Contact angles on the running surfaces of cross-country skis

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Why ski base have to be hydrophobic?

- The advantage of having a hydrophobic surface under all snow conditions was proved by the research of Samuel Colbeck. He showed that water slides more readily on hydrophobic surfaces, in the case of a water film deficit. In a case with excess lubrication, the capillary forces would be higher on a less hydrophobic ski base.

What is the most effective way to increase hydrophobicity?

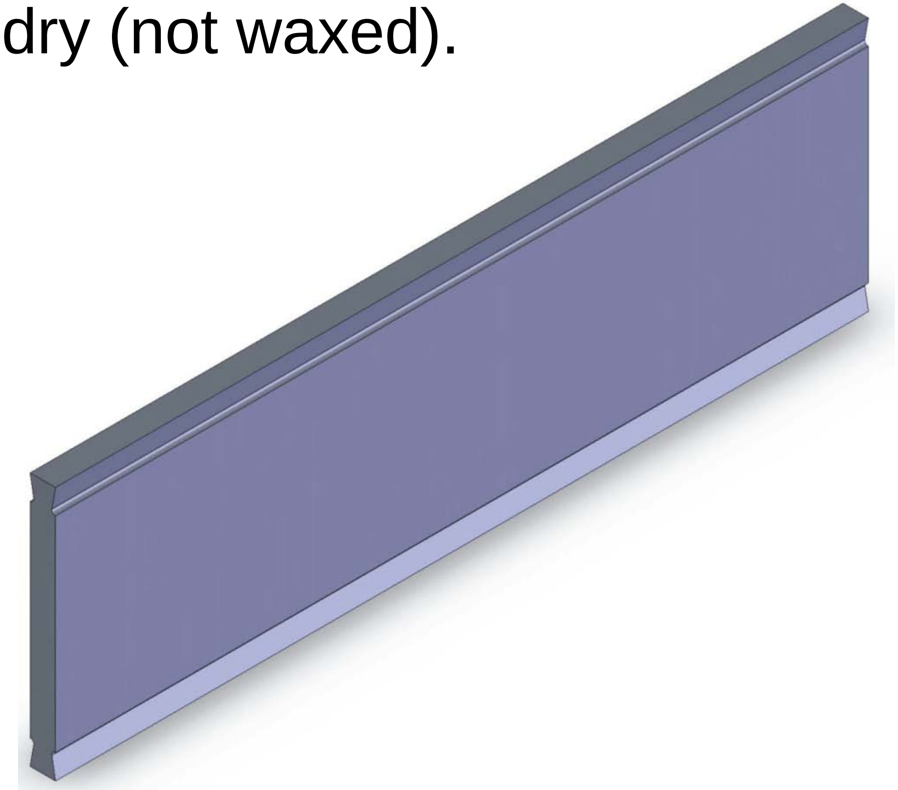
- An extremely hydrophobic wax, such as perfluorocarbon, has a water contact angle limited to 120°. Classic studies by Wenzel, Cassie and Baxter established that, regardless of the approach, the contact angle is always larger or equal on a rough surface, so giving the running surface a structure is the most effective way to increase hydrophobicity.

Samples - skis

- We used 5 similar Karhu skis from the same batch.

Samples - reference ski treatment

- One ski was treated with an HSS scraper and remained dry (not waxed).



Samples – test skis treatment

- 4 skis were treated with 4 different patterns of stone grinding on the Tazzari RP13.2 machine. For waxing we used Swix® CH8.

