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Leidenfrost Energy Barriers

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MOTIVATION

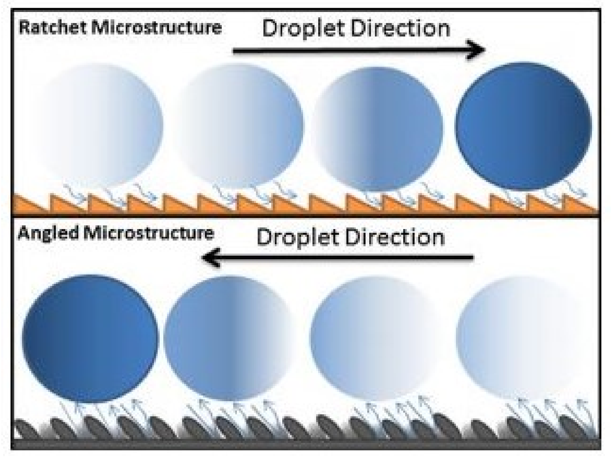

Figure 1. Mechanisms of Leidenfrost Droplet self-propulsion for ratchets and FLSP fish scales. Taken From: Kruse, et al., (2015). Microfluid Nanofluid. 18: 1418.

- Self-propulsion of Leidenfrost droplets can be very important in microfluidics applications
- Mechanisms causing self-motion of Leidenfrost droplets have been previously studied by our group using FLSP
- Recently, our group discovered that there exists a barrier between two surfaces with different wettability near the Leidenfrost state
- Understanding the fundamental mechanisms governing the Leidenfrost Energy Barrier will lead to better control of Leidenfrost droplets for microfluidics applications

EXPERIMENTAL SETUPS

- Femtosecond Laser Surface Processing of polished Stainless Steel 304 sample to create super-hydrophilic region
- SEM imaging of micro structures
- Sample angled with a 1 degree incline sloping from the needle to the processed strip to draw liquid into barrier
- 50 trials of 4.17 µL deionized water droplets carried out for each temperature, with 5 degrees Celsius temperatures increments
- Due to inconsistencies in droplet/barrier interactions from droplet bouncing, a new experimental setup will be used to test these Leidenfrost Energy Barriers

(A)

(B)

