



Innovative Leather Manufacturing: Enhancing Hydrophobicity and Strength through Silane Treatment

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Background



Chrome-free tanning and silane modification



Silane modification of wet blue



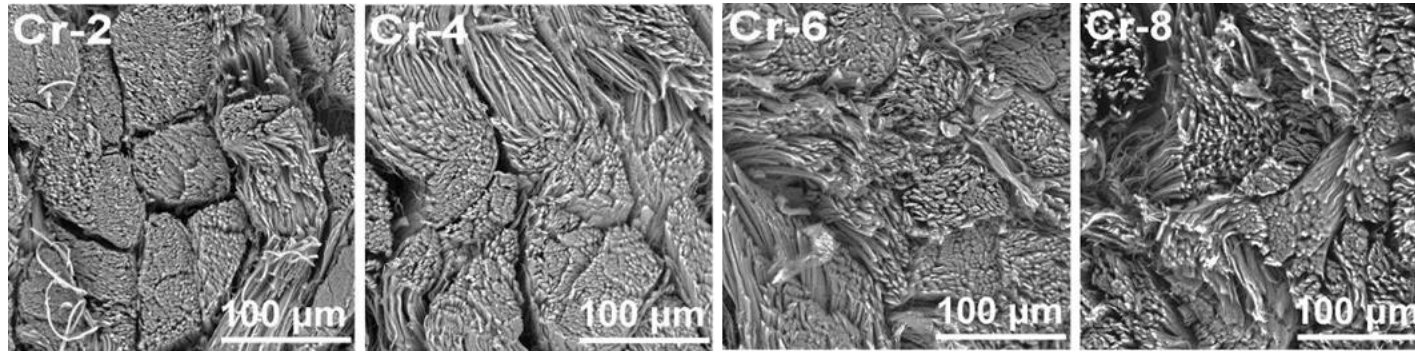
Conclusion

1. Background

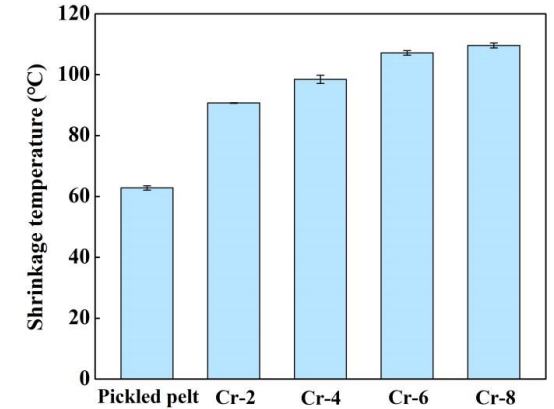
Positive correlation between fiber dispersion and physical properties

