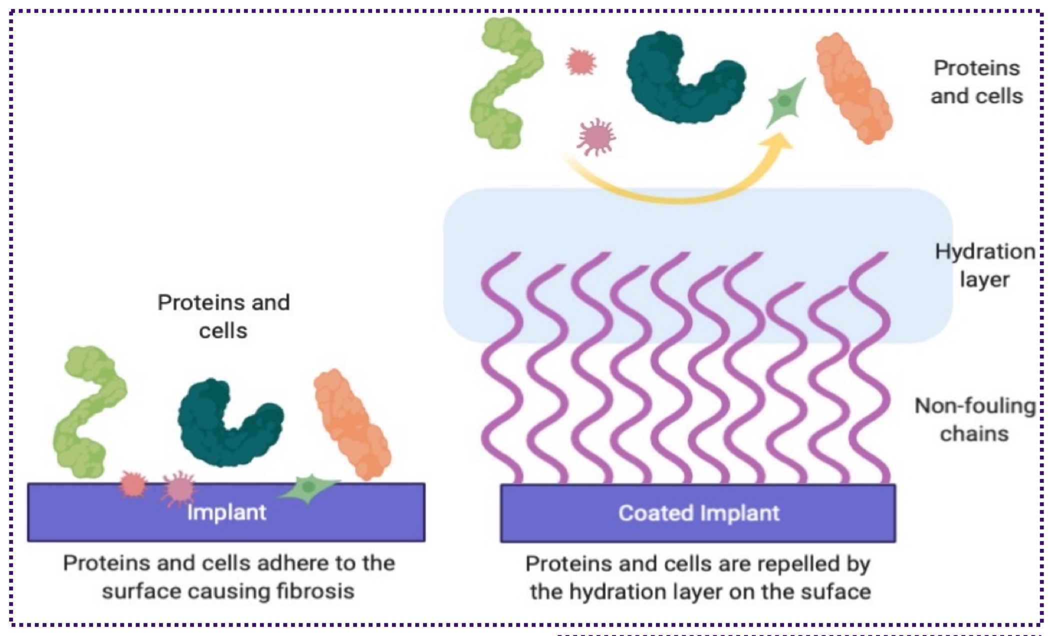
A Solvent-Free Method for Initiator Immobilization for Grafting Zwitterionic Polymer Brushes using Surface Initiated Polymerization

Prabhleen Kaur[1] and Buddy D. Ratner[1,2]

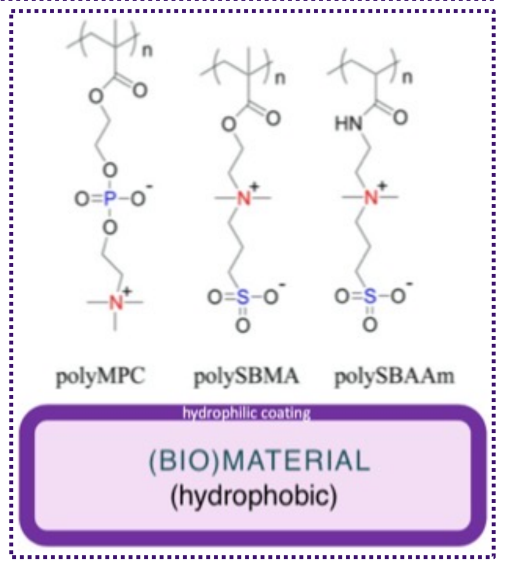
[1]Department of Chemical Engineering, University of Washington, Seattle, WA 98195, USA
[2]Department of Bioengineering, University of Washington, Seattle, WA 98195, USA

1. INTRODUCTION

Most materials used in biomedical implants are selected for their mechanical properties. Typically, these substrates require substantial surface modification to enhance their biocompatibility and mitigate the foreign body response (FBR). Super-hydrophilic zwitterionic polymers including polysulfobetaine methacrylate (pSBMA) can be grafted onto material surfaces in the form of polymer brushes. This creates strong hydration layers at the interface of the material and the biological environment, preventing protein adsorption and thus inhibiting FBR. Flexible polymer chains with continuous movement also block protein adsorption by utilization of steric excluded volume effects.



