Drop Impact Study on Bare and Superhydrophobic Copper Meshes

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Abstract

This report presents a systematic experimental investigation on the drop impact behavior of water on copper meshes, both untreated and chemically modified to be superhydrophobic. The experiment was carried out using water drops falling from different heights (1 cm, 3 cm, 5 cm, and 10 cm) to determine the critical penetration height for various mesh types. The primary objective was to observe whether a water droplet can pass through the mesh depending on its pore size and the nature of the surface (bare vs. coated). For bare meshes, penetration was observed at heights above 5 cm. For the superhydrophobic meshes, fabricated in-house, no penetration was recorded for any of the tested heights. This indicates a clear transition in behavior due to the surface modification.

1 Introduction

Water repellency of metal meshes is a topic of interest in filtration, mist separation, and hydrophobic surface engineering. This project aims to compare how untreated and superhydrophobic copper meshes behave when impacted by falling water droplets. By analyzing drop behavior at varying heights, we attempt to determine the effect of hydrophobic surface treatment and mesh size on penetration resistance.

2 Experimental Setup

The experiment was conducted using a simple setup comprising the following components:

- A mesh holding stand was 3D printed in-house and used to secure the copper mesh horizontally using two clips.
- A needle (30G) attached to a tube and a water dispenser machine was used to generate individual water drops.
- A Tokina macro lens was mounted in front of the mesh at a specific fixed distance to capture high-speed video footage of the drop impact.
- The Phantom Camera Control (PCC) software was used for recording the experiments.
- To enhance visibility and focusing, a light source was placed behind the mesh setup and covered with white paper to provide a uniform background.

Four heights were tested: 1 cm, 3 cm, 5 cm, and 10 cm. For each mesh type and each height, multiple trials were performed.