Taking traditional chrome tanning as an example

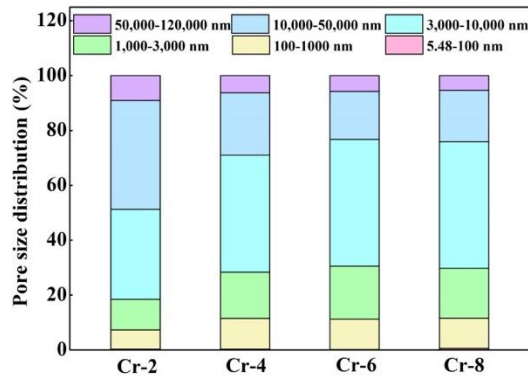
SEM



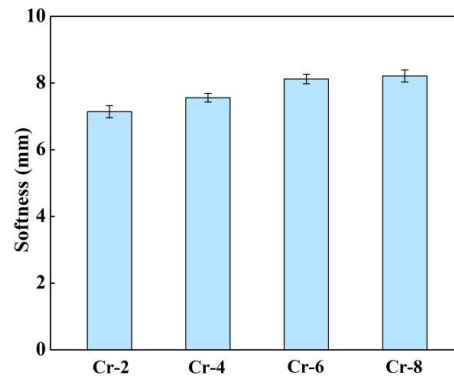
Ts



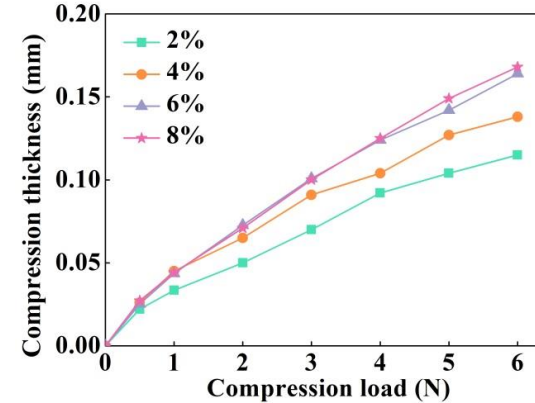
Pore size distribution



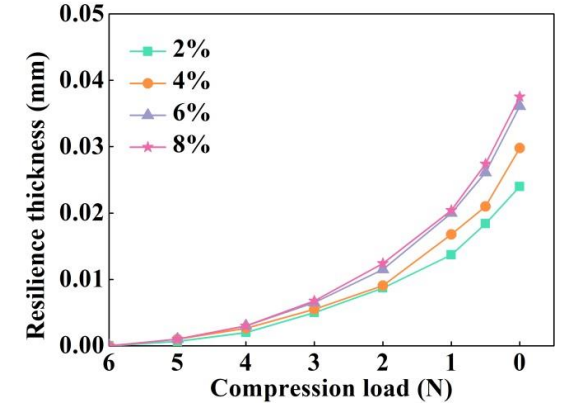
Softness



Compression performance

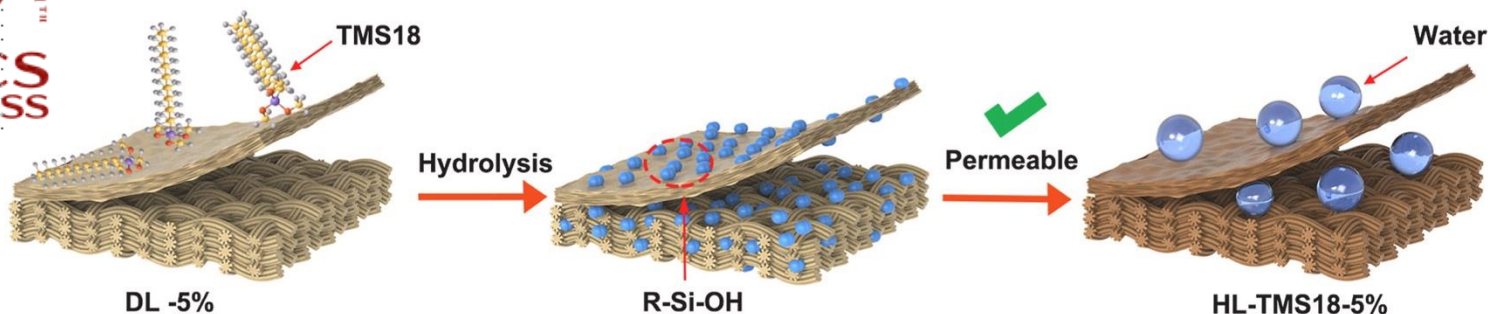


Resilience performance



1. Background

□ Enhance collagen fiber dispersion through hydrophobic modification

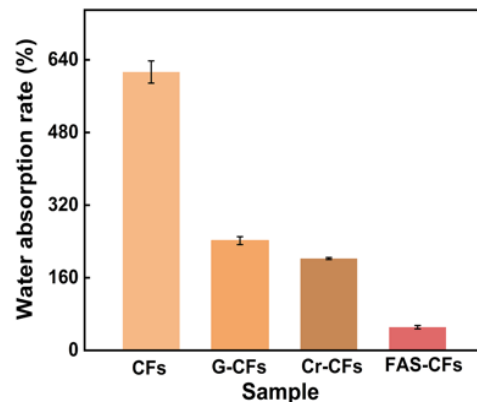


Shi B, et al. *JALCA*. 2022, 117, 422-431

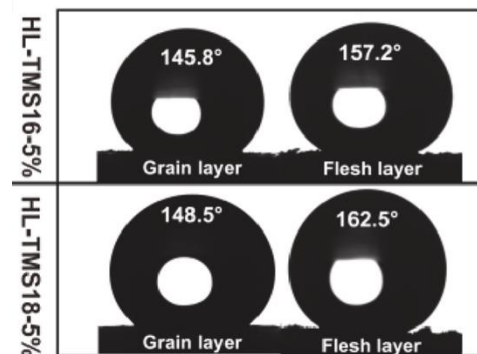
Shi B, et al. *J Clean Prod*. 2023, 383, 135526

Tanning-free leather production

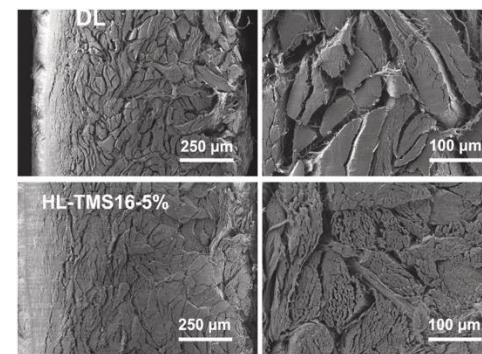
Low water absorption rate



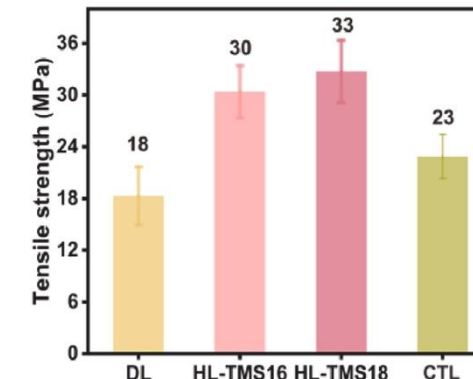
Strong hydrophobicity



High fiber dispersion



Superior mechanical strength

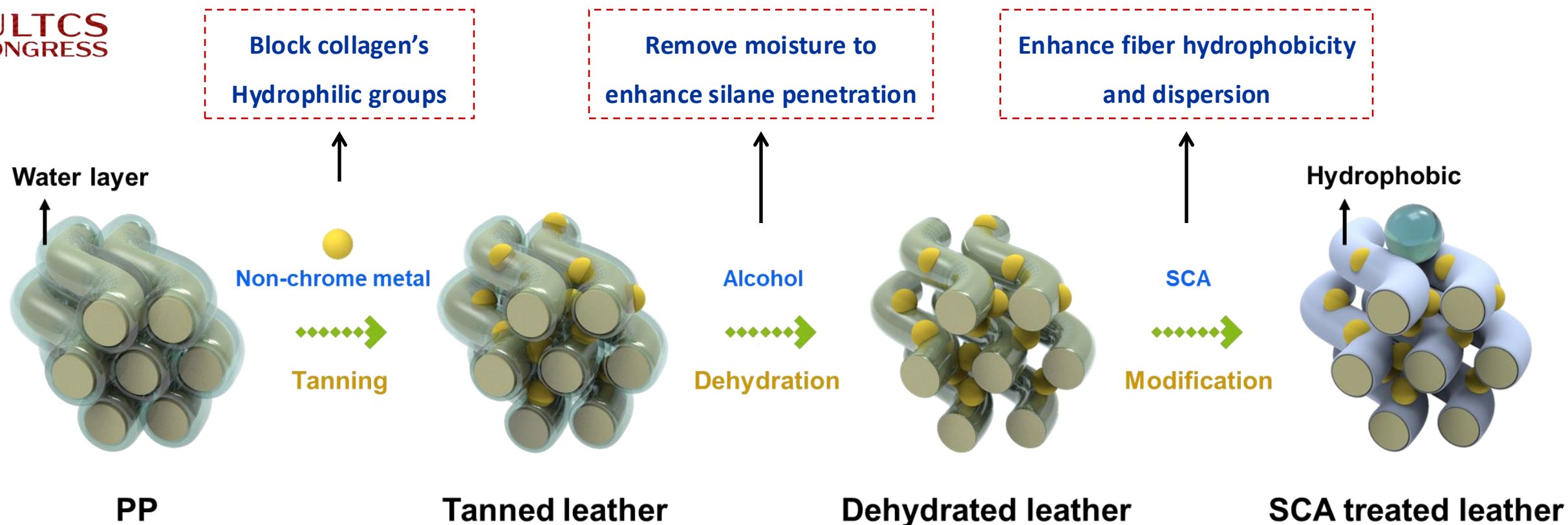


Organosilicon treatment alone cannot achieve the same organoleptic properties as chrome tanning

Strategy: metal tanning before silane modification to enhance leather quality

2. Chrome-free tanning and silane modification

□ Non-chrome metal tanning before silane modification

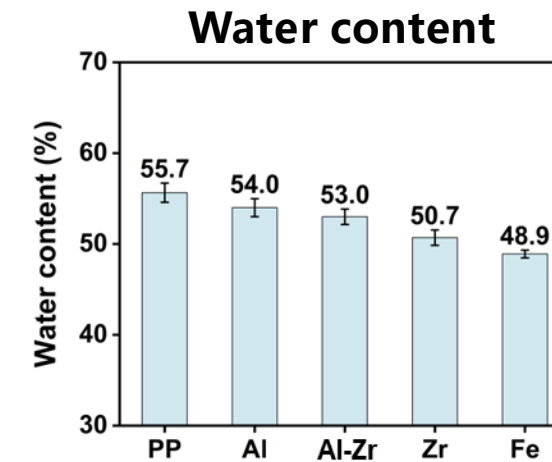
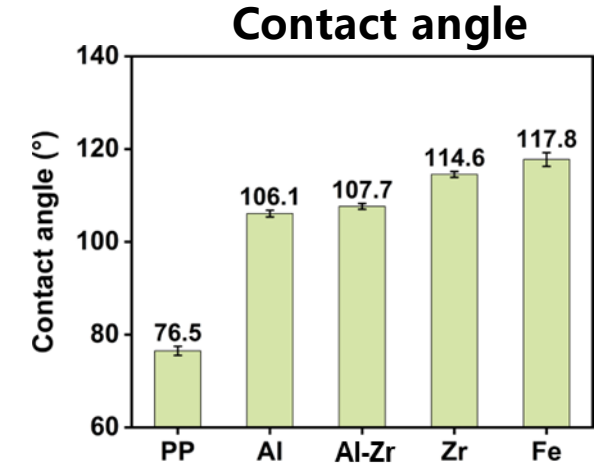
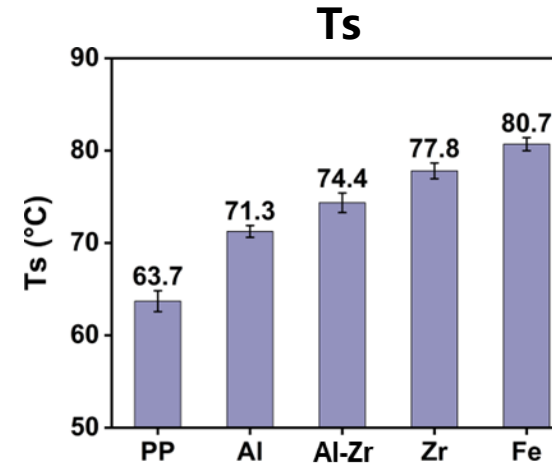