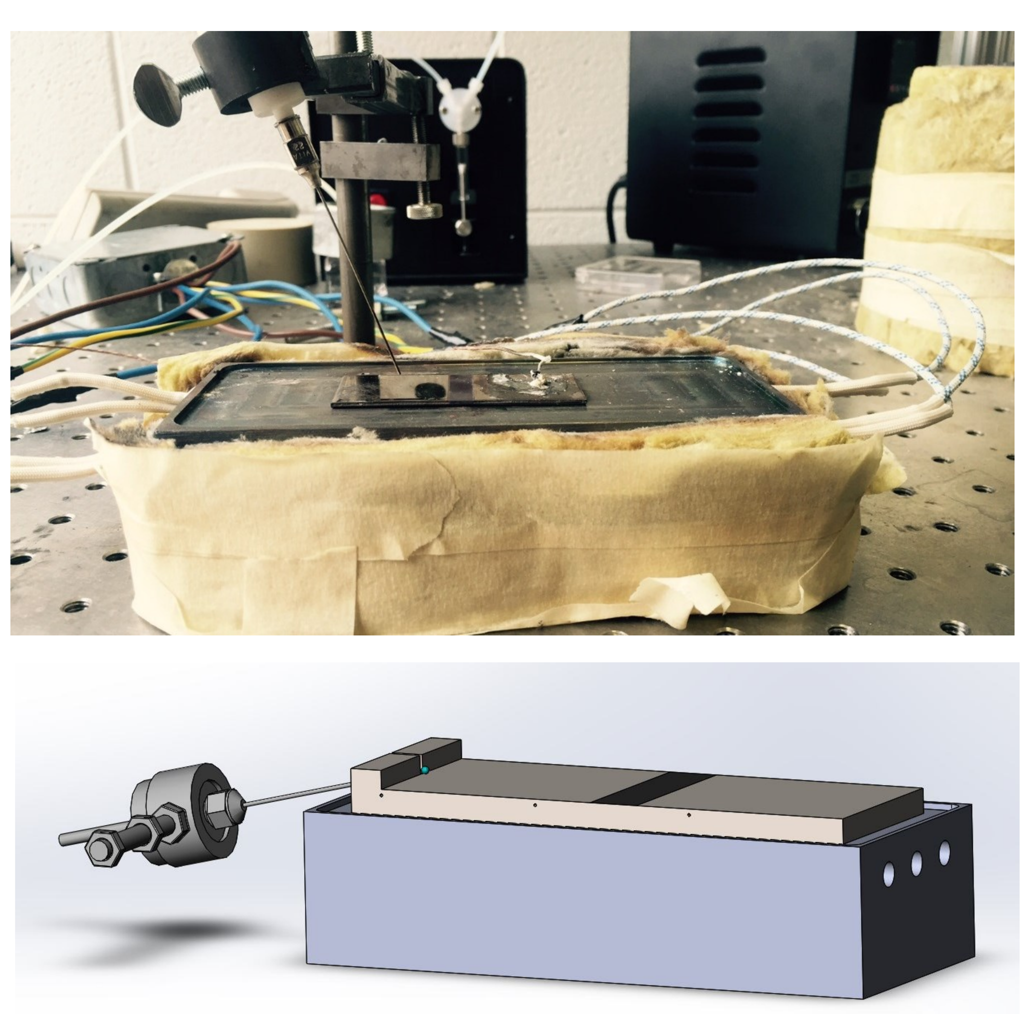

Figure 2. (A) Preliminary Energy Barrier Sample on Hot Plate. (B) New Energy Barrier Sample & Setup.

FEMTOSECOND LASER SURFACE PROCESSING

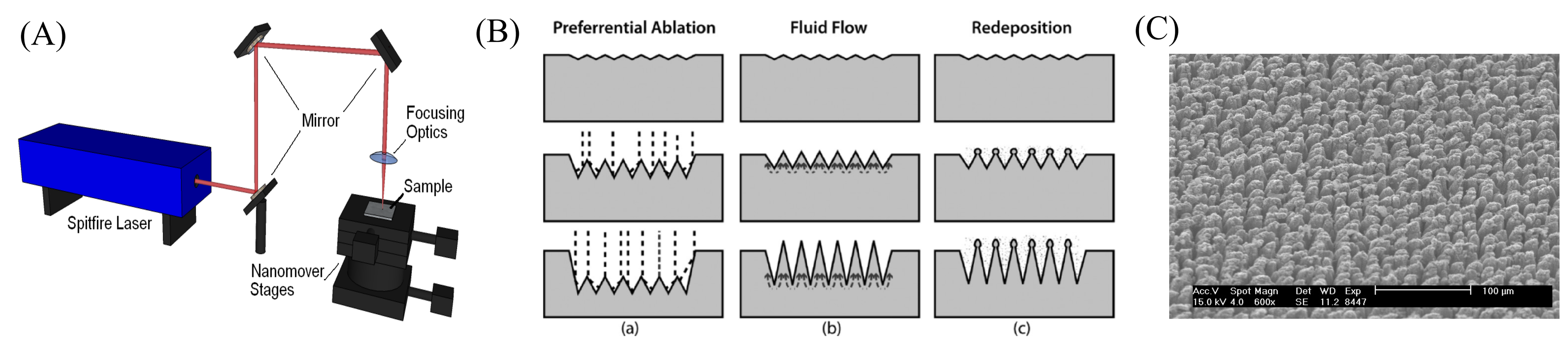

Figure 3. (A) Spectra-Physics Spitfire Laser. (B) Microstructure formation from preferential ablation, melting, fluid flow, and redeposition. (C) SEM image of FLSP microstructures

LEIDENFROST ENERGY BARRIER THEORY

- Leidenfrost temperature represents the maximum surface temperature at which efficient heat transfer can occur
- It represents the onset of the film boiling regime
- At the Leidenfrost point, a droplet floats on cushion of own vapor
- At the Leidenfrost point, droplet lifetime is longest
- The Leidenfrost temperature can be controlled by surface wettability of the substrate using FLSP