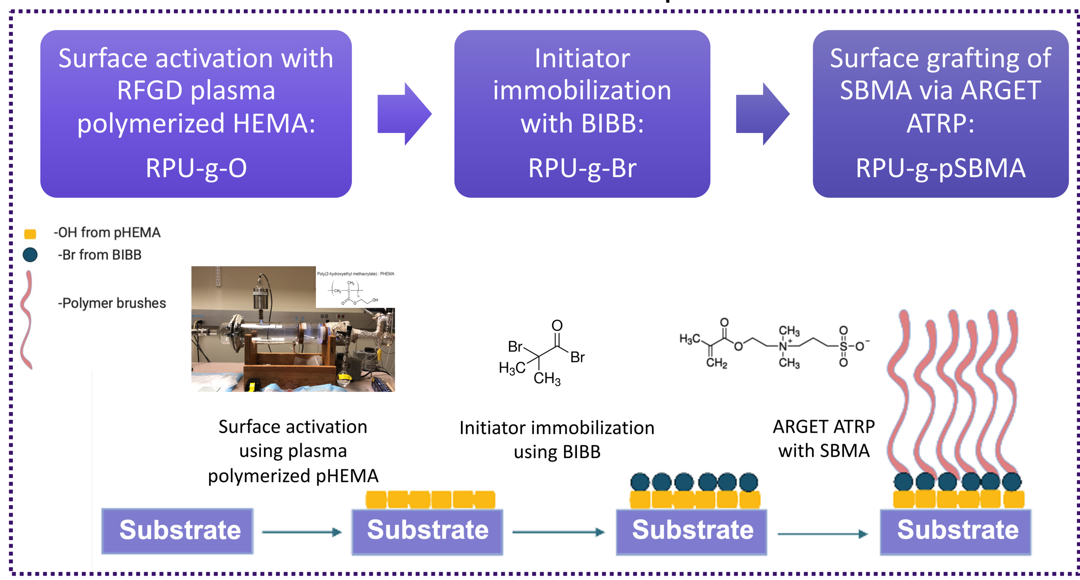
However, many relevant polymeric substrates such as polyurethanes are incompatible with the silane and thiol-based chemistries and organic solvents used in conventional techniques for grafting pSBMA brushes. This work replaces conventional initiator immobilization approaches by a solvent-free method using radio frequency glow discharge (RFGD) plasma polymerized bromoesters as initiators for surface-initiated polymerization.[1] In this work, this concept is illustrated using reinforced polyurethane (RPU-70) as a substrate and methyl-3-bromopropionate (M3BP) as the bromoester. This is then used for grafting pSBMA brushes to enhance non-fouling and lubrication characteristics of the implant surface.