It is expected to remarkably improve the **organoleptic properties** of the resultant leather

2. Chrome-free tanning and silane modification

□ Tanning Performances

Tanning process	
Leather	Chemical formulas (half the conventional dosage)
Al	9.8% $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ + 0.75% citric acid
Al-Zr	3% $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ + 1.25% $\text{Zr}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$ + 0.75% oxidized polysaccharide
Zr	4.35% $\text{Zr}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$ + 1.2% oxidized polysaccharide
Fe	5% $\text{Fe}_2(\text{SO}_4)_3$ + 3% sodium tartrate



Increase Ts

★ **High contact angle**

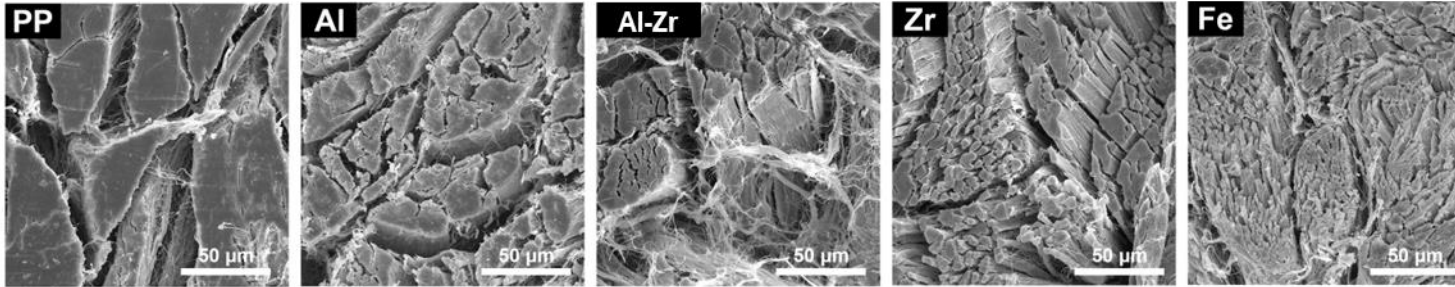
★ **Low water content**

Chrome-free tanning improved leather's hydrophobicity and reduced moisture content

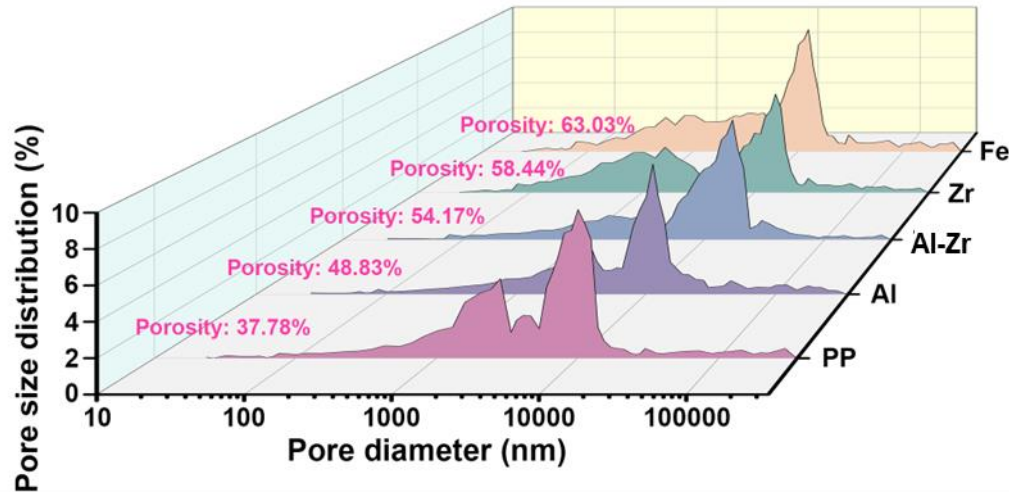
2. Chrome-free tanning and silane modification

