Supporting Information

Relationships between Surface Properties and Snow Adhesion and its Shedding Mechanisms

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Calculation of Shear Adhesion Strength.

Shear adhesion strength was calculated in two methods to ensure accuracy of the obtained values in the first method force vs displacement graph and in the second method an average of instantaneous shear adhesion. The two methods vary in results by less than 5% on average.

Method 1: Force vs Displacement for Calculating Snow Shear Adhesion Strength

1. Force probe data is first collected from an experiment shown in Figure S4.
2. The maximum value for the force with snow present on the sample is determined. In this case, the max force is 10.15 N.
3. The average of the non-zero values for the friction force (the second pull without snow present on the sample) is taken. In this scenario, the average friction is 0.96 N.
4. The average friction force is subtracted from the maximum force with snow on the substrate to obtain the total force required to shear the snow deducting the impact of friction.

$$10.15\ (N) - 0.96\ (N) = 9.19\ N$$

5. The force required to shear the snow is then divided by the area of the test sample, which is this case is a 6 in x 6 or 0.02323 m^2.

$$9.19\ (N) \div 0.02323\ (m^2) = 395.61\ Pa$$

Method 2: Average of Instantaneous Shear Adhesion

1. The average friction force is determined from the data (0.96 N) and subtracted from each sample point of the force data with snow (the first pull of the experiment with the snow on the sample) (Table S2).

2. The instantaneous area of snow remaining on the sample is calculated at each point by knowing the time required to complete the full experiment. This linear calculation of remaining area is accurate because the cart is moving at a constant speed.
3. The shear adhesion strength at each point is calculated and the average is taken.

Supporting Figures

Figure S1. A walk-in freezing room connected to a wind tunnel that is used for forming snow in controlled temperatures.

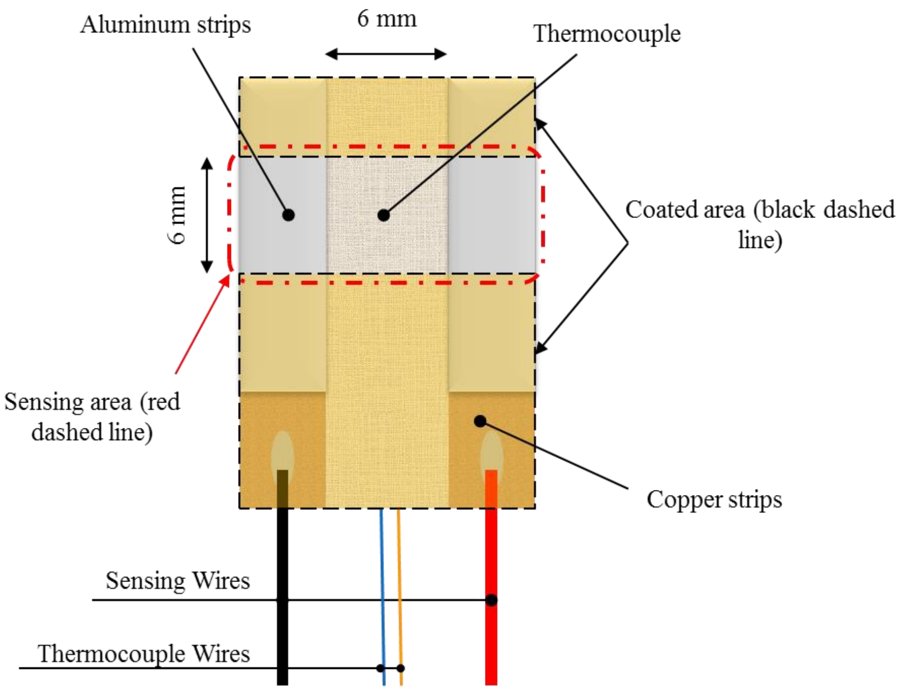

Figure S2. Schematic of the sensor for measuring the liquid water content (LWC) of snow.