2. METHODS

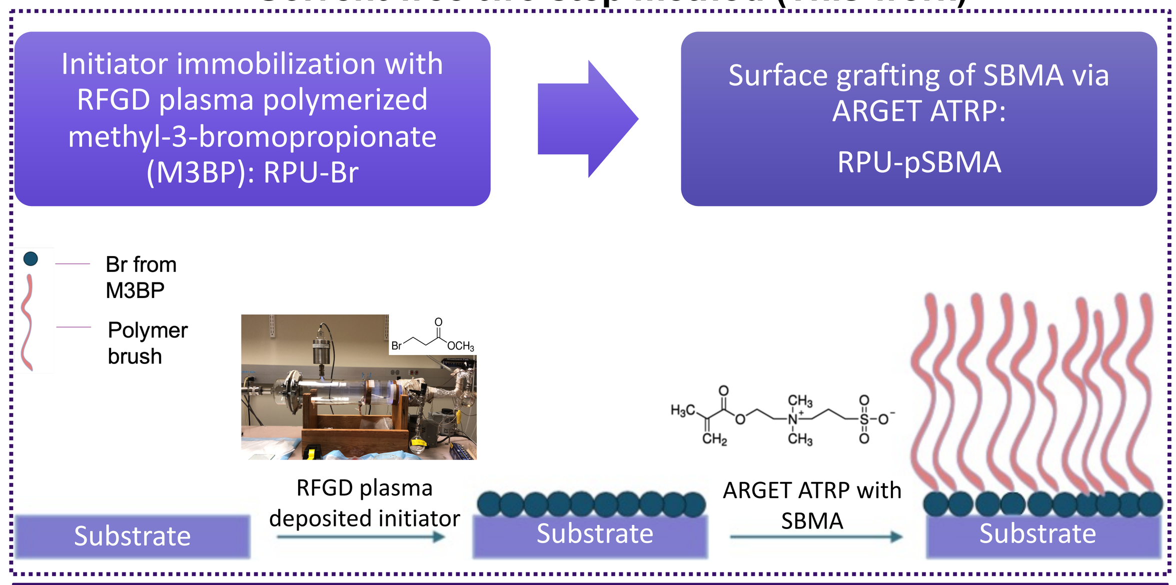
I. COATING PROCESS

Conventional three step method



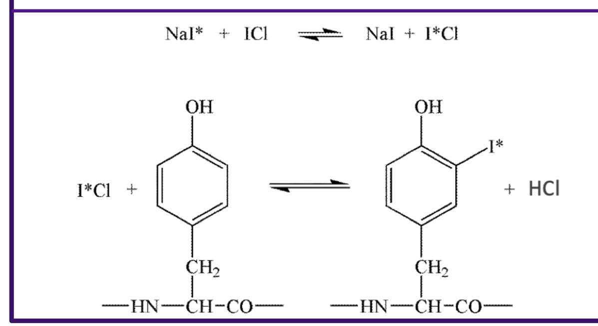
- Lower initiator density ~ 5.3%
- Lower grafting density
- Requires organic solvents for initiator immobilization, incompatible with substrates like polyurethanes

Solvent-free two step method (This work)



- **High initiator density ~ 30%**
- **High grafting density**
- **Solvent-free initiator immobilization**
- **Compatible with range of substrates, irrespective of surface chemistry**

