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Surface Wettability Characteristics of Polymer Blend Coatings

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Abstract: **Biofouling elicits harm to the marine environment as well as to the surfaces they grow on. To combat this issue, amphiphilic copolymers are used to remove growth safely without causing harm. Polymer blends of polydimethylsiloxane (PDMS), polyethylene glycol (PEG), hydroxypropyl cellulose (HPC), and polyvinylpyrrolidone (PVP) were then explored using contact angle techniques. Contact angle data revealed PEG, HPC, and PVP have hydrophilic characteristics while PDMS has hydrophobic characteristics. 100:0%-0:100% PDMS-PEG and HPC-PVP blends were made to investigate whether an amphiphilic polymer blend could be made. Contact angle data determined that 80:20-20:80 PDMS-PEG blends were amphiphilic. 100% PDMS and 90:10 PDMS-PEG were hydrophobic while 10:90 PDMS-PEG and 100% PEG were hydrophilic. Contact angle data revealed 100:0-0:100 HPC-PVP were hydrophilic, and no amphiphilic characteristics were found. This study serves as foundational work for the design of tailored polymeric systems for surface modification**

Keywords: **Biofouling elicits, amphiphilic copolymers, polymeric systems.**

1. INTRODUCTION

Polymers are an important class of materials that became widely used within the past century. The beneficial characteristics some polymers possess for coatings are flexibility, elasticity, thermal and electrical insulation, and lightness.[1] Unlike most paints that contain toxic metals, many polymers are non-toxic in nature.[2] Additionally, natural polymers are organic and not man-made materials.[3] They can be found in nucleic acids and proteins which are major building blocks.[3] Among polymers used for coatings, one important consideration is their hydrophilicity. The difference among hydrophilic, hydrophobic, and amphiphilic polymers is quite simple. Hydrophilic polymers are those with polar regions that can interact with and dissolve in water.[4] Hydrophobic polymers are those with nonpolar regions that cannot interact with or dissolve in water.[5] Amphiphilic polymers are those that possess polar and nonpolar regions.[6] Therefore, these polymers are characterized by hydrophilic and hydrophobic regions simultaneously in the same system. Amphiphilic polymers have a great use towards advanced surface modification, imparting both hydrophobic and hydrophilic properties that have been seen to be highly effective against fouling organisms.[7-10] They are also shown to be more stable, have better biocompatibility, and lower toxicity.[7]

Four polymers were explored as coatings individually before preparing blends of their mixtures. Polyethylene glycol (PEG), polydimethylsiloxane (PDMS), hydroxypropyl cellulose (HPC), and polyvinylpyrrolidone (PVP) were chosen based on their composition and applications. PEG is a hydrophilic polymer typically synthesized from ring-opening polymerization of ethylene oxide.[11] It can be synthesized in linear, branched, Y-shaped, or multi-arm geometries.[12] PEG contains a terminal hydroxyl end group that can be removed to make the molecule active during the reaction.[13] PDMS is a hydrophobic polymer containing carbon and silicon synthesized through hydrolysis and condensation polymerization.[14] PDMS is a silicone elastomer that provides PDMS with its oily properties.[15] HPC is a hydrophilic polymer that is an ether of cellulose that is made from etherification with hydroxypropyl groups.[16] PVP is a hydrophilic polymer synthesized via free radical polymerization.[17] PVP is derived from N-vinylpyrrolidone and has excellent solubility, binding properties, and stabilizing effects.[18] The structures of these polymers are shown in **Figure 1**. Applications for PDMS and PEG are found in antifouling processes.[8,9] PEG is a polar polymer that possesses hydrophilic properties while PDMS is a nonpolar polymer that possesses hydrophobic properties.[7] Combining these polymers will synthesize an amphiphilic copolymer. This will be beneficial because the amphiphilic copolymer when placed on surfaces will cause that surface to alternate between polar and nonpolar character.[19] The amphiphilic polymers disrupt fouling processes on the surfaces where organic materials and aquatic organisms may grow.[7] It is important to have this characteristic to ensure no harm to organic life, and only reduce fouling by preventing settlement (anti-fouling, AF) or by enabling easier removal due to weak binding (fouling release, FR).[7] Their AF property or FR is effective against species such as mussels, cyprids, barnacles, mollusks, and oysters.[7,8] Application for HPC and PVP are found in the stabilization of nanoparticles.[20-22] HPC and PVP provide steric hindrance in the stabilization process preventing aggregation.[21-23] These polymers prevent nanocrystals from accumulating by forming a double electric layer around the particle due to their hydrophilic properties.[24]

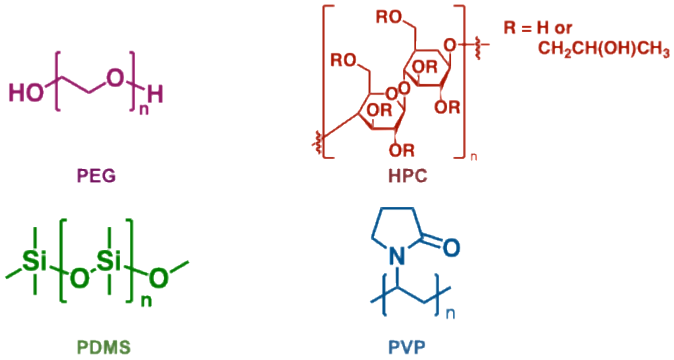


Figure 1. Chemical structures of PEG, PDMS, HPC, and PVP.