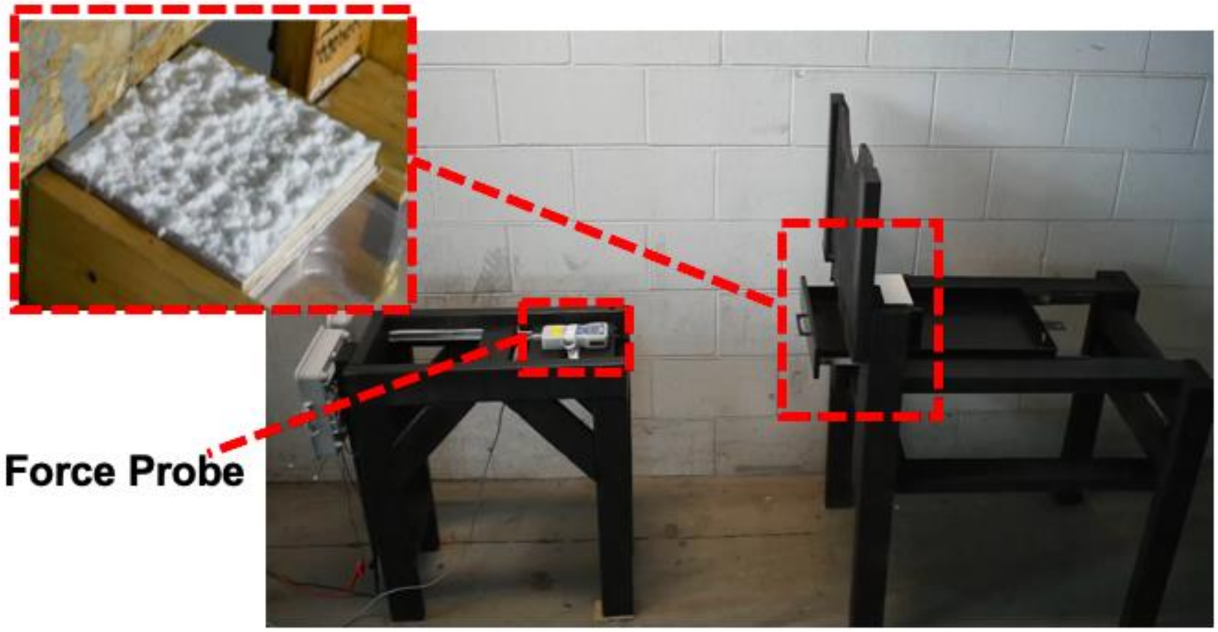

Figure S3. A photo of the snow adhesion measurement setup. Adhesion measurements conducted on coupons of 6 inch by 6 inch as shown in the inset photo.