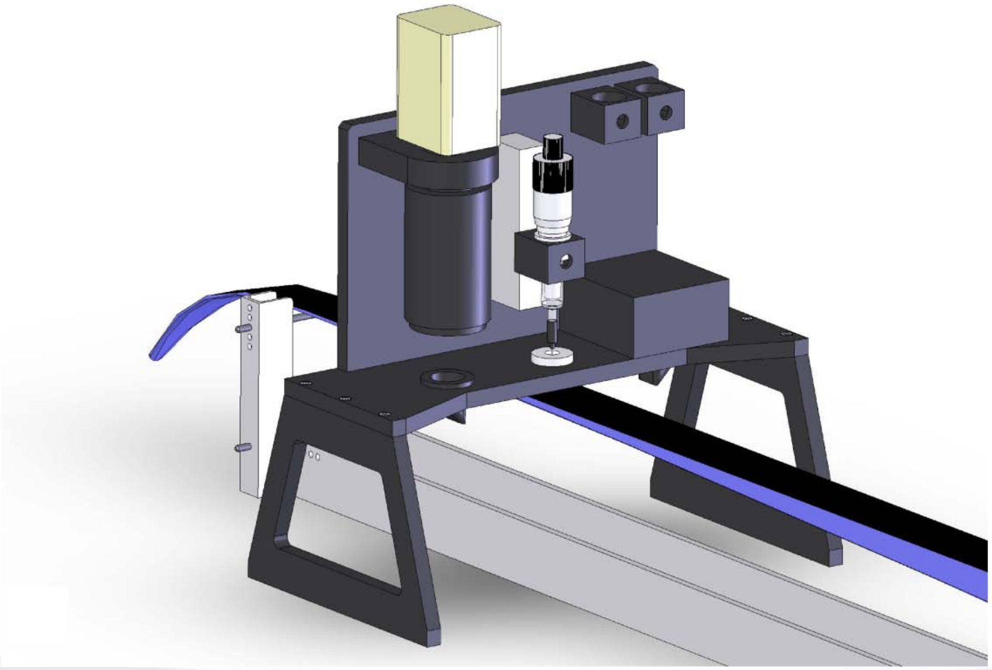
TAZZARI

Samples - finish

- Before measurement, the skis were brushed with a Red Creek® steel rotary (4000 r/min) brush. The waxed skis were brushed with one brush, and the dry ski with another clean brush.