2. EXPERIMENTAL SECTION

2.1. Materials

Poly(ethylene glycol) (PEG, MW: 200) (Sigma-Aldrich), polydimethylsiloxane (PDMS, MW: 94,300) (Sigma-Aldrich), hydroxypropylcellulose (HPC, MW: 100,000) (Sigma-Aldrich), polyvinylpyrrolidone (PVP, MW: 1,300,000) (Sigma-Aldrich), dichloromethane (Sigma-Aldrich), and ethanol (Sigma-Aldrich) were bought from the specified sources and used as it is.

2.2. Coating Preparation

Coating solutions (4 wt%) were prepared by dissolving PEG and PDMS in methylene chloride while PVP and HPC were dissolved in ethanol. For the blend coatings, coating solutions were prepared at 4 wt% concentration using polymer blend ratios of 100:0 - 0:100 PDMS-PEG in methylene chloride, and ratios of 100:0 - 0:100 HPC-PVP were dissolved in ethanol. Solutions were stirred using a vortex until homogenous. The coating solutions were then deposited onto clean glass slides using a Badger 250 spray-coater. The glass slides were then annealed in a vacuum oven at 110°C overnight.

2.3. Characterization Methods

Ossila Contact Angle Goniometer. Contact angling data was measured using a water droplet on a polymer-coated glass slide (**Figure 2**).

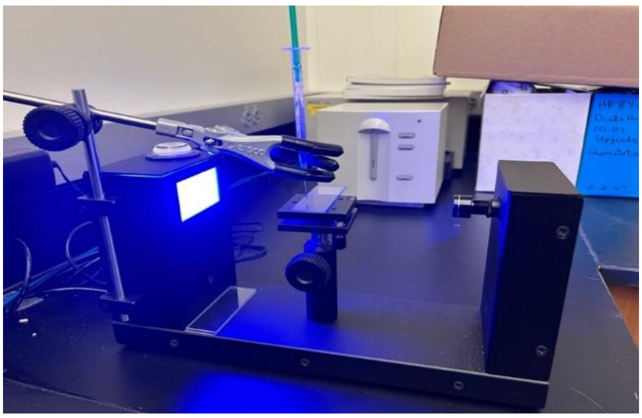


Figure 2. Ossila contact angle goniometer set up.

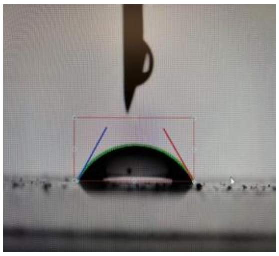
3. RESULTS AND DISCUSSION

3.1. Wettability of Pristine Polymer Coatings

3.1.1. Wettability of Water on PEG Coating

DCM was chosen as the solvent due to the polymer's solubility. Being that DCM is chlorinated and PEG is soluble in polar solvents made it an optimal choice. DCM has a low boiling point which would make it easier to evaporate the solvent from the polymer. This solvent also ejects well from the Badger 250 spray-coater which in turn causes the glass slides to be wetted uniformly. The polymer was dissolved in DCM and vortexed until homogeneous. The mixture was sprayed onto glass slides using a Badger 250 spray-coater. The glass slides were annealed overnight. Annealing of the glass slides was performed in a vacuum oven. Annealing was done to remove the solvent from the slides' coating, leaving only the polymer as a coating. Contact angles were gathered using the Ossila contact angle goniometer. The glass slides were placed on a stage in front of the instrument's camera. A syringe was secured into place above the slide and was pressed to slowly drop a water droplet onto the slide. Simultaneously, a video of this was being recorded by the instrument. A baseline at the direct top of the glass slide was found. The software then looks at the edges of the water droplet and analyzes the curvature frame by frame. The software calculates the contact angle for all frames and produces values for the left, right, and average curvature. Since the micro surface at different regions can be different, this contact angle measurement was repeated three times per glass slide and repeated for two coated slides to determine to eliminate variances arising from the coating method. This information is used to determine the wettability of a polymer coating. Wettability shows how one fluid clings or expands onto a solid surface when another fluid is present on the solid surface.[25] This can be used to determine if the coating on the solid surface is hydrophobic or hydrophilic. It is said that if the angle of the water droplet is less than 90° then the fluid is hydrophilic; likewise, if the angle of the water droplet is more than 90° then the fluid is hydrophobic.[26] The PEG average contact angle was calculated to be 52.33º. This is in line with literature-reported values for PEG coatings to be 53.00º. [27] This shows that PEG is hydrophilic and a water droplet is able to wet the coating surface. The hydrophilic nature is due to the structure of this polymer. It has two oxygen atoms that are electronegative. These atoms have a pulling force which causes partial charges to be formed which contributes to their polarity.