□ Tanning Performances

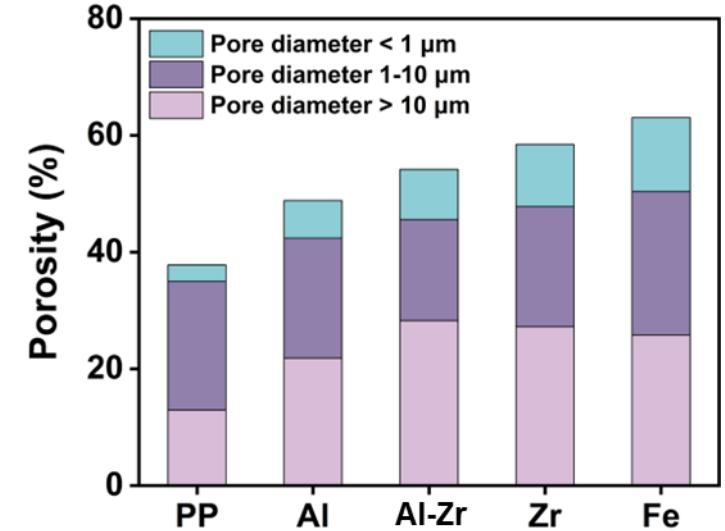
SEM analysis



Pore size distribution



Porosity

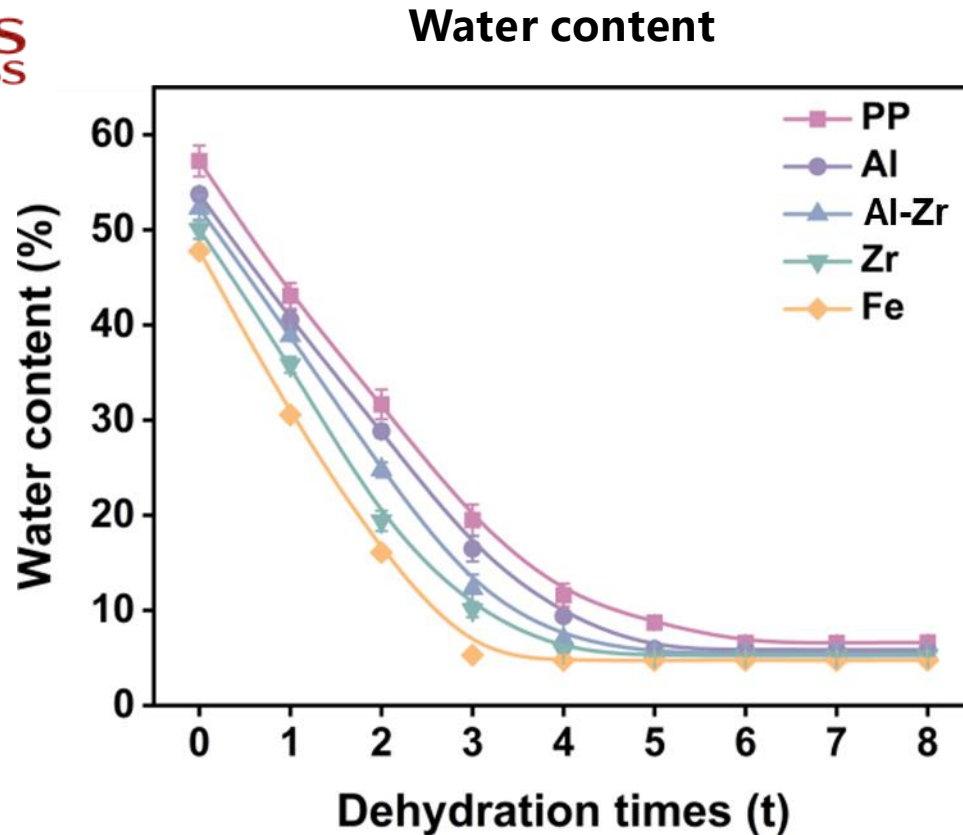


Chrome-free tanning improves fiber
 dispersion and increases leather porosity

Tanning effects: Fe > Al-Zr > Zr > Al

2. Chrome-free tanning and silane modification

Dehydration performance



Kinetic modeling on moisture content

$$C_t = C_0(\exp(-kt)) + C_\infty$$

Dehydration parameters				
Sample	C_0 (%)	k (t ⁻¹)	R^2	C_∞ (%)
PP	57.25	0.33	0.97	6.64
Al	53.75	0.35	0.96	5.85
Al-Zr	52.28	0.38	0.97	5.44
Zr	50.07	0.43	0.97	5.25
★ Fe	47.78	0.51	0.97	4.76

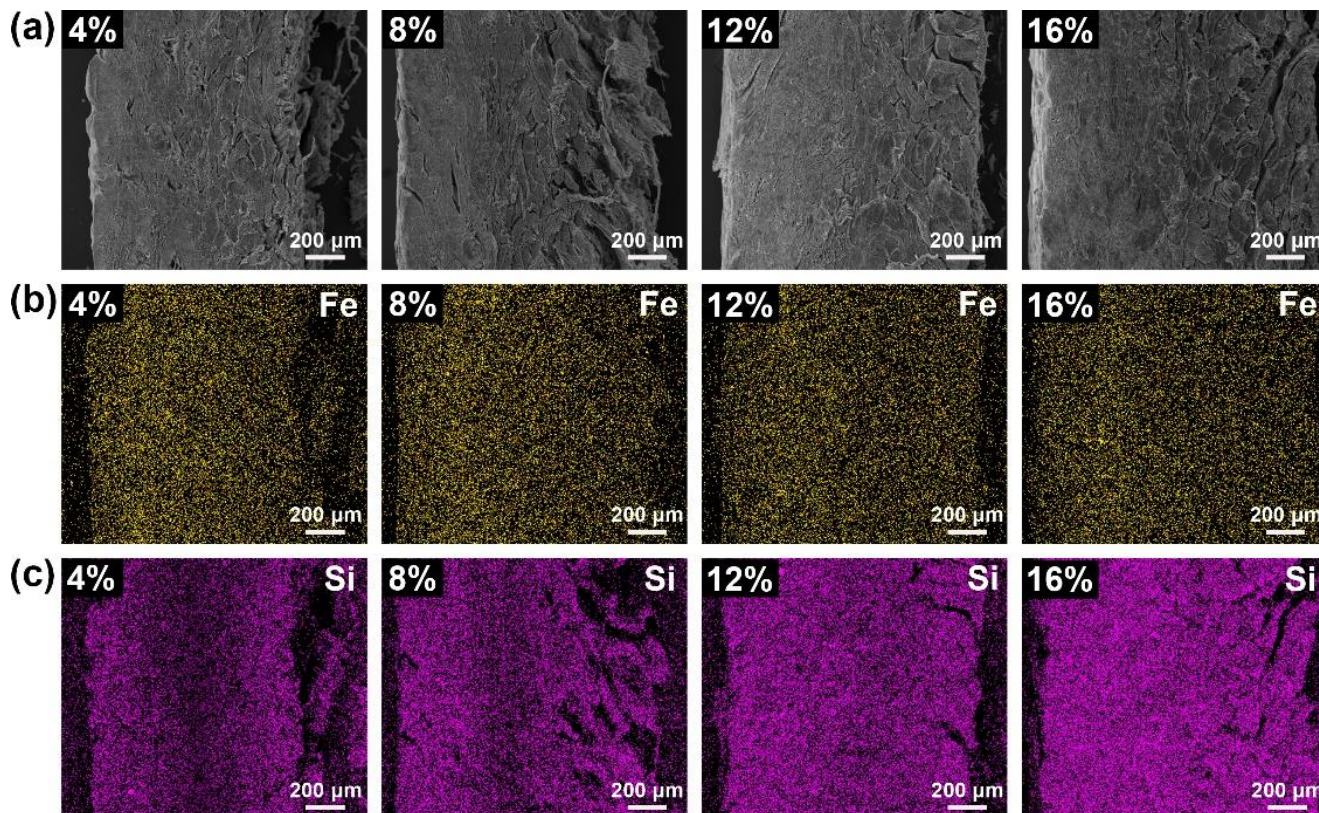
Applied for subsequent investigation

Chrome-free tanning improves dehydration efficiency and reduces the final moisture content

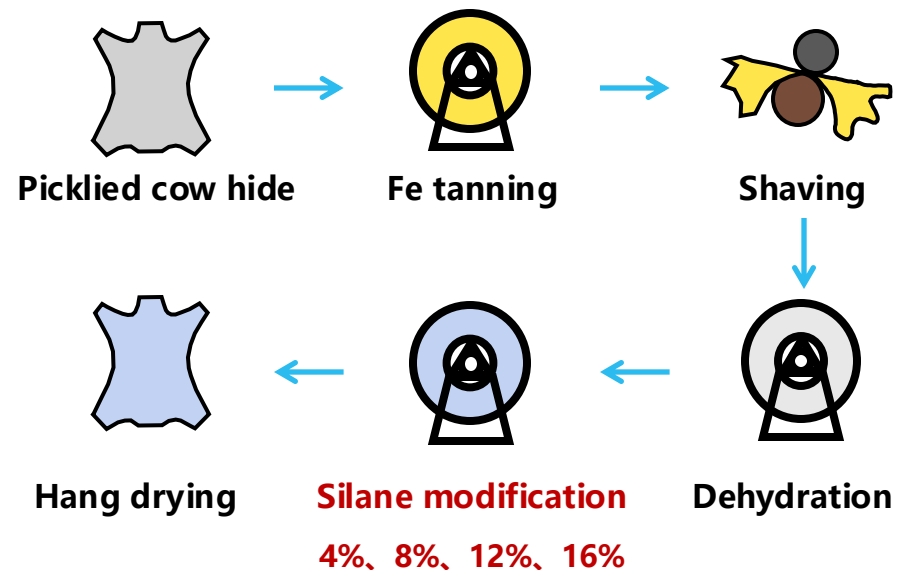
2. Chrome-free tanning and silane modification