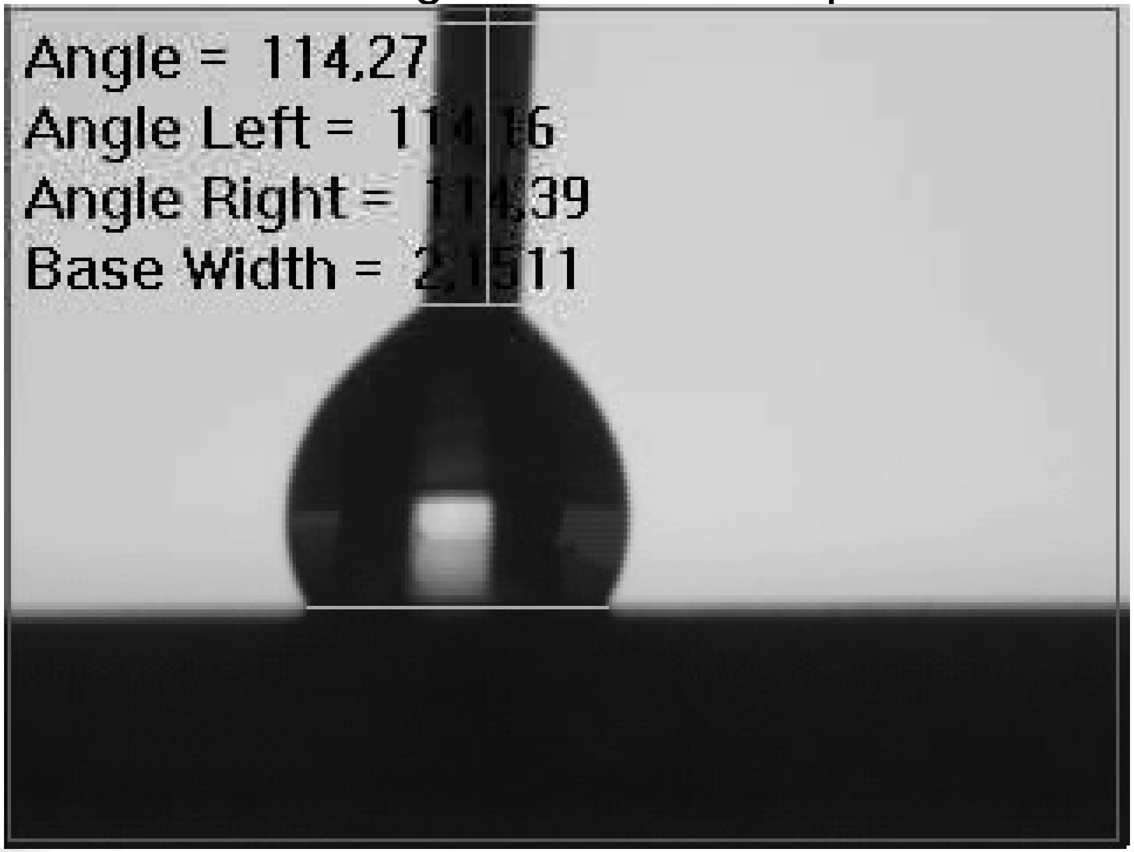
Measurement - hydrophobicity

- A goniometer FTA125 and the software Fta32_Video build 185 from “First Ten Ångstroms” were used



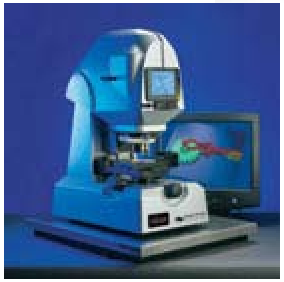
Measurement - contact angle

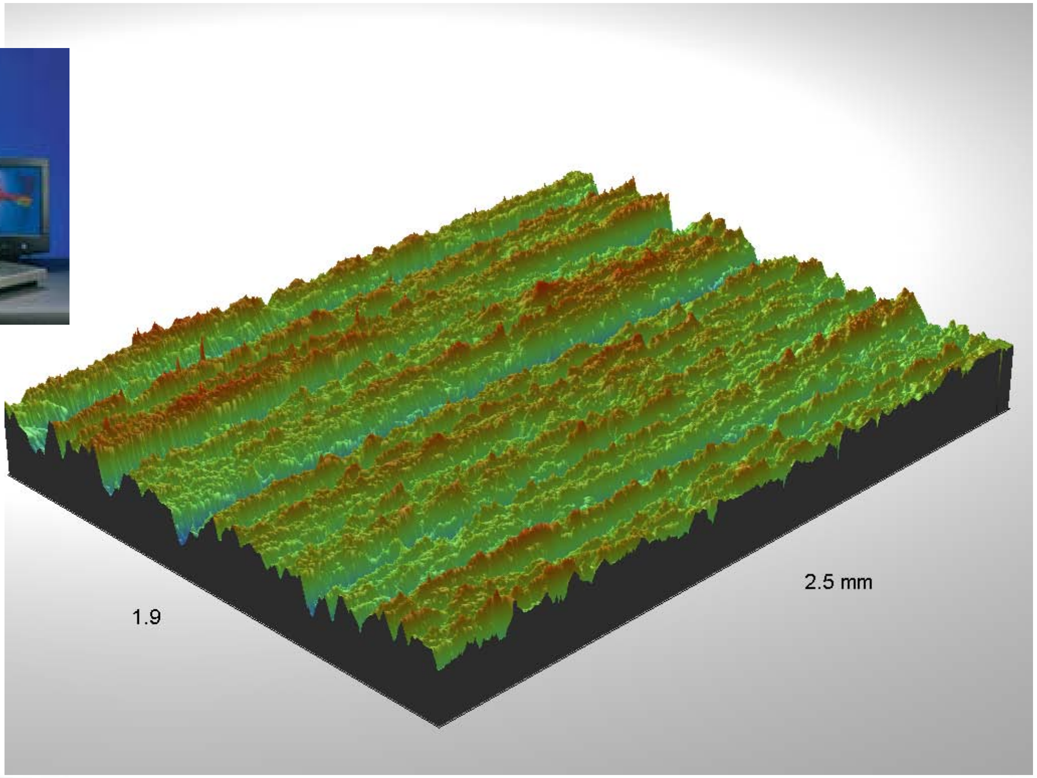
- The running surface hydrophobicity of the ski was measured as the advanced contact angle of a water drop.



Measurement - 3D ski running surface

- Measurements were taken using a Wyko NT1100 Optical Profiler and the software Vision32.