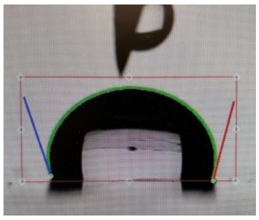
Table 1. Contact angle data for PEG-coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot trial	Solvent	Left	Right	Average	Overall Average
PEG slide-1	1	DCM	53.98º	53.85º	53.92º	Left Average Angle: 52.36º  Right Average Angle: 52.30º **Overall Average Angle: 52.33º**
PEG slide-1	2	DCM	52.98º	52.61º	52.79º	
PEG slide-1	3	DCM	50.17º	51.33º	50.75º	
PEG slide-2	1	DCM	52.07º	50.66º	51.37º	
PEG slide-2	2	DCM	53.72º	53.21º	53.47º	
PEG slide-2	3	DCM	51.29º	52.08º	51.69º	

3.1.2. Wettability of Water on PDMS Coating

DCM was chosen as the solvent due to the polymer's solubility. PDMS is classified as a nonpolar polymer. Being that DCM is a polar solvent and could dissolve nonpolar substances, made it the right solvent. DCM has a low boiling point which would make it easier to evaporate the solvent from the polymer. This solvent also ejects well from the Badger 250 spray-coater which in turn causes the glass slides to be wetted uniformly. The coating preparation and contact angle were done similarly to the previous polymer. The PDMS average contact angle was calculated to be 109.8º. This is in line with literature-reported values for PDMS coatings to be ~117º [28] This shows that PDMS is hydrophobic and the water droplet is not able to wet the coating surface very well. The hydrophobic nature is due to the structure of this polymer. Even though it has two electronegative atoms, the structure contains symmetry which contributes to why it is nonpolar.

Table 2. Contact angle data for PDMS-coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot trial	Solvent	Left	Right	Average	Overall Average
PDMS slide-1	1	DCM	111.44º	107.49º	109.47º	 Left Average Angle: 110.18º Right Average Angle: 109.44º Overall Average Angle: 109.81º
PDMS slide-1	2	DCM	108.94º	109.42º	109.18º	
PDMS slide-1	3	DCM	114.26º	110.53º	112.39º	
PDMS slide-2	1	DCM	114.54º	111.32º	112.93º	
PDMS slide-2	2	DCM	104.66º	110.18º	107.42º	
PDMS slide-2	3	DCM	107.25º	107.72º	107.49º	

3.1.3. Wettability of Water on HPC Coating

HPC was not soluble in DCM therefore ethanol was used as a solvent. Ethanol was chosen as the solvent due to its highly polar nature. Since ethanol has a short chain, it allows the -OH to dominate giving it its highly polar nature. This solvent also ejects well from the Badger 250 spray-coater which in turn causes the glass slides to be wetted uniformly. The coating preparation and contact angle were done similarly to the previous polymer. The HPC average contact angle was calculated to be 57.4º. This average differed from literature-reported values as they were reported to be 30º.[23] This shows that HPC is hydrophilic and a water droplet is able to wet the coating surface. The hydrophilic nature is due to the structure of this polymer. It has multiple oxygen atoms that are electronegative. These atoms have a pulling force which causes partial charges to be formed which contributes to their polarity.

3.1.4. Wettability of Water on PVP Coating

PVP was able to dissolve in DCM, however, the solvent was switched to ethanol so comparative data could be gathered. Ethanol has a highly polar nature which makes it an optimal solvent for the polar PVP. This solvent also ejects well from the Badger 250 spray-coater which in turn causes the glass slides to be wetted uniformly. The coating preparation and contact angle were done similarly to the previous polymer. The PVP dissolved in DCM and the PVP dissolved in ethanol average contact angle was calculated to be 34.56º and 48.22º, respectively. This is in line with literature-reported values for PVP coatings to be 32º).[29] This shows that PVP is hydrophilic and a water droplet is able to wet the coating surface very well. The hydrophilic nature is due to the structure of this polymer. It has two atoms, nitrogen, and oxygen, that are electronegative. These atoms have a pulling force that causes partial charges to be formed which contributes to its polarity. There is a difference in contact angle averages between the solvents. There is evidence based on previous studies that solvents may affect the morphology and dispersion of different polymers.[30] Using OMAX, a microscope image captured the surface of the glass slide coated with 100% PEG shown in **Figure 7.**

Table 3. Contact angle data for HPC-coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

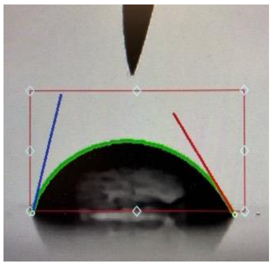
Sample	Spot trial	Solvent	Left	Right	Average	Overall Average
HPC slide-1	1	Ethanol	51.00º	48.08º	49.54º	 Left Average Angle: 57.82º Right Average Angle: 56.93º Overall Average Angle: 57.39º
HPC slide-1	2	Ethanol	62.41º	53.85º	58.13º	
HPC slide-1	3	Ethanol	64.78º	67.31º	66.04º	
HPC slide-2	1	Ethanol	54.99º	57.59º	56.29º	
HPC slide-2	2	Ethanol	60.19º	58.80º	59.50º	
HPC slide-2	3	Ethanol	53.52º	56.22º	54.87º	