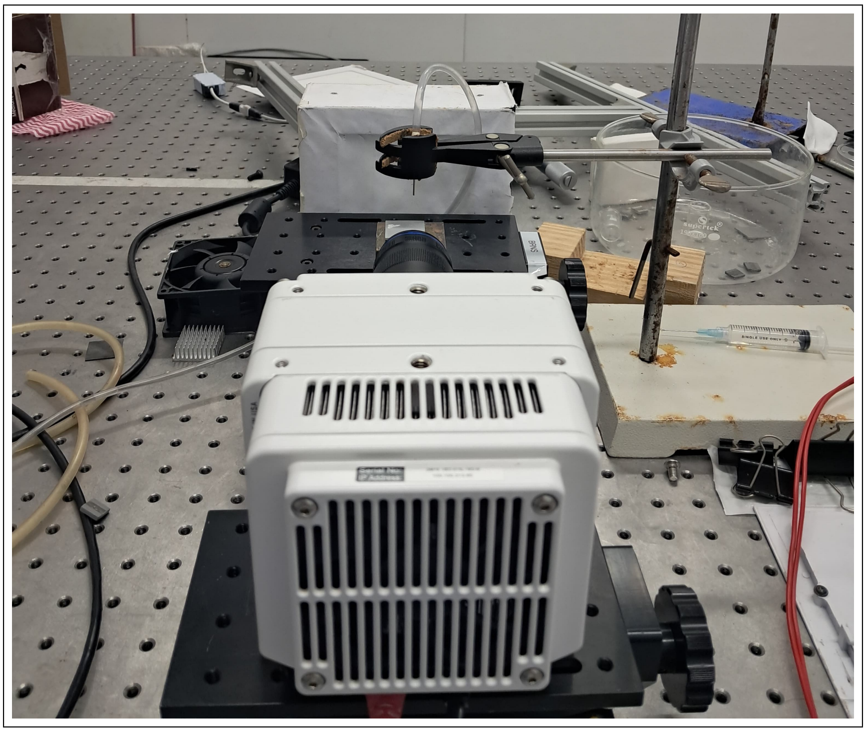

Figure 1: Camera Setup

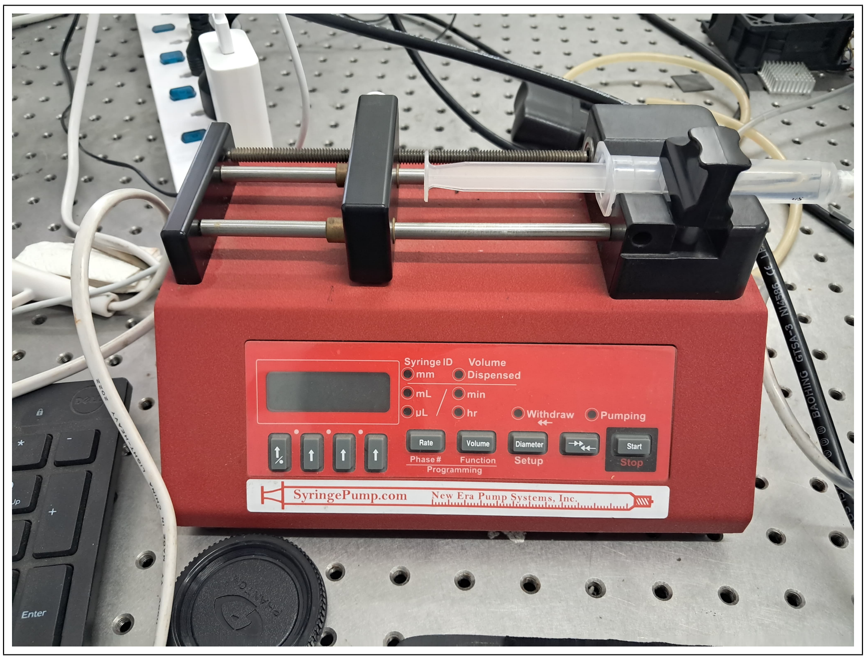

Figure 2: Droplet Dispensing Machine

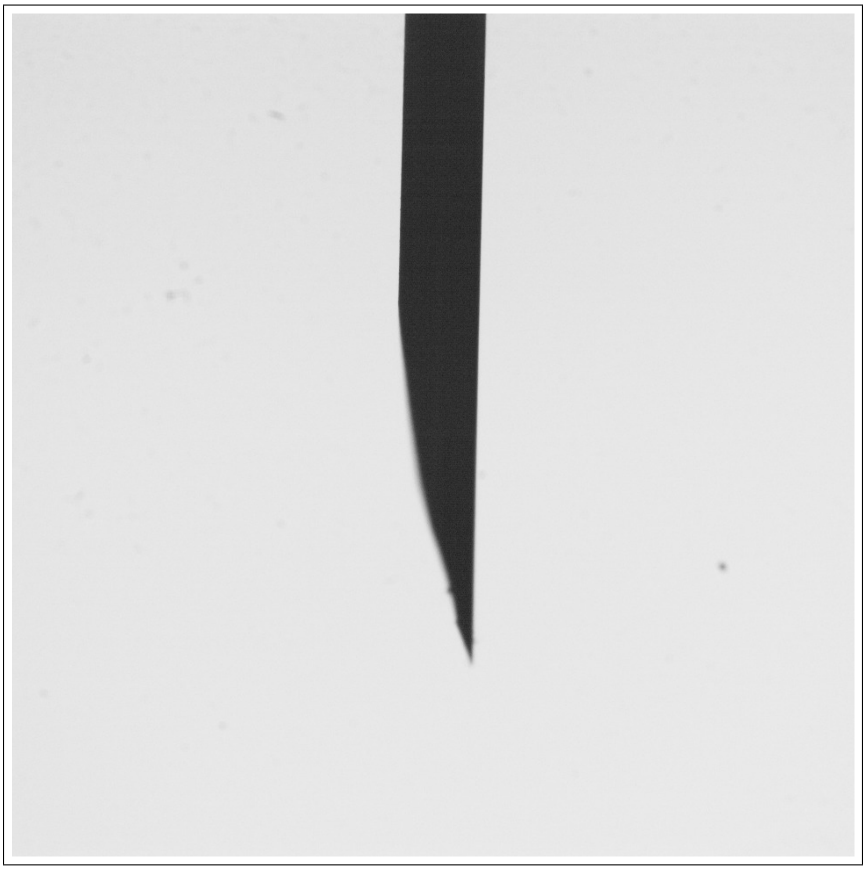

Figure 3: 30g Needle

3 Fabrication of Superhydrophobic Meshes

To compare the performance of regular copper meshes with superhydrophobic ones, the meshes were chemically treated following a step-by-step fabrication process:

1. **Cleaning:** All glassware used was cleaned thoroughly with acetone and deionized (DI) water, followed by drying with tissue paper.

2. **Sonication:** The copper mesh was initially cleaned with sandpaper and then sonicated in acetone for 10 minutes. This was followed by sonication in fresh DI water.

3. **Drying:** After the cleaning process, the samples were dried using a standard hair dryer.

4. **Oxide Layer Removal:** Samples were immersed in hydrochloric acid and sonicated for 10 minutes to remove any surface oxide layers. They were rinsed again with DI water.