II. RADIOLABELED PROTEIN ADSORPTION

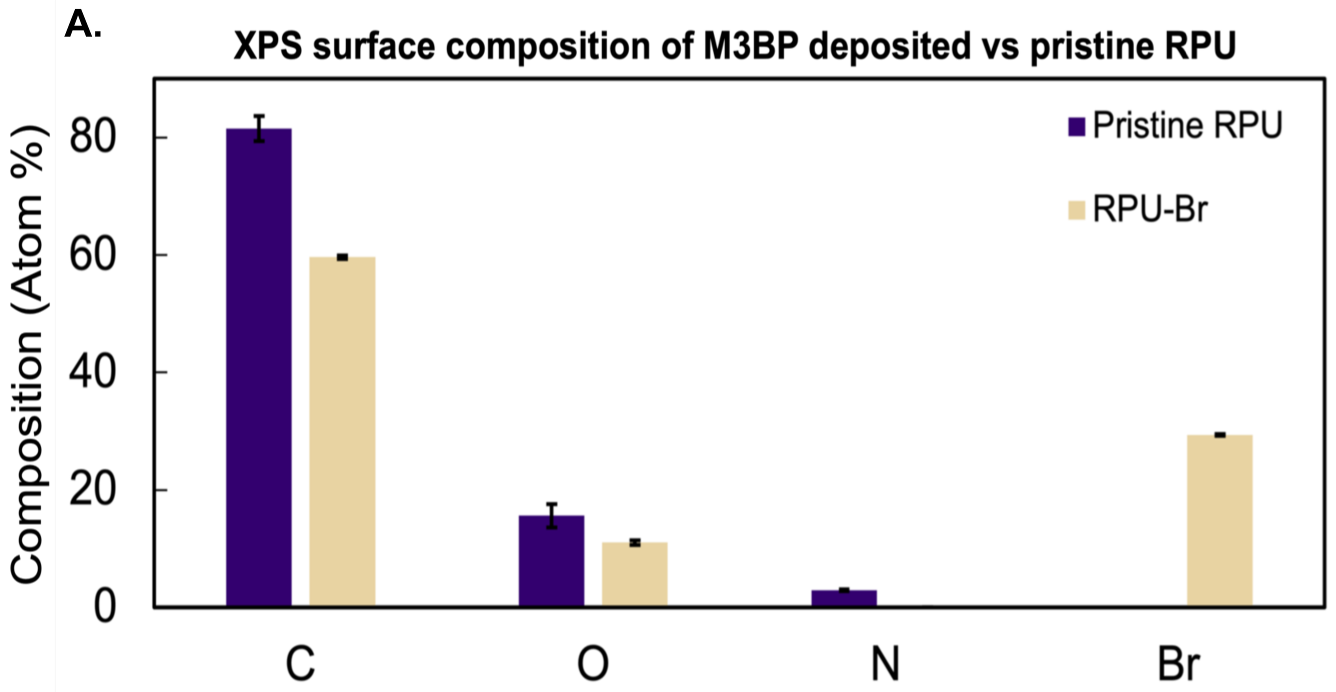


Radiolabeled human serum albumin (Alb) was used as model protein to study the non-fouling characteristics of the coated surfaces. *I-125* attaches to the tyrosine residue in the protein molecule as given by the reaction herein.