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Table 4. Contact angle data for PVP-coated slide dissolved in Ethanol. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

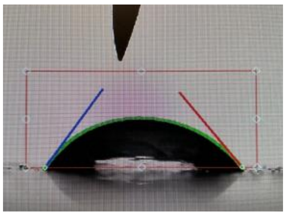
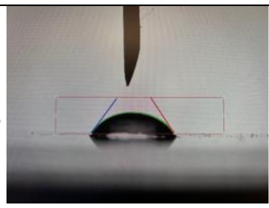
Sample	Spot trial	Solvent	Left	Right	Average	Overall Average
PVP slide-1	1	Ethanol	49.21º	55.43º	52.32 º	Left Average Angle: 49.56º  Right Average Angle: 48.88º Overall Average Angle: 48.22º
PVP slide-1	2	Ethanol	39.06º	35.81º	37.44º	
PVP slide-1	3	Ethanol	53.22º	48.58º	50.90º	
PVP slide-2	1	Ethanol	50.10º	43.34º	46.72º	
PVP slide-2	2	Ethanol	53.28º	46.61º	49.95º	
PVP slide-2	3	Ethanol	52.49º	51.48º	51.99º	

Table 5. Contact angle data for PVP-coated slide dissolved in DCM. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot trial	Solvent	Left	Right	Average	Overall Average
Sample	Spot trial	Solvent	Left	Right	Average	Left Average Angle: 34.85º  Right Average Angle: 34.29º Overall Average Angle: 34.56º
PVP slide-1	1	DCM	29.36º	32.18º	30.77º	
PVP slide-1	2	DCM	36.85º	32.76º	34.81º	
PVP slide-1	3	DCM	28.00º	27.44º	27.72º	
PVP slide-2	1	DCM	34.77º	30.73º	32.75º	
PVP slide-2	2	DCM	47.82º	47.67º	47.75º	

3.2. Polymer Blend Coatings

3.2.1. Wettability of Water on PDMS-PEG Coating

The coating preparation and contact angle were done similarly to the previous section. As shown in Figure 1, the PDMS-PEG blends start as hydrophobic with 100% PDMS and eventually transition to hydrophilic with 100% PEG. The PDMS-PEG ratio blend data showed a semi-linear relationship trend from hydrophobic to hydrophilic. Standard deviation data was gathered to show sample deviations from the mean. Most standard deviations were found to be ~2.5 except the following: 60:40, 50:50, and 20:80 which were 3.44, 4.96, and 4.75, respectively. At these compositions, the data dispersed further from the mean than at other compositions. These compositions can be described in three separate groups. At 100% PDMS, the surface is identified as hydrophobic. There is a sharp drop in contact angle measurement at 90:10 PDMS-PEG composition which stays roughly similar given deviation data until 20:80 PDMS-PEG composition. This group can be identified as amphiphilic moving towards becoming hydrophilic with a slight slope of -4.88 with respect to increasing PEG concentrations. There is then another sharp drop in contact angle measurement at 10:90 PDMS-PEG composition that is also similar to 100% PEG. This group is identified as hydrophilic. Within these compositions, there is a hydrophobic surface at 100% PDMS, which moves to amphiphilic when little PEG is added and moves slightly towards hydrophilic as more is added, and then hydrophilic when PEG is at 90% and 100%. **Figure 8** depicts this trend. **Tables 6-14** show individual contact angles for the 90:10-10:90 PDMS-PEG ratio blends. Interestingly, there are little changes within the amphiphilic region, even though the composition is changing a lot.

Table 6. Contact angle data for 90:10 PDMS-PEG coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot Trial	Solvent	Left	Right	Average
PDMS/PEG 90:10 slide-1	1	DCM	98.17º	99.34º	98.74º
PDMS/PEG 90:10 slide-1	2	DCM	99.27º	88.04º	93.66º
PDMS/PEG 90:10 slide-1	3	DCM	97.32º	101.08º	99.20º
PDMS/PEG 90:10 slide-2	1	DCM	91.93º	104.27º	98.10º
PDMS/PEG 90:10 slide-2	2	DCM	100.26º	105.20º	102.73º
PDMS/PEG 90:10 slide-2	3	DCM	93.38º	100.04º	96.71º

Table 7. Contact angle data for 80:20 PDMS-PEG coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot trial	Solvent	Left	Right	Average
PDMS/PEG 80:20 slide-1	1	DCM	84.02º	98.84º	91.43º
PDMS/PEG 80:20 slide-1	2	DCM	86.52º	97.01º	91.76º
PDMS/PEG 80:20 slide-1	3	DCM	98.34º	98.20º	98.27º
PDMS/PEG 80:20 slide-2	1	DCM	90.04º	101.85º	95.94º
PDMS/PEG 80:20 slide-2	2	DCM	94.07º	97.48º	95.78º
PDMS/PEG 80:20 slide-2	3	DCM	94.31º	89.93º	92.12º