□ Penetration of silane

SEM and EDS-Mapping



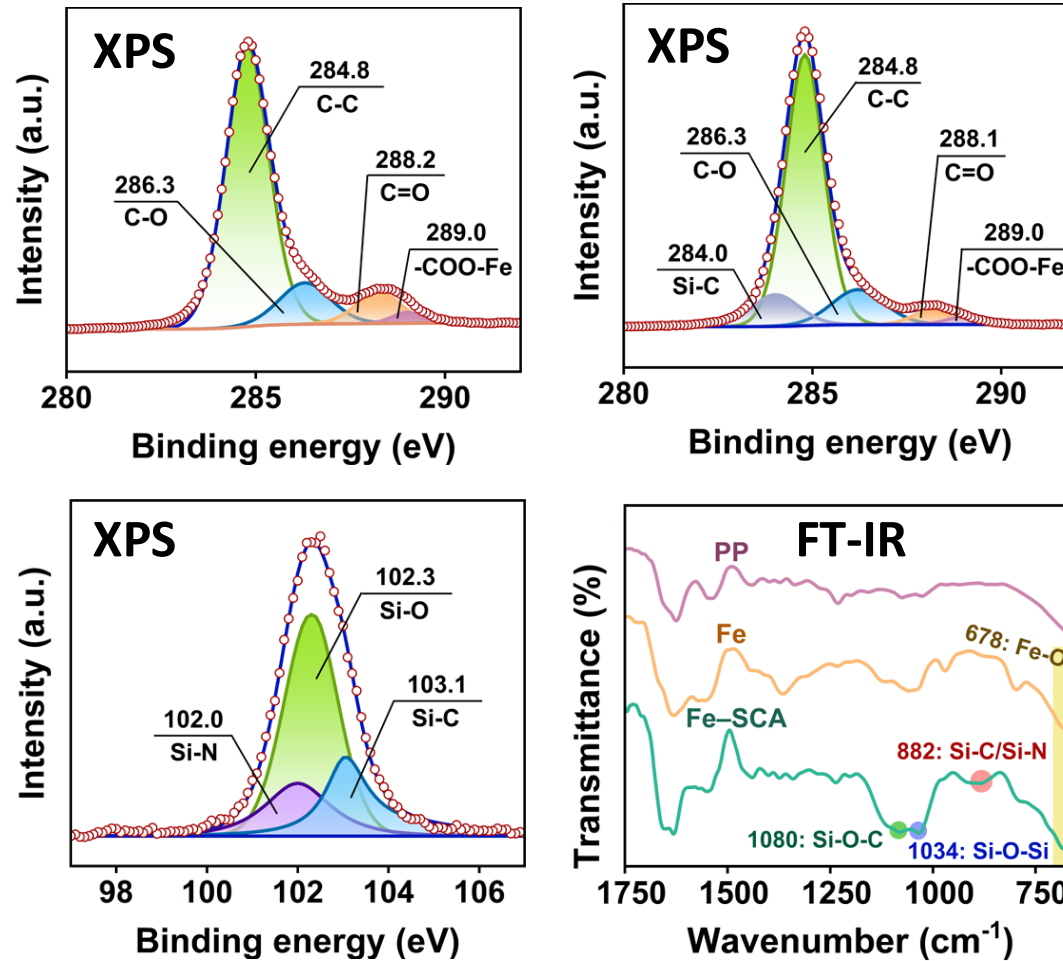
Process schematic



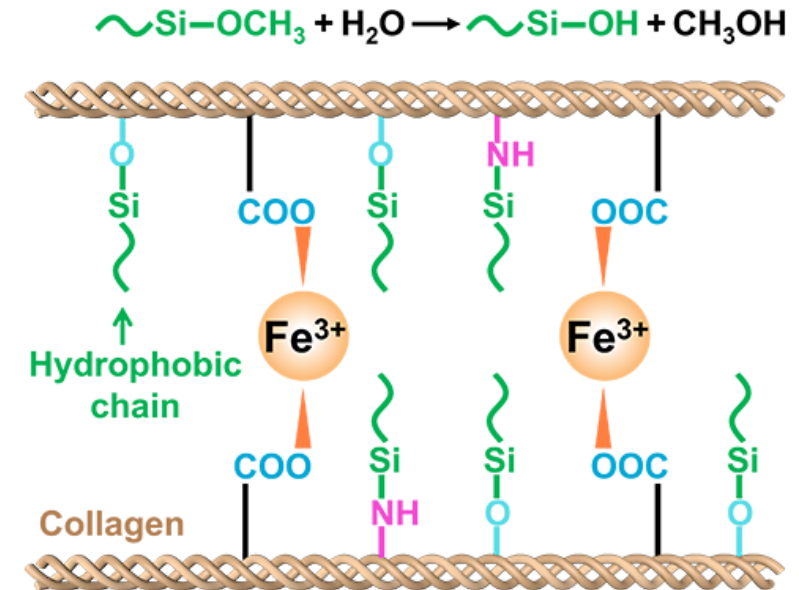
- SCA treatment does not affect the Fe distribution across the entire cross-section
- 12% SCA ensures a uniform Si distribution

2. Chrome-free tanning and silane modification

□ Silane modification mechanism



Reaction mechanism

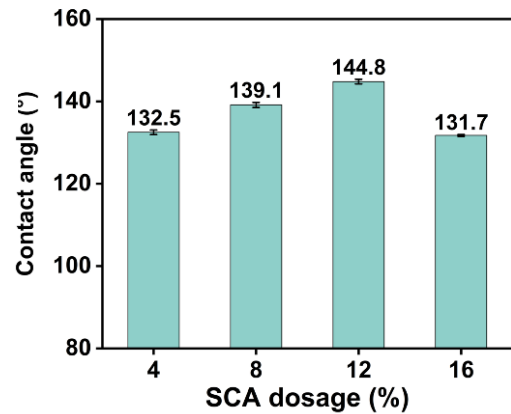


Silane hydrolyzes to form silanol, which then reacts with collagen's amino and hydroxyl groups

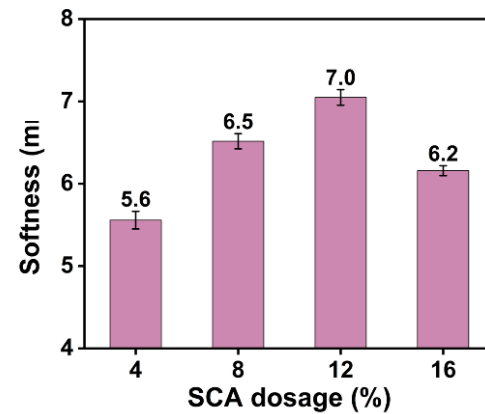
2. Chrome-free tanning and silane modification