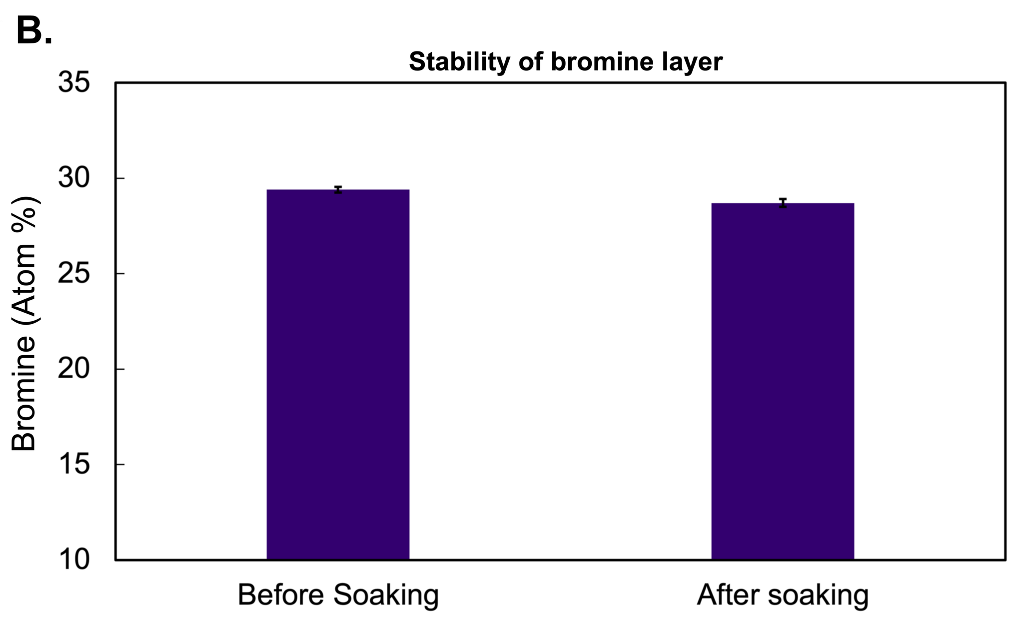
3. RESULTS AND DISCUSSION

I. VERIFICATION OF SUCCESSFUL SURFACE MODIFICATION

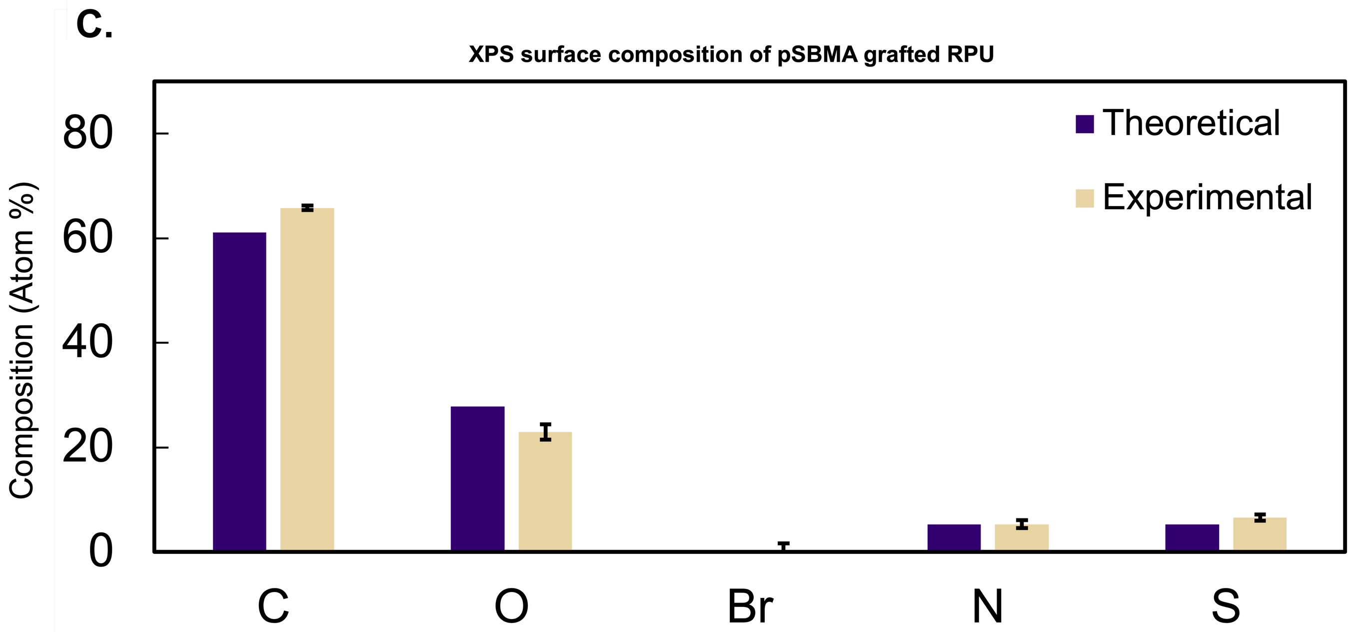
A.



B.



C.