Table 8. Contact angle data for 70:30 PDMS-PEG coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot Trial	Solvent	Left	Right	Average
PDMS/PEG 70:30 slide-1	1	DCM	83.64º	85.86º	84.75º
PDMS/PEG 70:30 slide-1	2	DCM	82.15º	97.98º	90.06º
PDMS/PEG 70:30 slide-1	3	DCM	89.15º	90.69º	89.92º
PDMS/PEG 70:30 slide-2	1	DCM	90.54º	86.18º	88.36º
PDMS/PEG 70:30 slide-2	2	DCM	91.62º	93.95º	92.79º
PDMS/PEG 70:30 slide-2	3	DCM	97.35º	86.88º	92.12º

Table 9. Contact angle data for 60:40 PDMS-PEG coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot Trial	Solvent	Left	Right	Average
PDMS/PEG 60:40 slide-1	1	DCM	82.63º	93.51º	88.07º
PDMS/PEG 60:40 slide-1	2	DCM	87.67º	78.52º	93.66º
PDMS/PEG 60:40 slide-1	3	DCM	84.59º	80.87º	82.73º
PDMS/PEG 60:40 slide-2	1	DCM	90.44º	82.68º	86.56º
PDMS/PEG 60:40 slide-2	2	DCM	85.88º	83.45º	84.67º
PDMS/PEG 60:40 slide-2	3	DCM	84.42º	86.94º	85.68º

Table 10. Contact angle data for 50:50 PDMS-PEG coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot trial	Solvent	Left	Right	Average
PDMS/PEG 50:50 slide-1	1	DCM	85.66º	79.10º	82.38º
PDMS/PEG 50:50 slide-1	2	DCM	78.87º	83.51º	81.19º
PDMS/PEG 50:50 slide-1	3	DCM	71.48º	80.02º	75.75º
PDMS/PEG 50:50 slide-2	1	DCM	89.88º	89.80º	89.84º
PDMS/PEG 50:50 slide-2	2	DCM	75.81º	96.53º	86.17º
PDMS/PEG 50:50 slide-2	3	DCM	79.48º	73.72º	76.60º

Table 11. Contact angle data for 40:60 PDMS-PEG coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot Trial	Solvent	Left	Right	Average
PDMS/PEG 40:60 slide-1	1	DCM	90.52º	76.78º	83.65º
PDMS/PEG 40:60 slide-1	2	DCM	83.96º	89.80º	86.88º
PDMS/PEG 40:60 slide-1	3	DCM	92.02º	92.18º	92.10º
PDMS/PEG 40:60 slide-2	1	DCM	80.32º	89.03º	84.71º
PDMS/PEG 40:60 slide-2	2	DCM	92.62º	89.03º	84.71º
PDMS/PEG 40:60 slide-2	3	DCM	90.54º	82.84º	86.69º

Table 12. Contact angle data for 30:70 PDMS-PEG coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot Trial	Solvent	Left	Right	Average
PDMS/PEG 30:70 slide-1	1	DCM	83.19º	73.11º	78.15º
PDMS/PEG 30:70 slide-1	2	DCM	85.29º	75.37º	80.32º
PDMS/PEG 30:70 slide-1	3	DCM	79.48º	83.80º	81.64º
PDMS/PEG 30:70 slide-2	1	DCM	87.47º	78.49º	82.98º
PDMS/PEG 30:70 slide-2	2	DCM	86.75º	78.35º	82.55º
PDMS/PEG 30:70 slide-2	3	DCM	82.82º	82.41º	82.61º

Table 13. Contact angle data for 20:80 PDMS-PEG coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot trial	Solvent	Left	Right	Average
PDMS/PEG 20:80 slide-1	1	DCM	77.22º	67.48º	72.35º
PDMS/PEG 20:80 slide-1	2	DCM	64.31º	84.46º	74.39º
PDMS/PEG 20:80 slide-1	3	DCM	81.46º	76.41º	78.94º
PDMS/PEG 20:80 slide-2	1	DCM	84.98º	82.56º	83.77º
PDMS/PEG 20:80 slide-2	2	DCM	85.24º	86.04º	85.64º
PDMS/PEG 20:80 slide-2	3	DCM	81.58º	80.12º	80.85º

Table 14. Contact angle data for 10:90 PDMS-PEG coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	Spot Trial	Solvent	Left	Right	Average
PDMS/PEG 10:90 slide-1	1	DCM	88.76º	77.82º	83.29º
PDMS/PEG 10:90 slide-1	2	DCM	77.64º	80.17º	78.91º
PDMS/PEG 10:90 slide-1	3	DCM	81.58º	76.23º	78.91º
PDMS/PEG 10:90 slide-2	1	DCM	76.75º	88.00º	82.37º
PDMS/PEG 10:90 slide-2	2	DCM	85.71º	85.03º	85.37º
PDMS/PEG 10:90 slide-2	3	DCM	73.72º	82.53º	78.12º