Leather performance

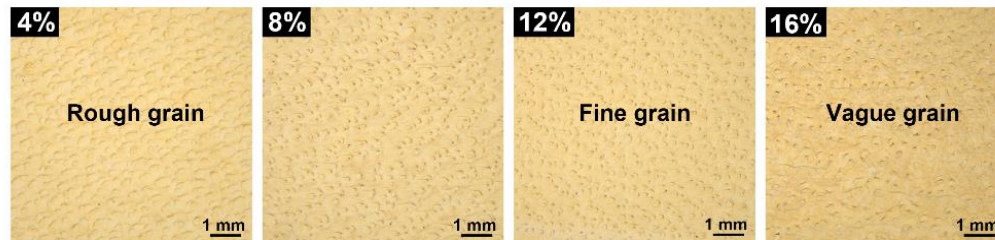
Contact angle



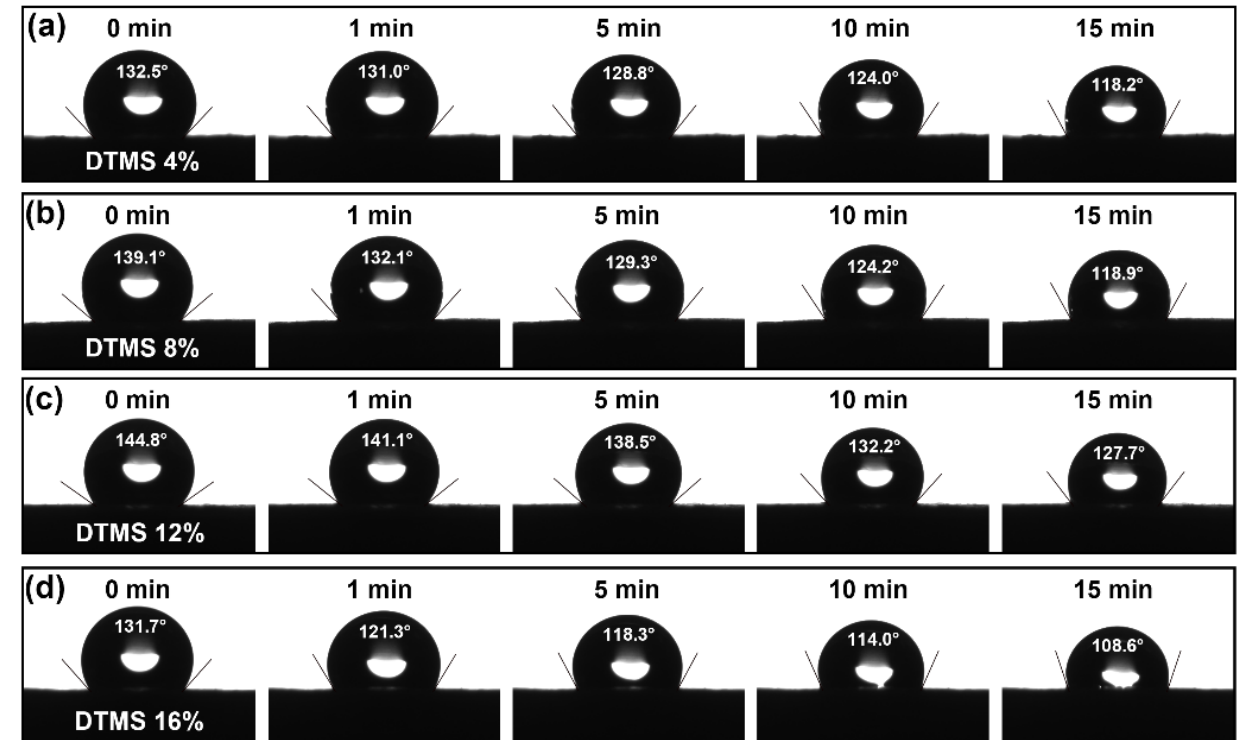
Softness



Grain surface morphology



Dynamic contact angles



12% SCA provided desirable hydrophobicity, with 127.7° contact angle after 15 min of water exposure

2. Chrome-free tanning and silane modification

Physical properties

Chemical formulas

Leather

Chemical formulas

SCA

12% SCA^b

Fe

10% Fe₂(SO₄)₃^a + 12% fatliquor^b

Cr

7% Cr₂(SO₄)₃^a + 12% fatliquor^b

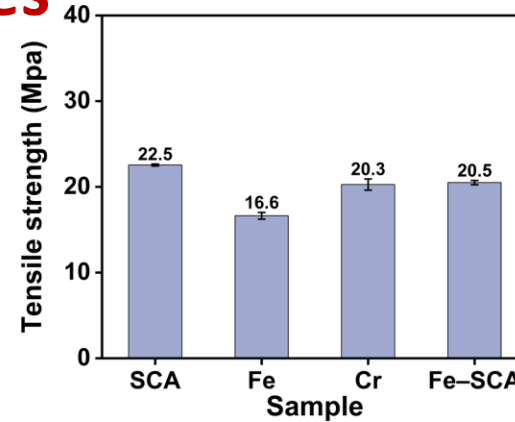
Fe-SCA

5% Fe₂(SO₄)₃^a + 12% SCA^b

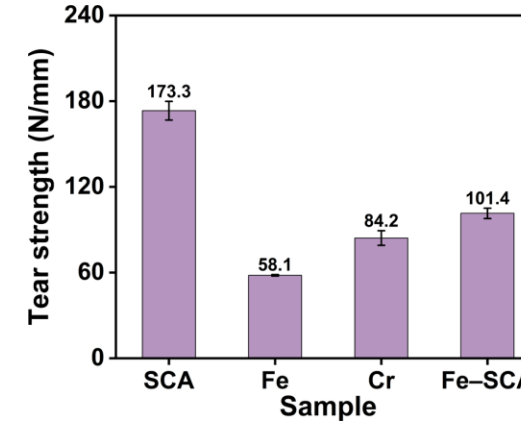
^a Chemicals are based on the limed weight