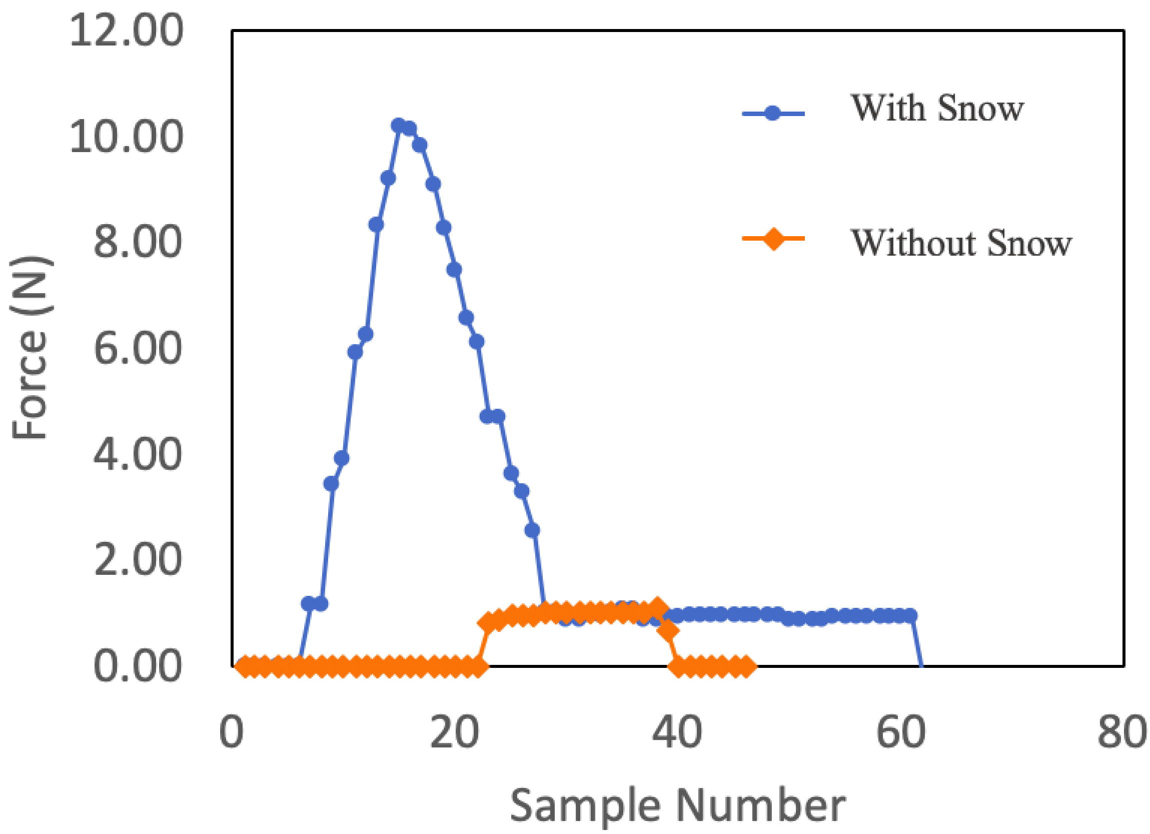

Figure S4 Representative plots of force values obtained from the force probe from the adhesion measurement with and without snow on the test substrate (aluminum 6061 at -2 °C). Data points were recorded every 0.2 seconds. The sample number reflects the number of data points taken.

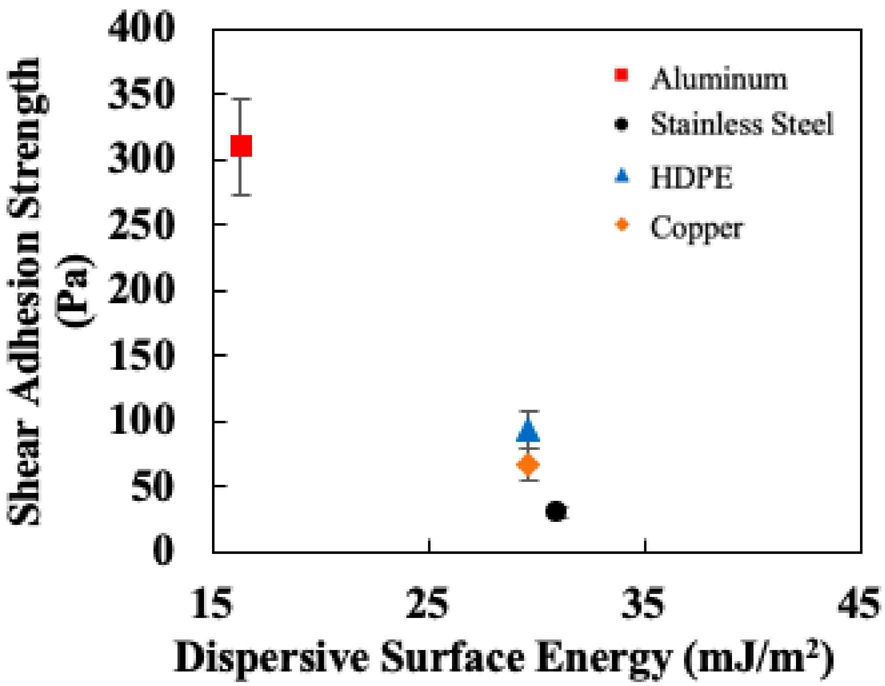

Figure S5 Plot of shear adhesion strength of snow (LWC of ~ 22%) as a function of dispersive surface energy measured on aluminum 6061, copper, stainless steel, and HDPE substrates.