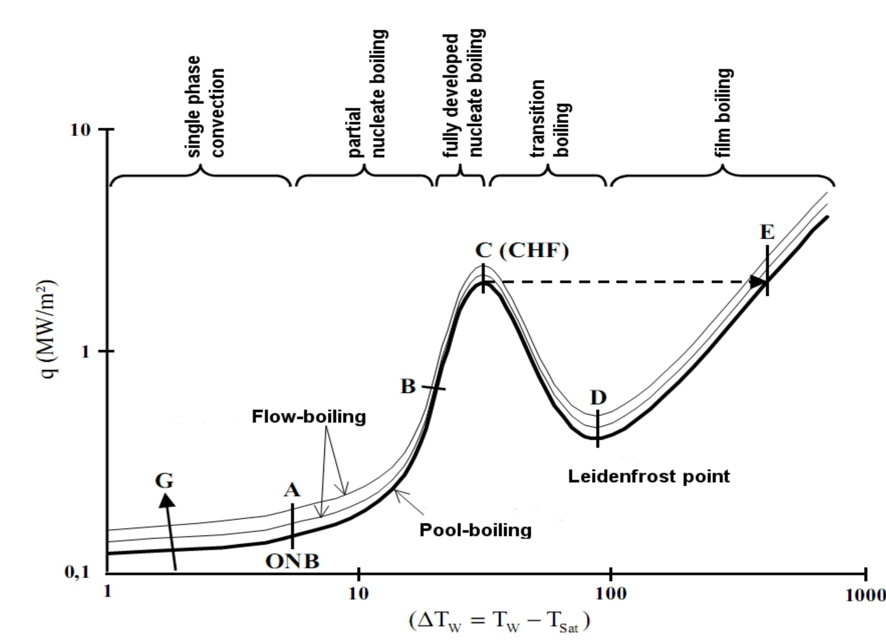

Figure 4. Boiling Regimes According to Nukiyama's Boiling Curve. Image Taken From : Thermaodynamik. [Image]. http://129.187.45.233/tum-td/de/forschung/themen/subcooled_flow_boiling

- Leidenfrost Barrier can be created on a substrate with distinct surface regions having different Leidenfrost Points
- With the sample heated to the Leidenfrost Point of the polished surface, the processed region will be in transition boiling
- A droplet moving from the polished surface to the processed region will encounter a net force pushing it away from the processed region due to thrust from asymmetric boiling and wetting