^b Chemicals are based on the shaved weight

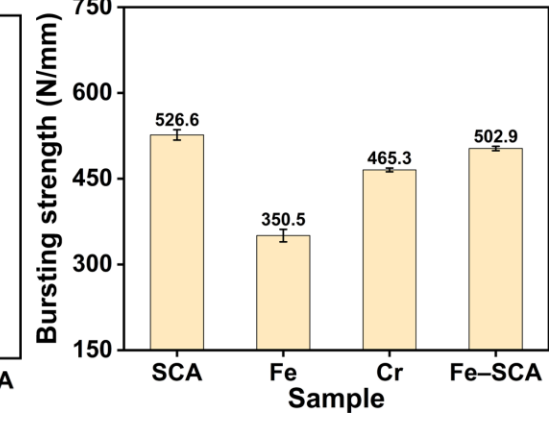
Tensile strength



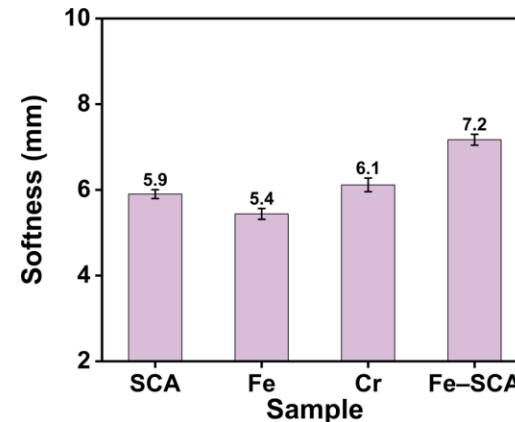
Tear strength



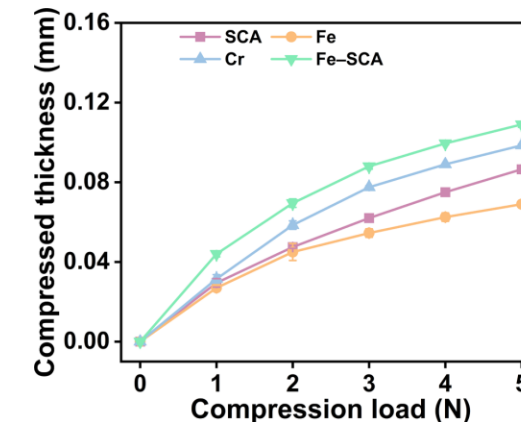
Bursting strength



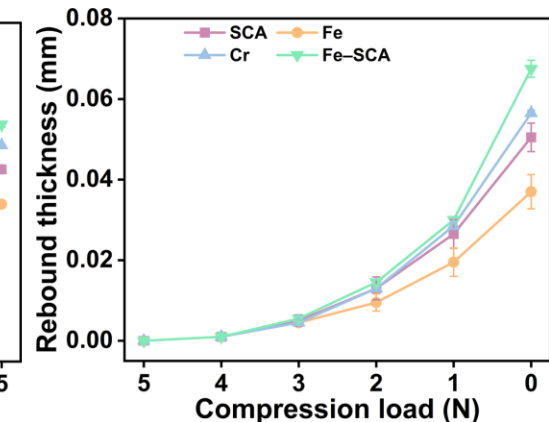
Softness



Compression performance



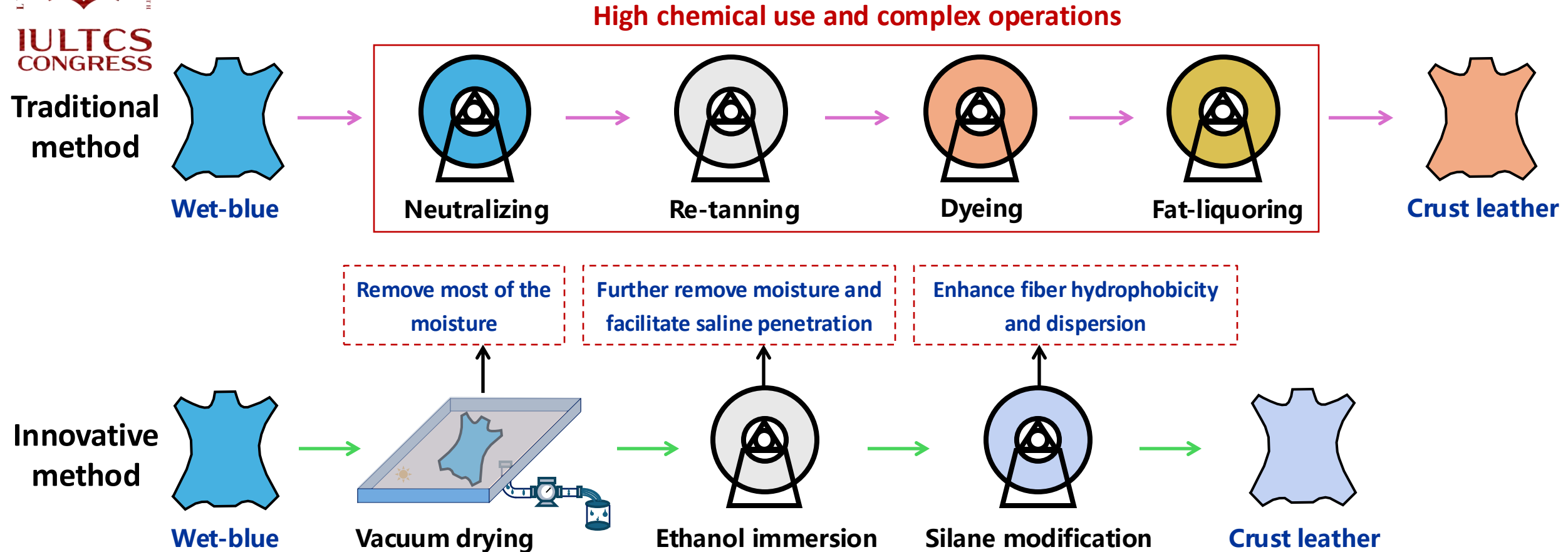
Resilience performance



Fe-SCA leather exhibits improved physical properties compared to Fe and Cr crust leathers