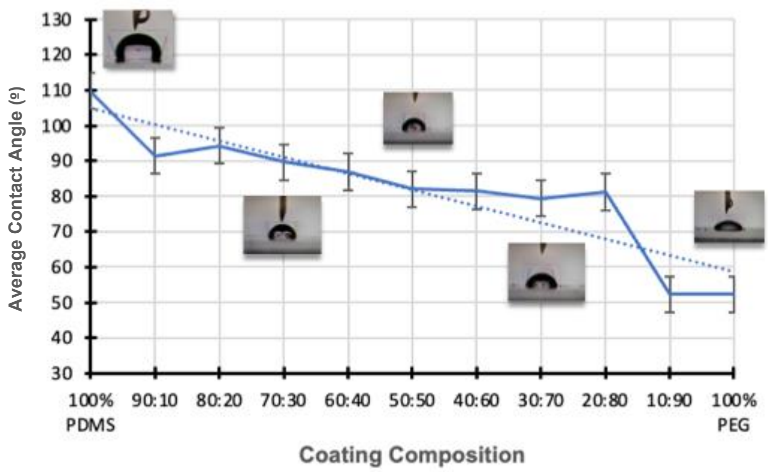


Figure 8. Graph of contact angle averages of 100:0-0:100 PDMS-PEG ratio blends.

3.2.2. Wettability of Water on HPC-PVP Coating

The coating preparation and contact angle were done similarly to the previous section. As shown in Figure 4, the HPC-PVP blends start as hydrophilic with 100% HPC and stay hydrophilic with 100% PVP. This is expected since both the polymers are individually hydrophilic. The HPC-PVP ratio blend data showed no relationship trend from hydrophobic to hydrophilic or hydrophilic to hydrophobic. Standard deviation data was gathered to show sample deviations from the mean. Most standard deviations were found to be less than ~3.00 except the following: 100% HPC, 100% PVP, 50:50 HPC-PVP, 20:80 HPC-PVP, and 10:90 HPC-PVP which were 4.98, 5.16, 8.68, 4.69, and 8.61, respectively. At these compositions, the data dispersed further from the mean than at other compositions. Within these compositions, the contact angle measurements did not have a specific trend. From 100% HPC to 100% PVP the angles stayed in the range of hydrophilic, with a very steady slope of -1.02 with respect to increasing PVP concentration. This is plausible given the angles for the polymers were originally hydrophilic. The increases and decreases among the set can be explained through contact angle equipment deviations, or differences in surface morphology, which might be more influential, since hydrophilicity differences are low. AFM studies could be conducted to determine if there are any differences in surface roughness and uniformity. **Figure 9** depicts this relationship. **Tables 15-23** show individual contact angles for the 90:10-10:90 HPC-PVP ratio blends.

Table 15. Contact angle data for 90:10 HPC-PVP coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	**Spot Trial**	**Solvent**	**Left**	**Right**	**Average**
HPC/PVP 90:10 slide-1	1	Ethanol	66.15°	64.38°	65.27°
HPC/PVP 90:10 slide-1	2	Ethanol	56.37°	58.07°	57.22°
HPC/PVP 90:10 slide-1	3	Ethanol	60.89°	60.64°	60.77°
HPC/PVP 90:10 slide-2	1	Ethanol	71.18°	62.04°	66.61°
HPC/PVP 90:10 slide-2	2	Ethanol	64.41°	62.27°	63.34°
HPC/PVP 90:10 slide-2	3	Ethanol	59.63°	57.66°	58.65°

Table 16. Contact angle data for 80:20 HPC-PVP coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	**Spot trial**	**Solvent**	**Left**	**Right**	**Average**
HPC/PVP 80:20 slide-1	1	Ethanol	54.08°	59.78°	56.93°
HPC/PVP 80:20 slide-1	2	Ethanol	56.41°	57.27°	56.84°
HPC/PVP 80:20 slide-1	3	Ethanol	57.10°	64.13°	60.61°
HPC/PVP 80:20 slide-2	1	Ethanol	54.20°	59.82°	57.01°
HPC/PVP 80:20 slide-2	2	Ethanol	53.59°	58.02°	55.80°
HPC/PVP 80:20 slide-2	3	Ethanol	60.57°	62.24°	61.40°

Table 17. Contact angle data for 70:30 HPC-PVP coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	**Spot Trial**	**Solvent**	**Left**	**Right**	**Average**
HPC/PVP 70:30 slide-1	1	Ethanol	46.51°	47.91°	47.21°
HPC/PVP 70:30 slide-1	2	Ethanol	44.92°	44.99°	44.95°
HPC/PVP 70:30 slide-1	3	Ethanol	49.08°	44.87°	46.98°
HPC/PVP 70:30 slide-2	1	Ethanol	43.12°	47.79°	45.46°
HPC/PVP 70:30 slide-2	2	Ethanol	37.72°	40.25°	39.99°
HPC/PVP 70:30 slide-2	3	Ethanol	43.21°	48.77°	45.99°