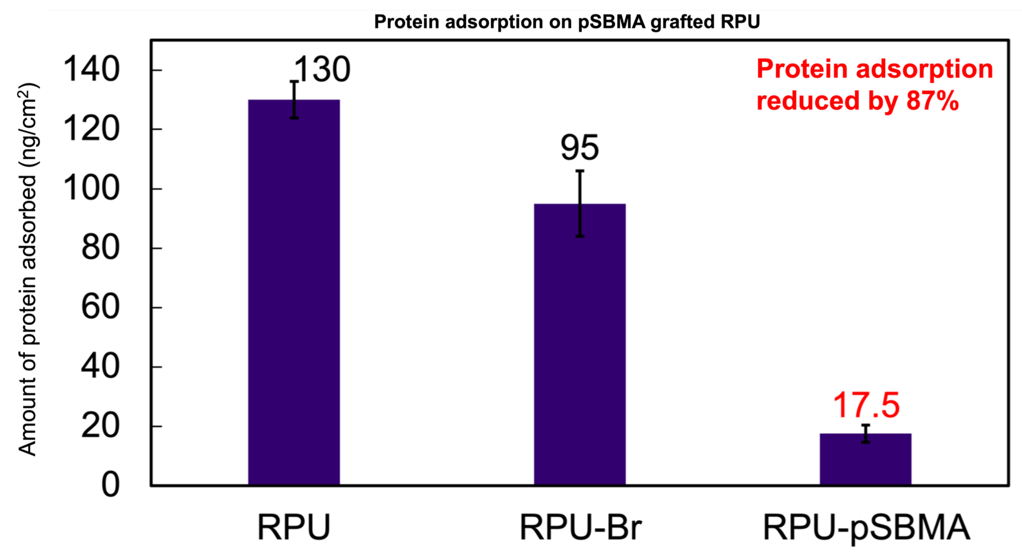
A. Successful deposition of plasma polymerized M3BP was confirmed by composition analysis from XPS survey scans. A **high Br content (~29%)** can be seen.

B. The Br content on the surface is **mostly retained** even after vigorous washing in a methanol-water solution for 60 minutes, including changing the solvent every 20 minutes. This suggests that the Br layer is **stable and resistant to delamination** in solvent systems of interest. A **small decrease** of **2.3%** was noticed, likely corresponding to loosely bound bromine compounds.[1]

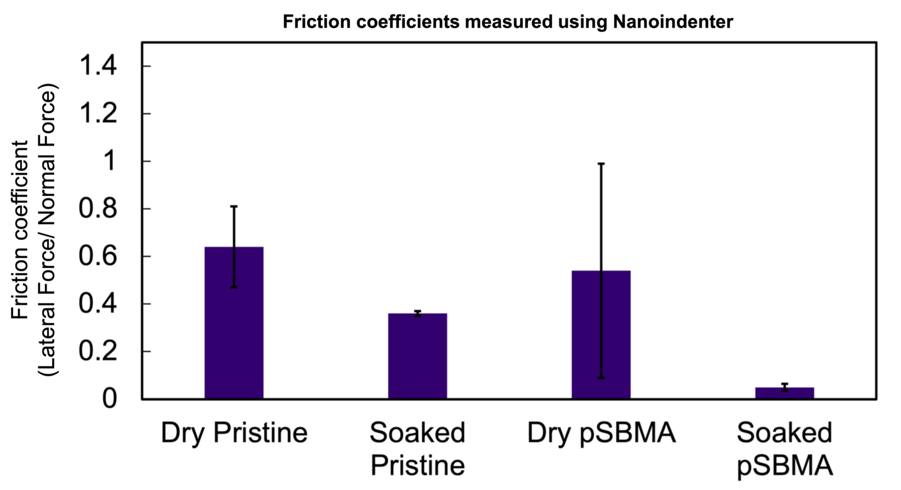
C. Successful grafting of pSBMA using our two-step method was verified by composition analysis from XPS survey scans. The elemental percentages for **N (~5.3%)** and **S (~6.6%)** are comparable to their theoretical values of **5.3%**, suggesting uniform pSBMA coating and near complete utilization of the Br initiator.

II. PROTEIN ADSORPTION AND LUBRICATION STUDIES

A.



