nitrate medium; electrochemical copper electrodeposition*

## *1-Intrduction*

*Copper (Cu), with an FCC crystal structure and high electrical and thermal conductivity, is considered one of the most important non-ferrous metals in modern industries. A major share of global copper consumption is allocated to the electrical and electronics sector[1]. Also, due to its suitable thermal conductivity and acceptable corrosion resistance, it is widely used in heat exchangers, heat-transfer parts, and industrial equipment [2]. In addition, high recyclability and the strategic role of copper in clean-energy technologies (such as electric vehicles and energy transmission infrastructure) have increased the importance of this metal in recent decades [3]. Along with bulk applications, copper powder is also regarded as a key feedstock in modern technologies, including powder metallurgy, porous parts, conductive inks and pastes, and also some additive-manufacturing routes and energy systems. In these applications, particle size and morphology play a decisive role in compressibility, specific surface area, sintering behavior, and finally the performance of the component or electrode[4].*

## *2-Importance of Morphological Characteristics of Powder*

*Traditional powder production methods (such as milling and atomization) face limitations in controlling particle shape, achieving a uniform size distribution, and avoiding contamination [5]. In contrast, electrochemical deposition is considered a suitable route for producing copper powder with diverse morphologies (from compact structures to dendritic ones), because it allows control over parameters such as current density, electrolyte composition, and processing conditions [6]. Therefore, understanding the electrochemical behavior of copper ions and their reduction/oxidation reactions in the electrolyte is the basis for analyzing and controlling the deposition process. In copper electrochemical deposition systems, the main reaction at the cathode is the reduction of copper ions and the formation of metallic copper, while at the anode, depending on the type of anode (soluble or insoluble), either copper dissolution or water oxidation occurs [7].*

*Powder is recognized as a starting material whose processing behavior (such as flowability, apparent density, and size distribution) directly affects the quality of the final component. Nikolić and Popov emphasize that characteristics such as specific surface area, apparent density, and particle size distribution are among the most important parameters determining powder behavior, and these characteristics depend on the conditions of powder formation and production [8]. Therefore, for any route of copper powder production, controlling and quantifying particle morphology and size is considered a scientific and practical necessity. Copper electrochemical deposition can lead to the formation of particles/structures with different morphologies, and parameters such as current density, temperature, and copper-ion concentration play a major role in changing particle shape and size, and they also affect structural features[9].*

*Copper electrochemical deposition can lead to the formation of particles and structures with different morphologies, and parameters such as current density, temperature, and copper-ion concentration have a significant role in changing particle shape and size. For example, the effect of current density on the morphology and characteristics of electrolytic copper powder has been reported[6], and dendritic morphology is observed in copper powders under constant-current conditions, and its relationship with electrochemical conditions can be analyzed[9]. In another study, the effect of current density on the morphology and structure of copper powder/deposit was investigated, showing that changing the current can even affect structural features [10].*

*In this paper, the effect of adding polyvinylpyrrolidone on the morphology of electrochemically deposited copper in a nitrate medium was investigated based on SEM images.*

## *3. Research Method*

*The electrolyte used in this study was prepared based on copper nitrate salt, and double-distilled water was used as the solvent. Before each run, the solutions were thoroughly homogenized to minimize possible variations caused by solution non-uniformity. In some experiments, the polymeric additive polyvinylpyrrolidone (PVP) was used as a growth-controlling and morphology-modifying agent, and the effect of adding polyvinylpyrrolidone on the morphology of electrochemically deposited copper in a nitrate medium was examined and presented using SEM images. Polyvinylpyrrolidone (PVP) at the desired concentration was added to the electrolyte prior to the start of electrodeposition, and stirring was continued until complete dissolution to prevent lump formation and non-uniformity.*

*For repeatability, the order of adding materials was maintained, and mixing conditions—including stirring time, stirring speed, avoiding vortex formation, and comparable hydrodynamic conditions—were standardized. In addition, the solution volume and immersion depth were controlled; the electrolyte volume and the immersion depth of the electrodes were kept constant so that mass-transfer variations caused by these factors would not affect the results. Sufficient time was also provided for temperature stabilization before starting electrodeposition, and prior to applying current, the solution was checked for clarity and uniformity. Electrodeposition was initiated by applying a constant current, and the run time was carried out according to the experimental plan.*

*After the specified time, the current was turned off and the electrodes were carefully removed to minimize mechanical damage to the structures. To reduce memory (carry-over) effects, the cell and equipment were washed as needed, and the next run was performed using the same control sequence. After each run, the formed deposit and powder were collected. To reduce the effect of electrolyte residues on morphology observation, washing was carried out in steps: first with water to remove soluble salts, and then with ethanol to facilitate drying and reduce agglomeration. Finally, the samples were dried under controlled conditions and SEM images were acquired.*

## *4. Results and Discussion*

*To isolate the effect of polyvinylpyrrolidone (PVP) on copper electrodeposition morphology, all operating parameters were kept constant, and only the presence/absence of PVP in the nitrate electrolyte was varied. The fixed deposition conditions are summarized below:*

- *Electrolyte temperature: **25 °C***
- *Copper nitrate trihydrate concentration: **36.2 mg/L***
- *Applied current: **1 A/cm$^2$***
- *Deposition time: **60 min***