5. **Solution Preparation:** A chemical solution was prepared consisting of 3.75 grams of sodium chlorite ($NaClO_2$), 5 grams of sodium hydroxide ($NaOH$), and 10 grams of tri-sodium phosphate dodecahydrate ($Na_3PO_4 \cdot 12H_2O$) in 100 mL of DI water. The solution was maintained at 97°C using a hot plate and continuously stirred.

6. **CuO Nanostructure Growth:** The copper meshes were then immersed in the prepared solution for 10 minutes. A visible color change from brown to black indicated the formation of CuO nanostructures on the mesh surface.

7. **Final Rinse and Drying:** Treated samples were rinsed again in DI water and dried in air, avoiding any further oxidation by storing them in an enclosed container.

Three different mesh sizes were fabricated using this method: 20×20, 30×30, and 50×50.

4 Testing Procedure

Each type of mesh was subjected to the same set of tests:

- Drops of water were released from fixed heights (1 cm, 3 cm, 5 cm, and 10 cm).
- The behavior of the drop after impact—whether it passed through the mesh or not—was visually observed and recorded.
- For each height, observations were repeated multiple times to ensure repeatability.

5 Observations and Results

Bare Meshes:

The bare copper meshes allowed water to pass through only at drop heights greater than 5 cm. For lower heights (1 cm, 3 cm, 5 cm), the drop either stayed on the mesh or was partially absorbed, but no full penetration was recorded.

Superhydrophobic Meshes:

The superhydrophobic meshes, regardless of pore size (20×20, 30×30, or 50×50), successfully prevented the passage of water droplets even at the maximum tested height of 10 cm. The drops either rebounded or remained suspended without breaking through.

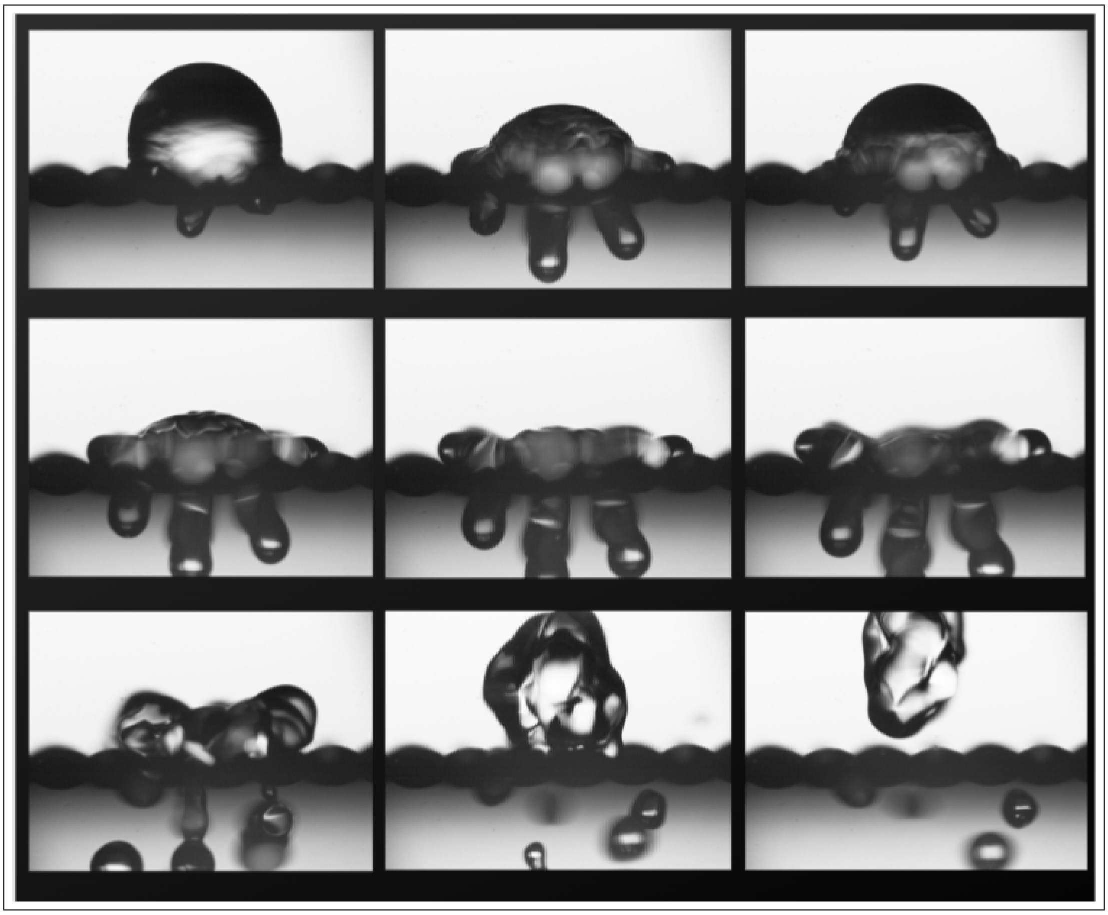

Figure 4: Droplet Impact progression

Droplet behaviour for various mesh sizes:

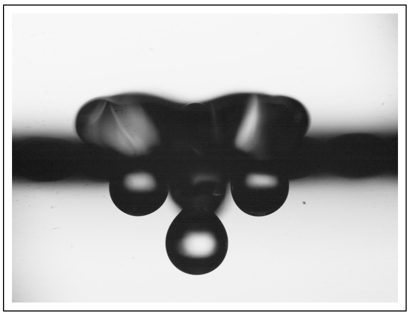

Figure 5: 3cm

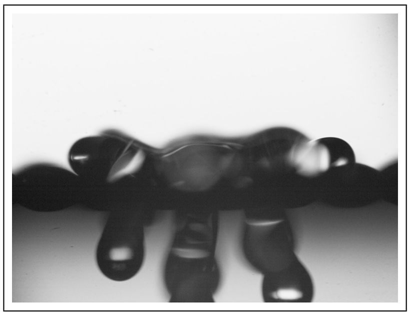

Figure 6: 5cm

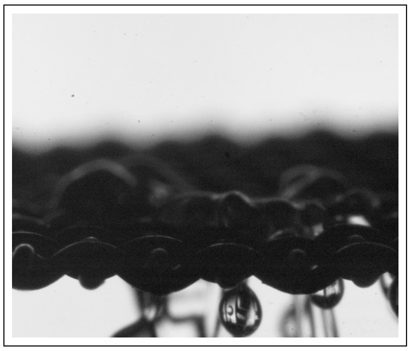

Figure 7: 10cm

Figure 8: Droplet Impact at 3cm, 5cm and 10cm for 30x30 Mesh

Droplet behaviour for different mesh sizes:

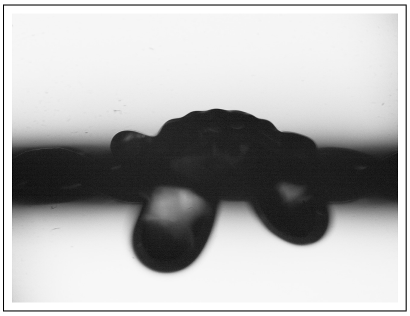

Figure 9: 20x20

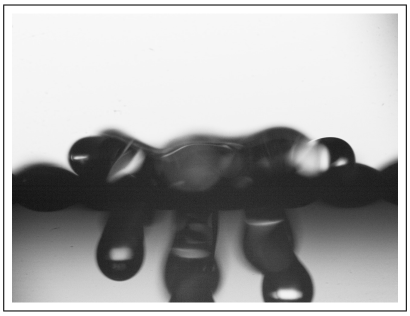

Figure 10: 30x30

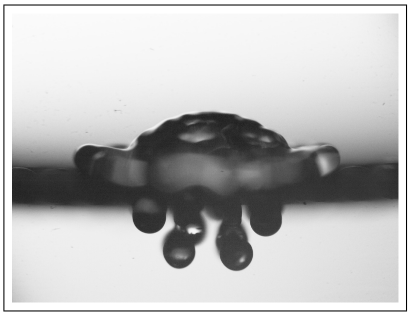

Figure 11: 50x50

Figure 12: Droplet Impact at 5cm height for 20x20, 30x30, 50x50 Mesh

6 Conclusion

The drop impact tests clearly show a significant difference in behavior between untreated and superhydrophobic copper meshes. While bare meshes start allowing penetration beyond a certain impact energy (around 5 cm), superhydrophobic meshes fabricated using a low-cost in-house process showed complete water repellency up to the highest tested height. This demonstrates the effectiveness of the CuO nanostructure-based surface modification in improving the impact resistance of porous metal meshes.

7 Acknowledgement

We sincerely thank Prof. Soumyadip Sett for assigning us this project and for providing his valuable guidance, encouragement and continuous support throughout this project. This project provided us with an excellent learning opportunity, allowing us to gain hands-on experience and deepen our understanding of the subject.