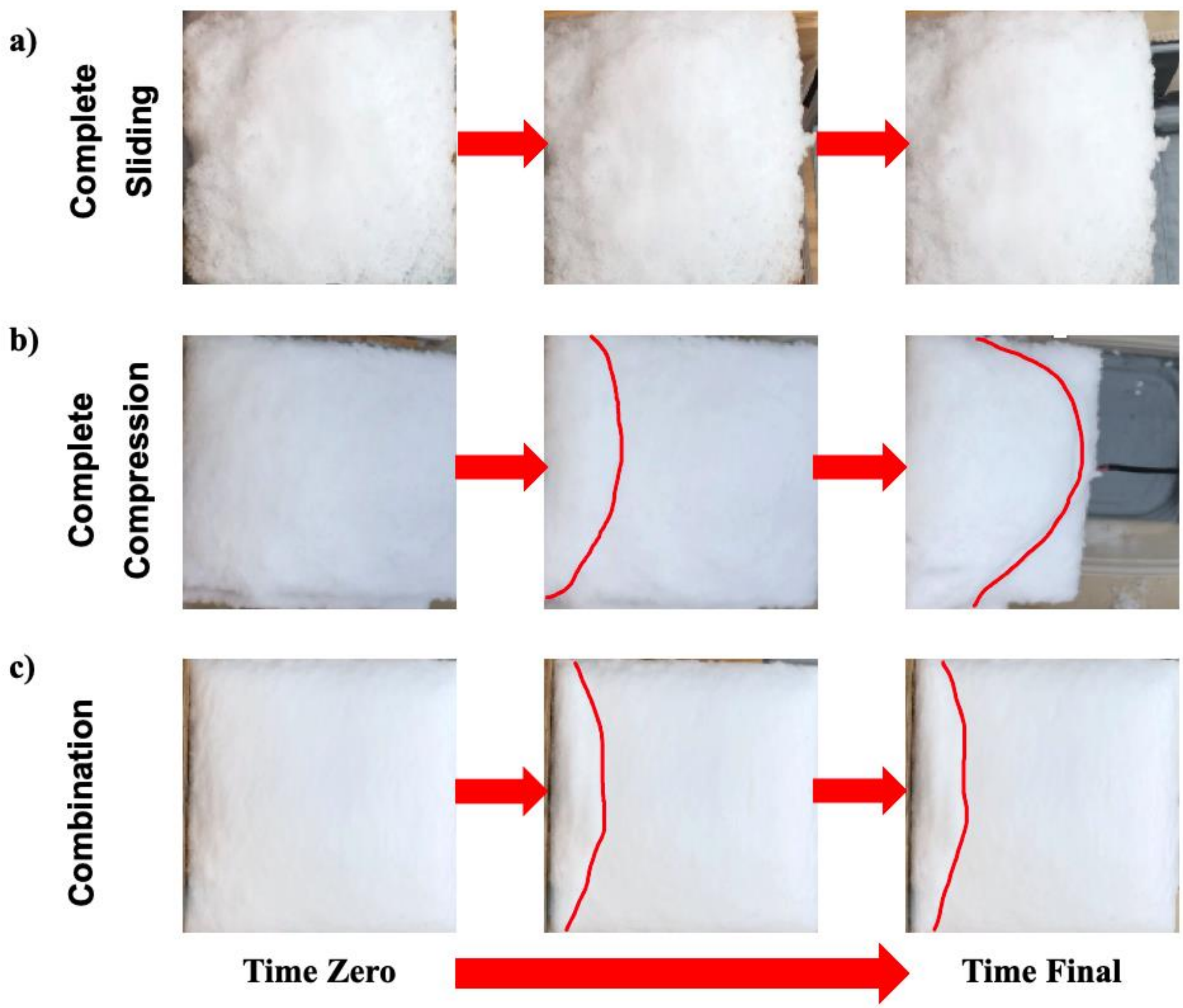

Figure S6. Time progression of snow shear adhesion failure mechanisms. The LWC was held constant at ~ 22% for each experiment. a) Complete sliding occurs at -2℃. b) Complete compression occurs at 2℃. c) A combination of the two failure mechanisms occurs at 0℃. The red lines in b) and c) intend to guide eyes for compression and pilling of snow, occurred during its de-adhering/shedding.

a)