Results - surface roughness and hydrophobicity

Ski and kind of treatment	Contact Angle	Ra	Rq	Rz	Rt
Nr. 3 Stone grinding - pattern 1A. Dry.	104,83	3,66	4,52	31,69	41,33
Nr. 3 Stone grinding - pattern 1A, CH8.	113,14	3,19	4,13	28,79	33,80
Nr. 4 Stone grinding - pattern 1B. Dry.	110,48	4,75	5,72	31,46	35,26
Nr. 4 Stone grinding - pattern 1B, CH8.	113,14	4,78	6,08	35,08	36,84
Nr. 5 Stone grinding - pattern 2A. Dry.	107,18	2,76	3,51	26,10	31,62
Nr. 5 Stone grinding - pattern 2A, CH8.	115,88	2,73	3,49	23,94	26,50
Nr. 6 Stone grinding - pattern 2B. Dry.	111,92	3,12	4,02	27,48	30,14
Nr. 6 Stone grinding - pattern 2B CH8.	112,15	3,07	3,89	24,78	29,63
Nr. 7 Treated with HSS scraper. Dry.	117,26	4,60	5,71	32,11	34,69
Nr. 7 Treated with HSS scraper, CH8.	115,17	3,75	4,64	28,91	33,03

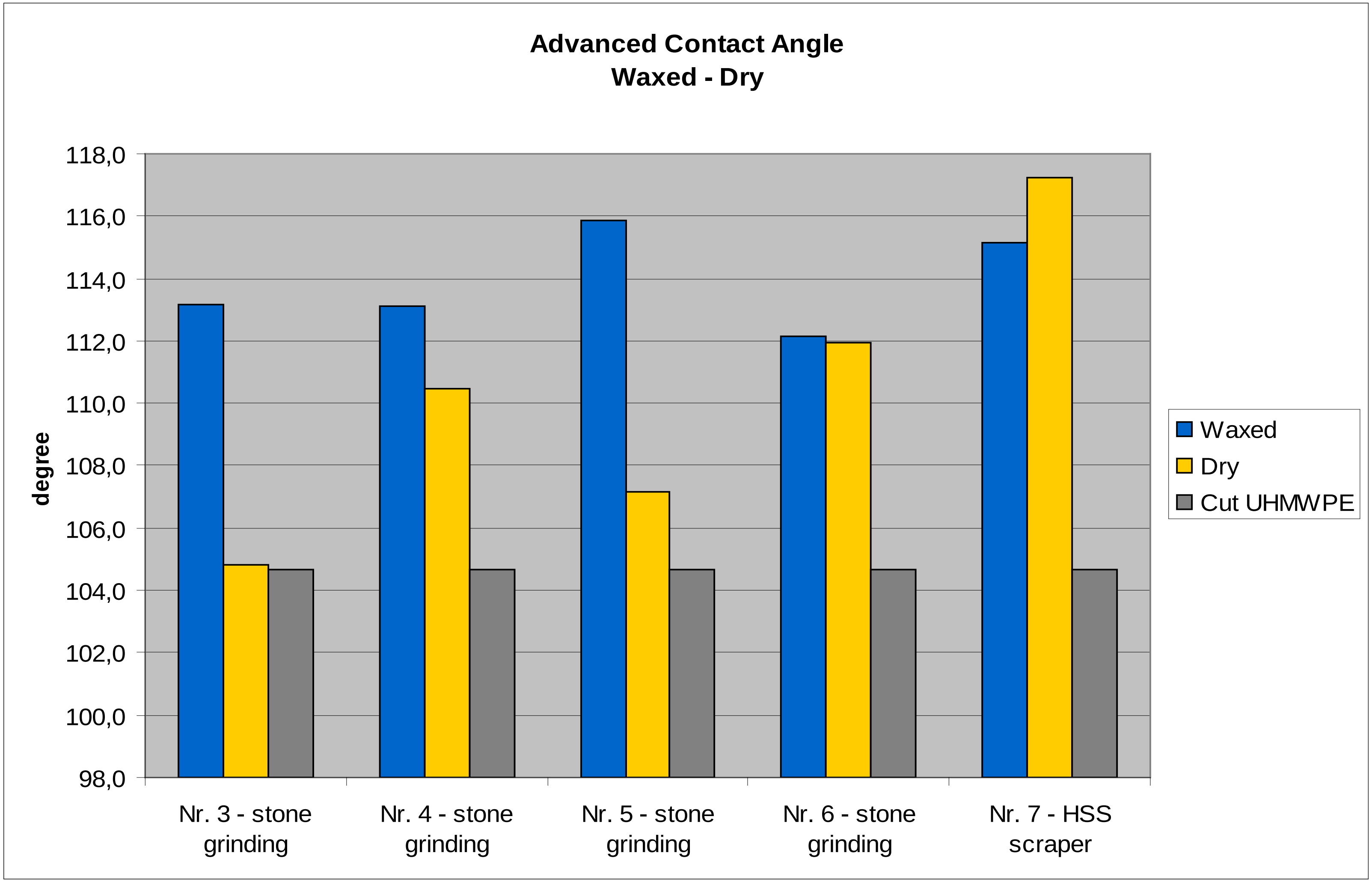
- Ra is the average roughness, Rq is the root-mean-squared roughness, Rt is the peak-to-valley difference, and Rz is the average of the ten greatest peak-to-valley separations on the sample.