Table 18. Contact angle data for 60:40 HPC-PVP coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	**Spot Trial**	**Solvent**	**Left**	**Right**	**Average**
HPC/PVP 60:40 slide-1	1	Ethanol	51.91°	61.73°	56.82°
HPC/PVP 60:40 slide-1	2	Ethanol	56.39°	54.80°	55.59°
HPC/PVP 60:40 slide-1	3	Ethanol	53.45°	51.16°	52.31°
HPC/PVP 60:40 slide-2	1	Ethanol	51.79°	55.62°	53.71°
HPC/PVP 60:40 slide-2	2	Ethanol	49.00°	55.38°	55.63°
HPC/PVP 60:40 slide-2	3	Ethanol	58.12°	53.14°	55.63°

Table 19. Contact angle data for 50:50 HPC-PVP coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	**Spot trial**	**Solvent**	**Left**	**Right**	**Average**
HPC/PVP 50:50 slide-1	1	Ethanol	44.81°	39.22°	42.01°
HPC/PVP 50:50 slide-1	2	Ethanol	59.38°	57.75°	58.57°
HPC/PVP 50:50 slide-1	3	Ethanol	41.27°	42.61°	41.94°
HPC/PVP 50:50 slide-2	1	Ethanol	32.83°	36.88°	34.85°
HPC/PVP 50:50 slide-2	2	Ethanol	43.89°	49.21°	46.55°
HPC/PVP 50:50 slide-2	3	Ethanol	55.20°	48.68°	57.94°

Table 20. Contact angle data for 40:60 HPC-PVP coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	**Spot Trial**	**Solvent**	**Left**	**Right**	**Average**
HPC/PVP 40:60 slide-1	1	Ethanol	47.94°	44.62°	46.28°
HPC/PVP 40:60 slide-1	2	Ethanol	40.59°	47.08°	43.84°
HPC/PVP 40:60 slide-1	3	Ethanol	44.98°	38.94°	41.96°
HPC/PVP 40:60 slide-2	1	Ethanol	47.45°	45.59°	46.52°
HPC/PVP 40:60 slide-2	2	Ethanol	48.92°	46.59°	47.76°
HPC/PVP 40:60 slide-2	3	Ethanol	55.94°	43.26°	49.60°

Table 21. Contact angle data for 30:70 HPC-PVP coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	**Spot Trial**	**Solvent**	**Left**	**Right**	**Average**
HPC/PVP 30:70 slide-1	1	Ethanol	56.81°	53.17°	54.99°
HPC/PVP 30:70 slide-1	2	Ethanol	43.15°	50.83°	46.99°
HPC/PVP 30:70 slide-1	3	Ethanol	54.32°	49.74°	52.03°
HPC/PVP 30:70 slide-2	1	Ethanol	48.88°	57.00°	52.94°
HPC/PVP 30:70 slide-2	2	Ethanol	52.88°	55.42°	54.15°
HPC/PVP 30:70 slide-2	3	Ethanol	52.75°	55.65°	54.60°

Table 22. Contact angle data for 20:80 HPC-PVP coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	**Spot trial**	**Solvent**	**Left**	**Right**	**Average**
HPC/PVP 20:80 slide-1	1	Ethanol	55.37°	59.53°	57.45°
HPC/PVP 20:80 slide-1	2	Ethanol	47.67°	51.05°	49.36°
HPC/PVP 20:80 slide-1	3	Ethanol	42.95°	49.29°	46.12°
HPC/PVP 20:80 slide-2	1	Ethanol	54.24°	56.75°	55.50°
HPC/PVP 20:80 slide-2	2	Ethanol	59.34°	57.95°	58.64°
HPC/PVP 20:80 slide-2	3	Ethanol	53.77°	61.42°	57.60°

Table 23. Contact angle data for 10:90 HPC-PVP coated slide. Two glass slides were sprayed with the coating and data was collected from three different spots on each slide.

Sample	**Spot Trial**	**Solvent**	**Left**	**Right**	**Average**
HPC/PVP 10:90 slide-1	1	Ethanol	57.71°	55.98°	56.85°
HPC/PVP 10:90 slide-1	2	Ethanol	52.73°	52.56°	52.64°
HPC/PVP 10:90 slide-1	3	Ethanol	57.77°	57.44°	57.60°
HPC/PVP 10:90 slide-2	1	Ethanol	57.45°	57.02°	57.23°
HPC/PVP 10:90 slide-2	2	Ethanol	34.33°	40.50°	37.42°
HPC/PVP 10:90 slide-2	3	Ethanol	43.70°	34.11°	38.91°

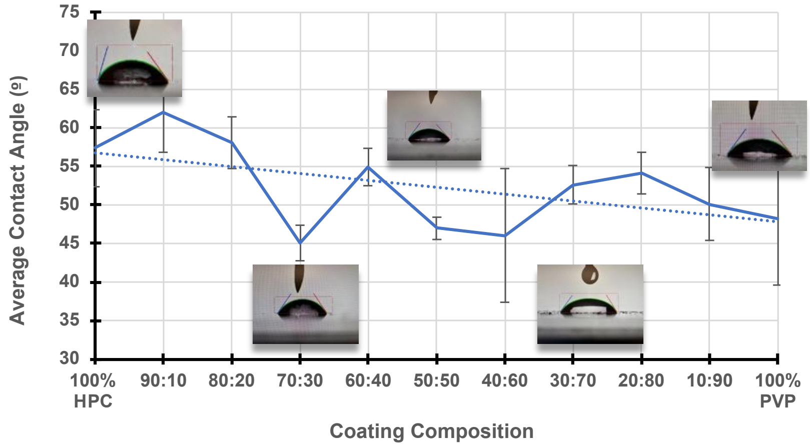


Figure 9. Graph of contact angle averages of 100:0-0:100 HPC-PVP ratio blends.