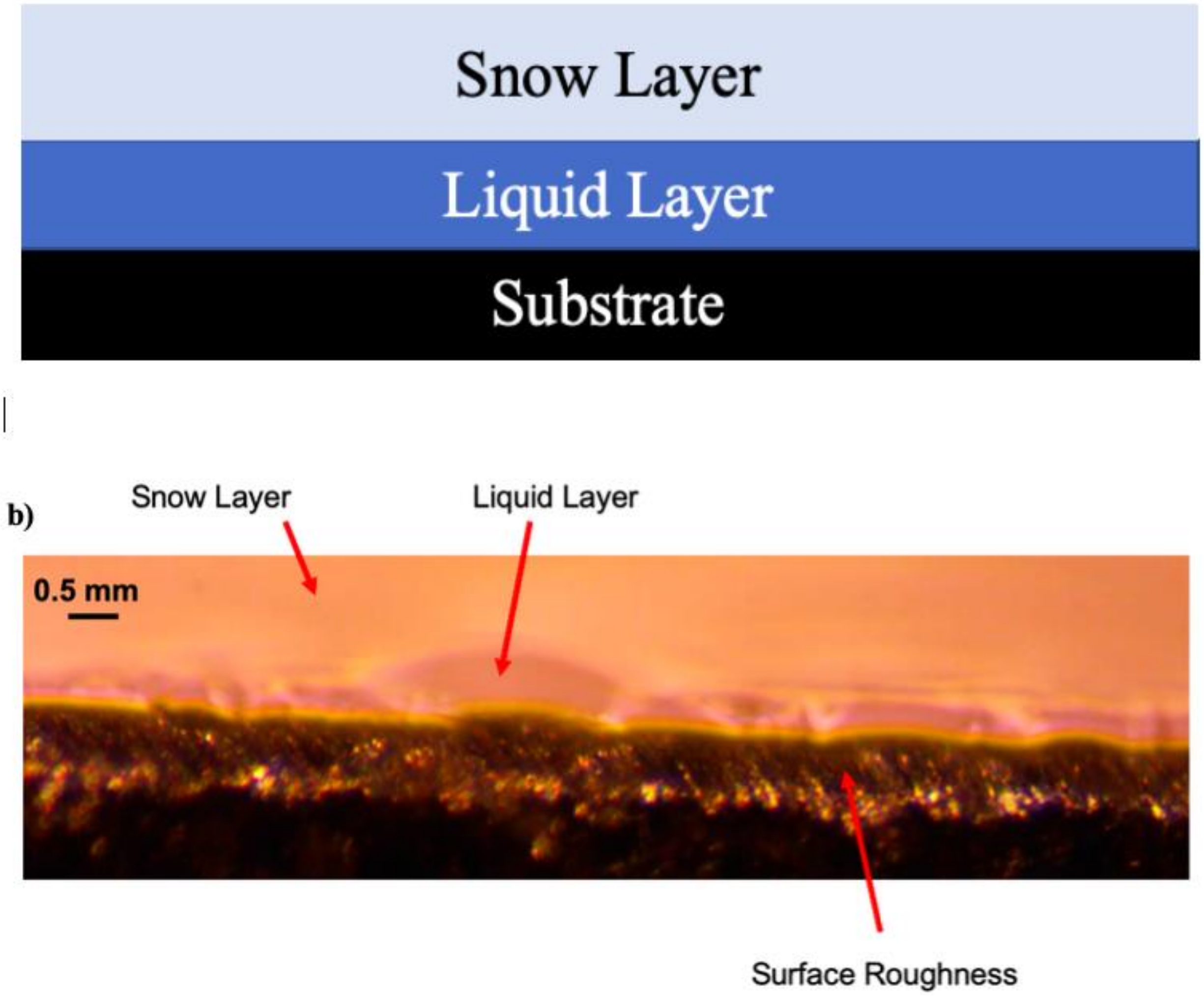

Figure S7. a) A schematic of the liquid layer formed at a snow-substrate interface. b) A close-up view of a liquid layer formed between the snow and the substrate.

Table S1. Experimental results of snow shear adhesion testing.