Results - relation between surface roughness and hydrophobicity

- We did not find any significant correlation between the roughness of the samples and hydrophobicity. Pearson's correlation between each of the indexes and the contact angle was in the range: -0,07 - +0,19.

Pearson's correlation index - contact angle			
Ra	**Rt**	**Rq**	**Rz**
0,16	-0,07	0,19	0,03

Results - the magnitude of the contact angle



- Swix CH8 – 108,01°, solid sample of graphite UHMWPE – 104,67°

Discussion - roughness and hydrophobicity

- From our results we can draw the conclusion that the above-mentioned standard surface indexes are unsuitable for measuring hydrophobicity.
- We have to find other methods to measure the fractality of the surface.

Discussion - is stone grinding and waxing an optimum procedure?

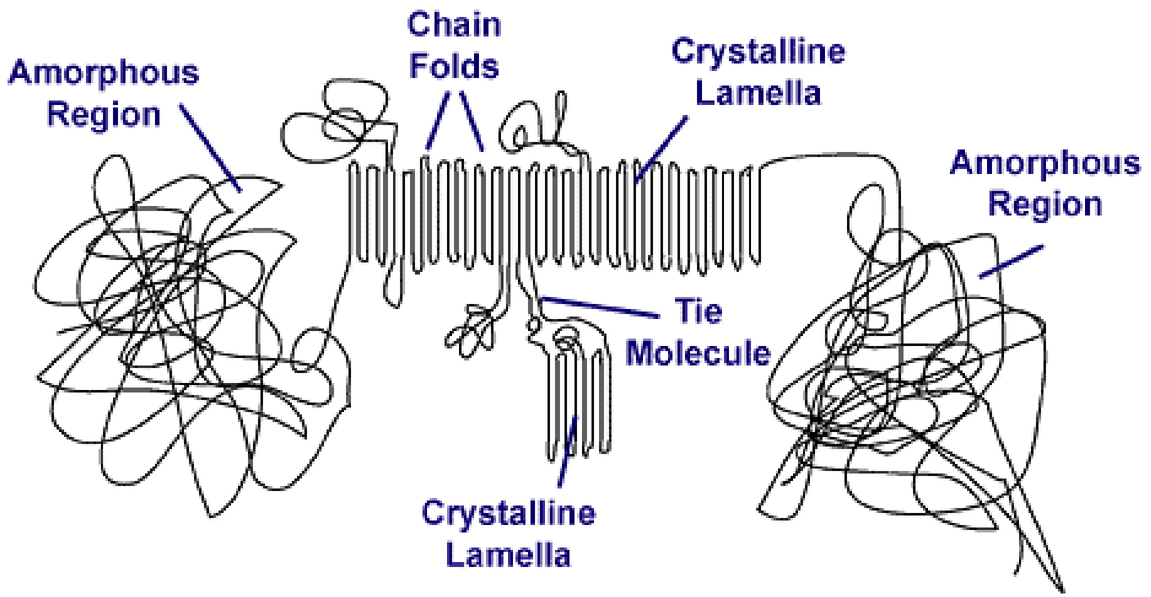
- Dry stone ground surfaces have a low contact angle, much lower than the scraped surface (104,83° compared with 117,26°).