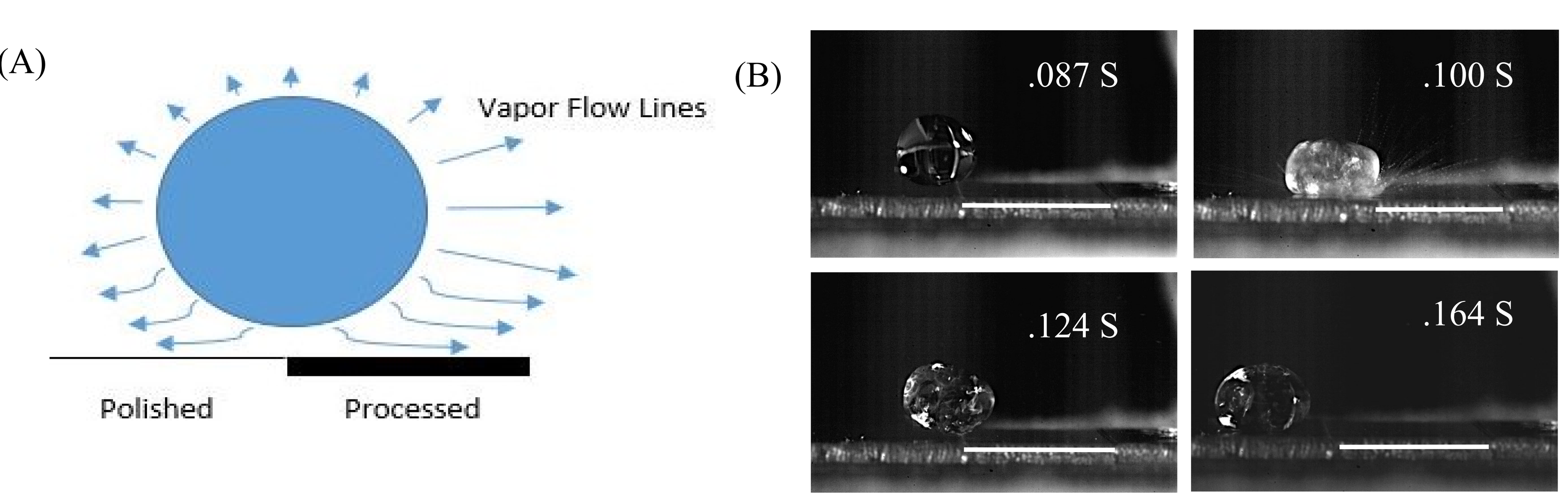

Figure 5. (A) Visualization of vapor flow field off Leidenfrost droplet near Energy Barrier (B) Images taken of a Leidenfrost droplet contacting the barrier and rejecting at a substrate temperature of 285 deg. C. The FLSP barrier is underlined in white.

PRELIMINARY RESULTS & DISCUSSION

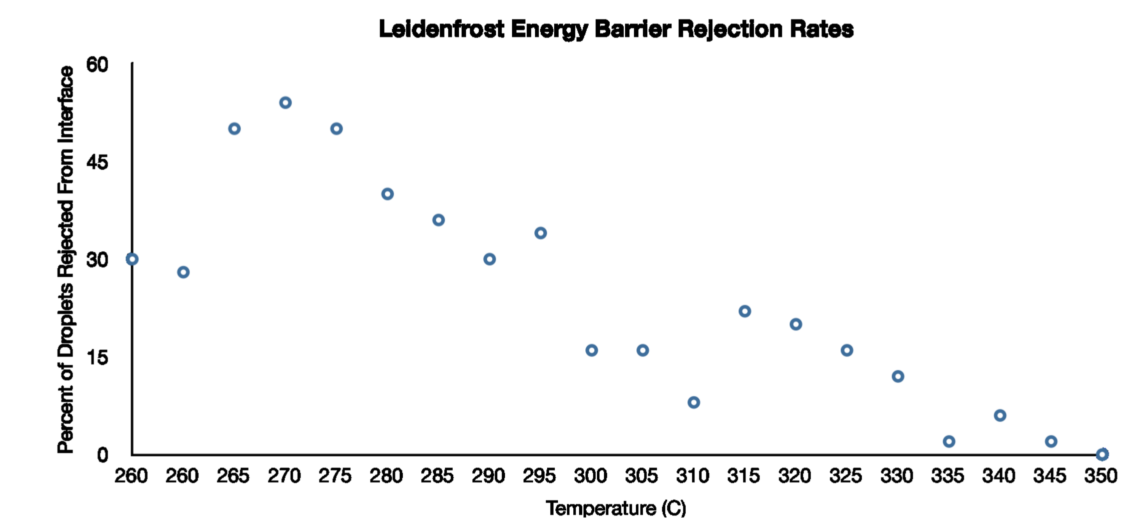

Figure 6: Percent of droplets from preliminary set-up rejected from Barrier across a range of temperatures.

- As the Leidenfrost Point of the processed Energy Barrier was approached from below, the rejection percentage decreased
- Highest rejection percentage of 54% occurred at Leidenfrost Point of polished surface region (275 Deg. C) - largest difference between sample temp. and processed region Leidenfrost Point.
- Right side of the chart with rejection percentage below 10% corresponds to temperatures above Leidenfrost Point of processed surface
- Wide variation in results observed from inconsistencies in droplet interactions with Energy Barrier from unpredictable droplet bouncing

CONCLUSION & FUTURE WORK

- Inconclusive results due to inability to prevent droplet bouncing with either experimental setup
- Create new sample to minimize bouncing by using a square channel heated on all sides, utilizing the Leidenfrost effect on upper surface to repel bouncing droplets back towards channel floor
- Determine droplet lifetime curves with deionized water on polished and processed surfaces of new sample to compare Leidenfrost Temperatures
- Test the energy barrier concept by running Leidenfrost droplets into processed strip over a range of temperatures at and below the Leidenfrost temperature of the FLSP surface, while varying droplet mass and impact velocity

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