Surface	Total Surface Energy mJ/m2	Dispersive Surface Energy mJ/m2	Polar Surface Energy mJ/m2	RMS (μm)	LWC (%)	Shear Adhesion (Pa)					
Aluminum 6061	30.95	21.58	9.37	308.33	22	28.1	32.9	34.8	37.1	29.1	
	28.61	9.44	19.17	273.31	22	45.5	51.8	55.5	54.0	47.2	
	28.78	13.77	15.01	238.29	22	47.1	52.4	65.3	34.1	58.3	
	31.31	28.46	2.86	169.42	22	122.2	139.7	129.2	150.8	144.6	
	27.16	26.59	0.56	134.4	22	155.1	163.0	150.3	130.8	156.2	
	26.2	16.34	9.86	36.35	22	326.9	321.8	344.0	333.9	330.6	
	28.09	27.71	0.38	15.34	22	138.6	222.7	139.8	221.5	215.9	
	30.29	27.13	3.16	7.17	22	155.8	103.4	128.8	118.3	91.6	
HDPE	37.18	31.03	6.15	36.35	22	24.5	30.6	36.7	28.1	28.0	31.4
SS	37.05	29.64	7.41	36.35	22	85.2	64.5	73.3	52.5	69.3	53.8
Copper	35.4	34.26	1.15	36.35	22	33.8	85.1	101.2	32.7	78.8	108.1
Aluminum 6061	26.2	16.34	9.86	36.35	22	326.6	321.5	285.7	344.0	333.7	245.4
				36.35	9	45.1					
				36.35	13	26.2					
				36.35	10	56.1					
				36.35	12	38.0					
				36.35	11	34.9					
				36.35	23	161.9					
				36.35	20	171.9					
				36.35	26	150.8					
				36.35	22	158.2					
				36.35	24	166.2					
				36.35	39	93.3					
				36.35	44	67.9					
				36.35	45	65.7					
				36.35	38	64.5					
				36.35	46	64.1					
Photovoltaic Glass				1.19	9	41.1					
				1.19	11	33.1					
				1.19	12	44.2					
				1.19	7	27.9					
				1.19	8	24.9					
				1.19	24	57.0					
				1.19	23	67.7					
				1.19	18	78.4					
				1.19	16	73.1					
				1.19	21	62.0					
				1.19	42	37.3					
				1.19	28	53.2					
				1.19	29	47.4					
				1.19	31	52.0					
				1.19	27	53.0					

Table S2. Calculation of average instantaneous shear adhesion strength values.

Force with Snow (N)	Snow Shear Adhesion Force (N)	Instantaneous Length Remaining (m)	Area Remaining (m^2)	Instantaneous Shear Adhesion (Pa)
1.14	1.18	0.15	0.02323	7.75
1.15	0.19	0.15	0.02230	8.52
3.42	2.46	0.14	0.02137	115.13
3.91	2.95	0.13	0.02044	144.33
5.88	4.92	0.13	0.01951	252.18
6.22	5.26	0.12	0.01858	283.09
8.31	7.35	0.12	0.01765	416.39
9.18	8.22	0.11	0.01672	491.55
10.15	9.19	0.10	0.01579	581.88
10.13	9.17	0.10	0.01486	616.91
9.80	8.84	0.09	0.01394	634.35
9.10	8.14	0.09	0.01301	625.84
8.26	7.30	0.08	0.01208	604.43
7.45	6.49	0.07	0.01115	582.15
6.54	5.58	0.07	0.01022	546.02
6.11	5.15	0.06	0.00929	554.34
4.66	3.70	0.05	0.00836	442.52
4.67	3.71	0.05	0.00743	499.18
3.59	2.63	0.04	0.00650	404.41
3.26	2.30	0.04	0.00557	412.62
2.52	1.56	0.03	0.00465	335.83
1.00	0.04	0.02	0.00372	10.76
1.00	0.04	0.02	0.00279	14.35
0.84	0.00	0.01	0.00186	0.00
0.88	0.00	0.01	0.00093	0.00
0.94	0.00	0.00	0.00000	0.00
			Average Shear Adhesion Strength:	**373.24**

Movie S1. Shows video of the snow gun operating in a cold room between -2℃ and -5℃.

Movie S2. The complete compression shear adhesion failure mechanism of snow on aluminum 6061 (RMS=331 μm).

Movie S3. The complete sliding shear adhesion failure mechanism of snow on aluminum 6061 (RMS= 331 μm).

Movie S4. The combination of compression and sliding failure mechanisms of snow on aluminum 6061 (RMS=331 μm).