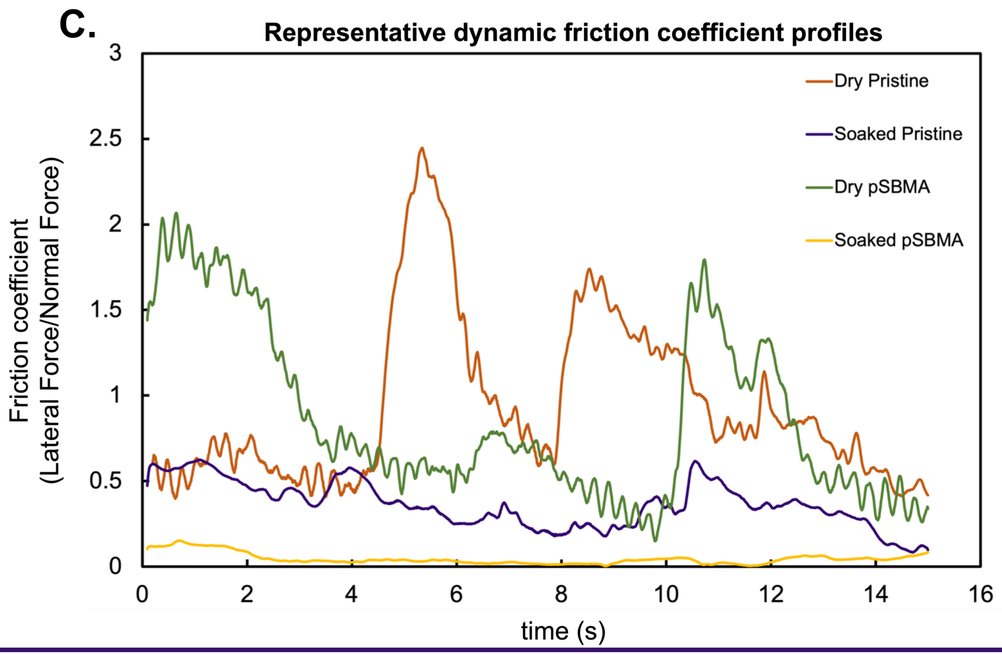
B.



A. Protein adsorption studies indicate excellent non-fouling performance. RPU-pSBMA surfaces show significantly reduced protein adsorption **(14-17 ng/cm²)** compared to pristine RPU surface **(130 ng/cm²)**, an **87% reduction**. These observations confirm robust binding of super-hydrophilic pSBMA coatings to the RPU surface, thereby successfully resisting non-specific protein adsorption.

B. The strong hydration effects are also manifested in friction coefficient measurements. The **~10x** reduction for **wet pSBMA** over the dry surfaces is indicative of the formation of hydration sheath layers by pSBMA brushes activated upon wetting. The soaked pSBMA also exhibits significantly lower friction coefficient than similarly soaked pristine surfaces, indicating increased hydration strength due to charged entities in dense layers of pSBMA brushes, in addition to lubricity due to fluidity of the adhered water.

C.



C. From the dynamic friction coefficient profiles, the clear reduction in local variations for wet pSBMA surfaces suggests uniformity of forces due to wetting of hydrophilic coatings. Dry surfaces expectedly show higher average friction coefficient and greatly increased local variations due to roughness.

4. CONCLUSIONS

In this work, a versatile and solvent-free method for initiator immobilization has been demonstrated, which greatly simplifies the surface modification process for industrially relevant polymeric substrates, irrespective of their surface chemistry and geometry. This method has been employed to achieve successful grafting of robust, highly non-fouling, and lubricious pSBMA brushes on reinforced polyurethane (RPU) using ARGET ATRP. The initiator immobilization method has been found to yield stable and uniform bromine layers resistant to delamination. In addition, the pSBMA brushes grafted using this initiator resulted in significantly lower albumin adsorption over the pristine substrates. The modified surfaces prepared using the method demonstrated herein also show greatly enhanced lubricity, characterized by nearly an order of magnitude reduction in friction coefficients. Ongoing work is focused on demonstrating this approach for metal and ceramic substrates such as titanium and glass. In addition, we also intend to evaluate these methods with other zwitterionic polymers including carboxybetaine methacrylate. A third goal is the optimization of the process parameters to further decrease protein adsorption (<5 ng/cm²) and improve lubrication metrics discussed in this work.

4. REFERENCES

1. Mecwan, M. M., et al; *Biointerphases* **2019**, *14* (4), 041006.

5. ACKNOWLEDGEMENTS

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