- Wax **has to be** applied to the stone grinded surface, that ever increases the attraction of dirt to the ski base.

- We may suppose that the manual scraping resulted in some kind of randomly rough surface.

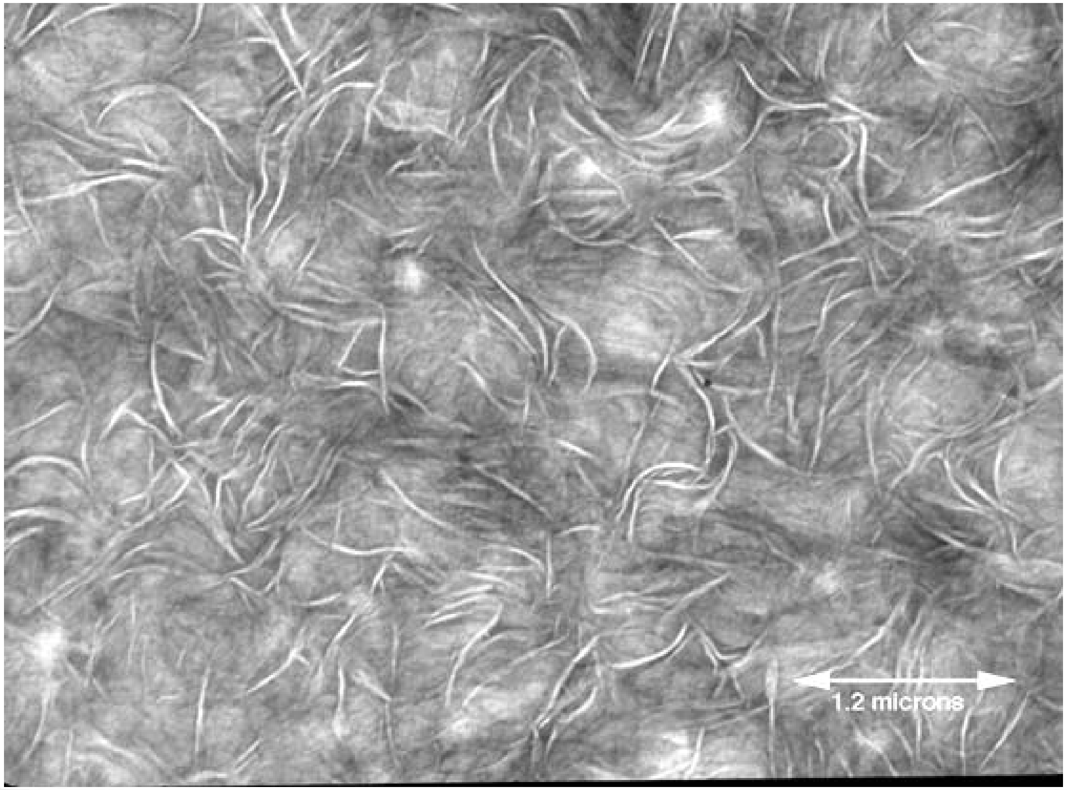
Discussion - www.uhmwpe.org (UHMWPE Lexicon)

- When cooled below the melt temperature, the molecular chain of polyethylene has the tendency to rotate about the C-C bonds and create chain folds. This chain folding, in turn, enables the molecule to form local ordered, sheet-like regions known as crystalline lamellae. These lamellae are embedded within amorphous (disordered) regions.



Discussion - transmission electron microscopy (TEM)

- The lamellae are on the order of 10-50 nm in thickness, and 10-50 μm in length. The average spacing between lamellae is on the order of 50 nm.
- From the TEM micrograph shown below, one can appreciate the composite nature of UHMWPE as an interconnected network of amorphous and crystalline regions.



Discussion - our molecular level hypothesis

- The stone grinding procedure brushes out the amorphous phase of UHMWPE.
- The crystalline lamellae rise up and make the running surface bristly and dry.
- The grey coloured areas on the ski running surface have nothing to do with “oxidized base”. They are a result of raised lamellae.
- Glide wax can not penetrate into the ski base. Glide wax is needed to bind up the lamellae and thereby increase hydrophobicity.

Conclusion – we have to find a replacement for SG treatment!!!

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