*SEM micrographs were acquired at two comparable length scales (100 µm for an overview and 10 µm for higher-magnification morphology) to enable a direct visual comparison between the two cases.*

*As shown in Figure 1 (without PVP), the deposited copper exhibits a morphology that is predominantly more rounded/compact at the particle/feature level, with relatively less pronounced anisotropic growth in the observed regions. In contrast, Figure 2 (with PVP, 100 ppm) indicates a clear change in morphology, where the deposit features become more elongated/needle-like, suggesting enhanced anisotropic growth under otherwise identical electrochemical conditions.*

*This comparison demonstrates that PVP can act as a morphology-modifying additive in copper electrodeposition in nitrate media. A plausible explanation is that PVP molecules adsorb on the growing copper surface and alter the relative growth rates of crystallographic facets, thereby promoting directional (anisotropic) growth and the formation of elongated features. From an application perspective, such morphology control provides a practical route to tailor copper deposits/powders toward needle-like structures when required.*

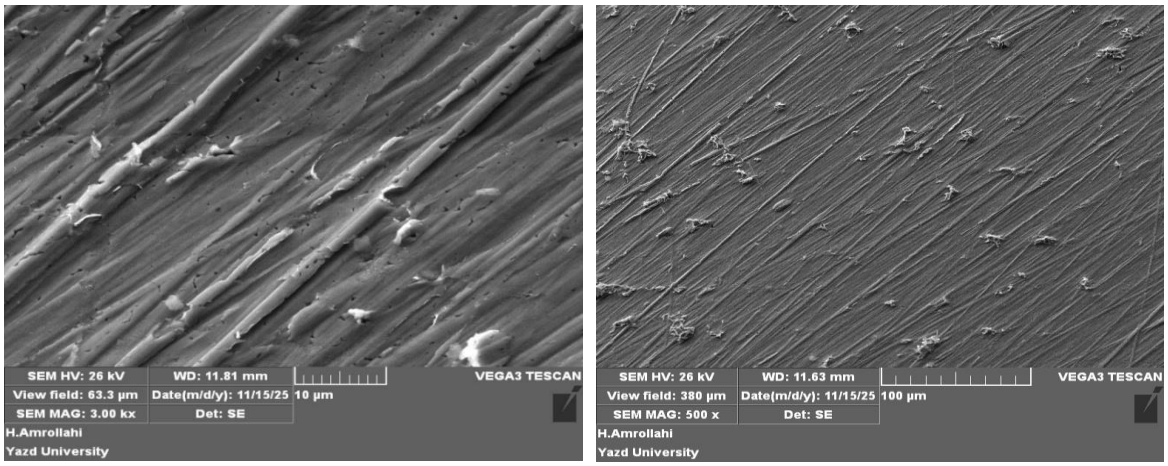



*Figure 1. SEM images of electrochemically deposited copper in a nitrate electrolyte without PVP, at two magnifications: (a) 100 µm and (b) 10 µm.*

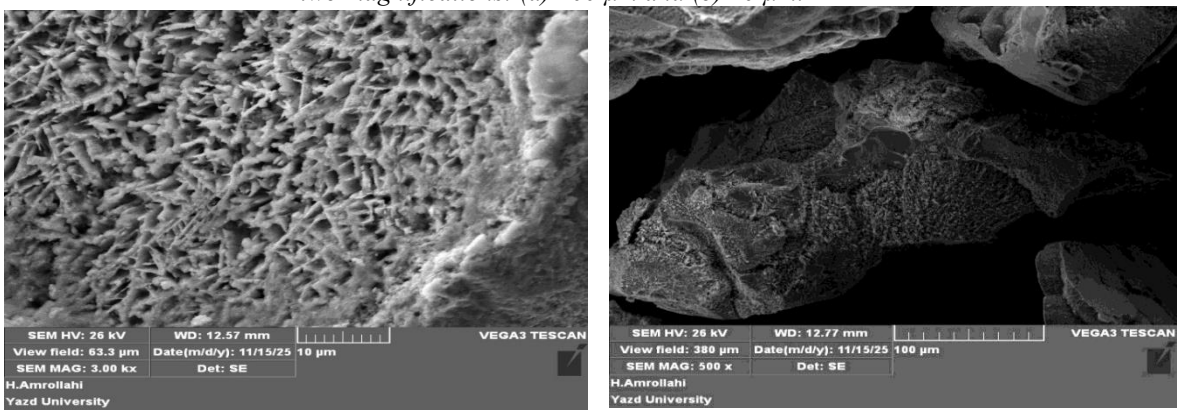



*Figure 2. SEM images of electrochemically deposited copper in a nitrate electrolyte with PVP (300 ppm), at two magnifications: (a) 100 µm and (b) 10 µm.*

## 5. Conclusion

By adding polyvinylpyrrolidone (PVP) under controlled conditions for electrochemical copper deposition, SEM images showed that PVP can convert the needle-shaped particles of electrochemically deposited copper in a controlled nitrate medium into spherical particles, and it produces effective qualitative impacts as an additive and a morphology-controlling agent in electrochemical copper deposition.

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