3.2.3. Wettability of Organic Liquids on HPC-PVP Coating

Since HPC and PVP have also been used as nanoparticle stabilization agents, we attempted to explore their direct interaction with a set of common organic solvents as well, to better understand any differences in their interaction tendencies. The coating preparation and contact angle were done similarly to the previous section. The organic liquids of DCM, toluene, ethylene glycol, and THF were chosen to investigate their wettability on HPC-PVP coatings. To investigate this, coatings of 100% HPC, 50:50 HPC-PVP, and 100% PVP were used. **Tables 24-27** show these results. DCM, toluene, and ethylene glycol completely wet the surfaces of 100% HPC, 50:50 HPC-PVP, and 100% PVP. THF completely wet the surfaces of 100% PVP and 50:50 HPC-PVP. THF did not completely wet the surface of 100% HPC and contact angle data was gathered (Table 27). The exact reason for this lower wettability of THF on 100% HPC coating is not fully understood, and theoretical studies could help shed more light on the interactions responsible.

Table 24. Contact angle data dropping DCM for 100% HPC, 50:50 HPC-PVP, and 100% PVP coated slide. Glass slides were sprayed with the coating, and data was collected.

Sample	Organic Liquid	Solvent	Left	Right	Average
HPC 100%	DCM	Ethanol	-	-	-
HPC/PVP 50:50	DCM	Ethanol	-	-	-
PVP 100%	DCM	Ethanol	-	-	-

*** (-) represents complete wetting of the slide's surface**

Table 25. Contact angle data dropping Toluene for 100% HPC, 50:50 HPC-PVP, and 100% PVP coated slide. Glass slides were sprayed with the coating, and data was collected.

Sample	Organic Liquid	Solvent	Left	Right	Average
HPC 100%	Toluene	Ethanol	-	-	-
HPC/PVP 50:50	Toluene	Ethanol	-	-	-
PVP 100%	Toluene	Ethanol	-	-	-

*** (-) represents complete wetting of the slide's surface**

Table 26. Contact angle data dropping Ethylene glycol for 100% HPC, 50:50 HPC-PVP, and 100% PVP coated slide. Glass slides were sprayed with the coating, and data was collected.

Sample	Organic Liquid	Solvent	Left	Right	Average
HPC 100%	Ethylene Glycol	Ethanol	-	-	-
HPC/PVP 50:50	Ethylene Glycol	Ethanol	-	-	-
PVP 100%	Ethylene Glycol	Ethanol	-	-	-

*** (-) represents complete wetting of the slide's surface**

Table 27. Contact angle data dropping THF for 100% HPC, 50:50 HPC-PVP, and 100% PVP coated slide. Glass slides were sprayed with the coating, and data was collected.

Sample	Organic Liquid	Solvent	Left	Right	Average
HPC 100%	THF	Ethanol	30.69	30.13	30.41
HPC/PVP 50:50	THF	Ethanol	-	-	-
PVP 100%	THF	Ethanol	-	-	-

*** (-) represents complete wetting of the slide's surface**

4. CONCLUSIONS

This study conducted explorations to understand the wettability of amphiphilic polymer coatings. Spray coatings were used with DCM as the solvent for PEG, PDMS, and PVP; HPC could not be dissolved in DCM, so ethanol was used instead. Contact angle data reported that PEG, HPC, and PVP coatings have hydrophilic properties while PDMS coatings have hydrophobic properties. These findings aligned with data reported previously. PVP was dissolved in both DCM and ethanol such that comparative data between HPC and PVP could be obtained. There were slight differences between PVP dissolved in ethanol and PVP dissolved in DCM; these differences may be due to how solvents impact the morphology and dispersion of polymers. Further, polymer blends were explored to generate amphiphilic coatings. Contact angle data for the polymer blends reported that PDMS-PEG blends had a hydrophobic character at 100% PDMS to 90:10 PDMS-PEG. The blends of 80:20 PDMS-PEG through 20:80 PDMS-PEG had amphiphilic character. At 10:90 PDMS-PEG and 100% PEG, the blends had a hydrophilic character. Contact angle data reported that all blends of 100% HPC through 100% PVP had hydrophilic characteristics. When exploring the interaction among HPC-PVP with different organic liquids, it was found that ethylene glycol, toluene, and DCM wet the slide surface completely at 100% HPC, 50:50 HPC-PVP, and 100% PVP. THF wet the surface of the slide completely at 50:50 HPC-PVP and 100% PVP. At 100% HPC, the interaction was found to be more hydrophilic in character. Overall, this study serves as a foundational work for the design of tailored polymeric coatings for surface modification, targeting specific surface interactions while disabling others, for both anti-fouling and nanoparticle stabilization applications.

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