3. Silane modification of wet-blue

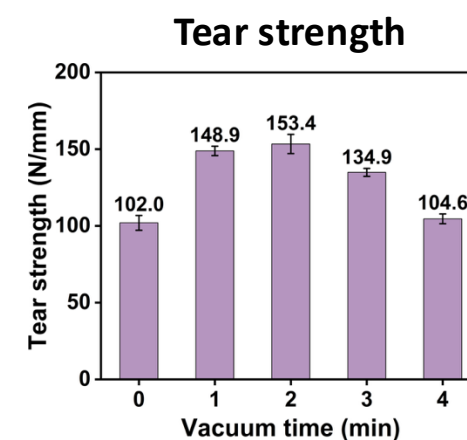
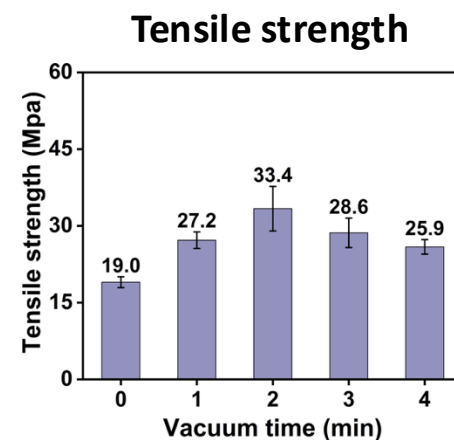
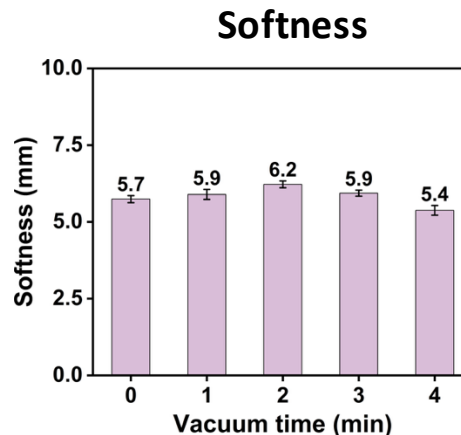
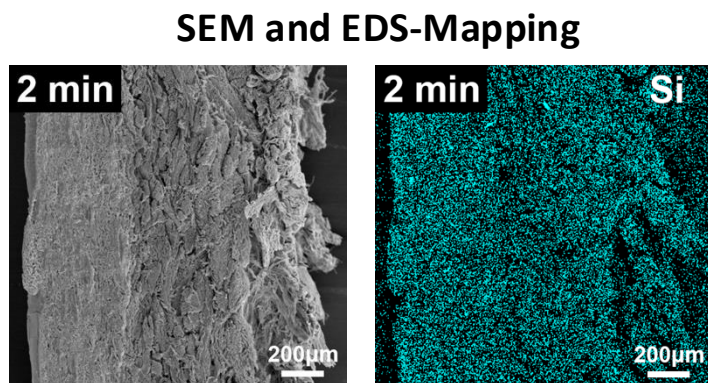
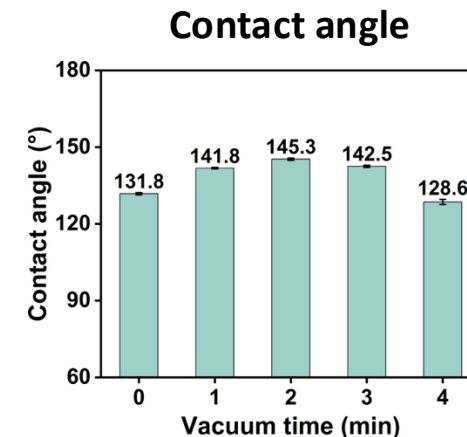
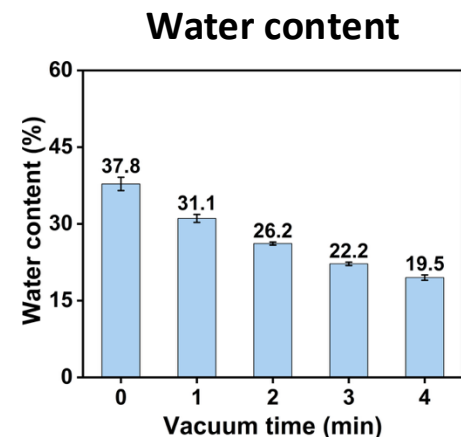
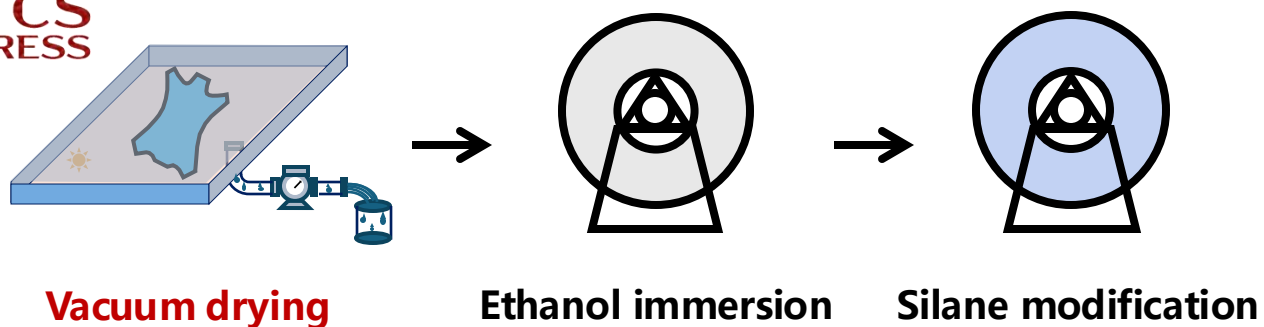
□ Technical routes



The innovative method is expected to be **simpler** than the traditional method

3. Silane modification of wet-blue

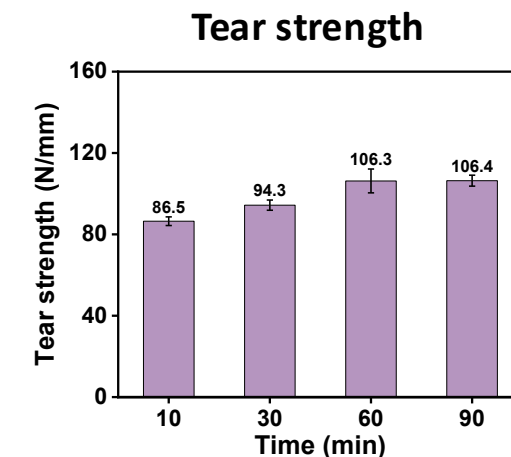
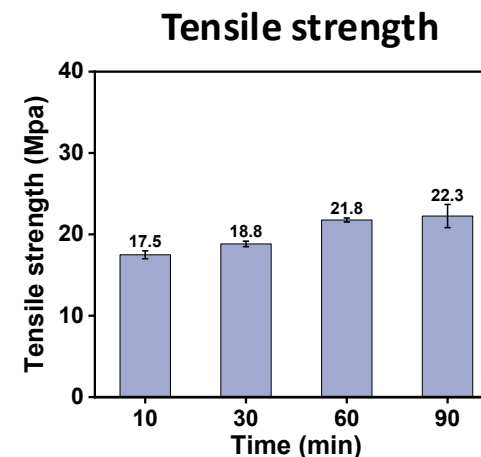
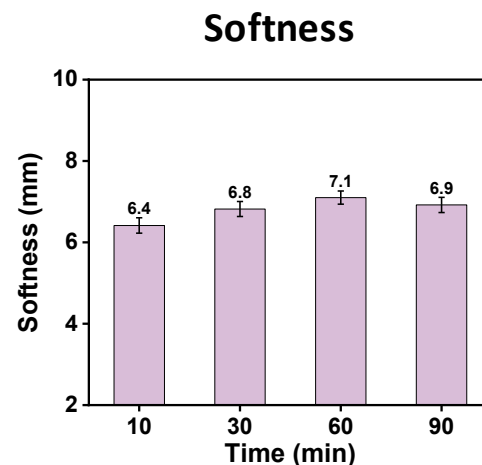
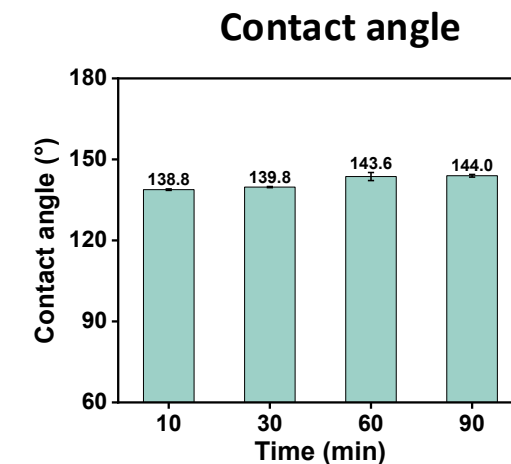
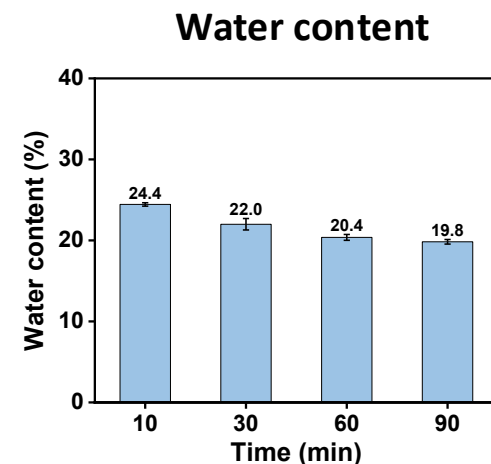
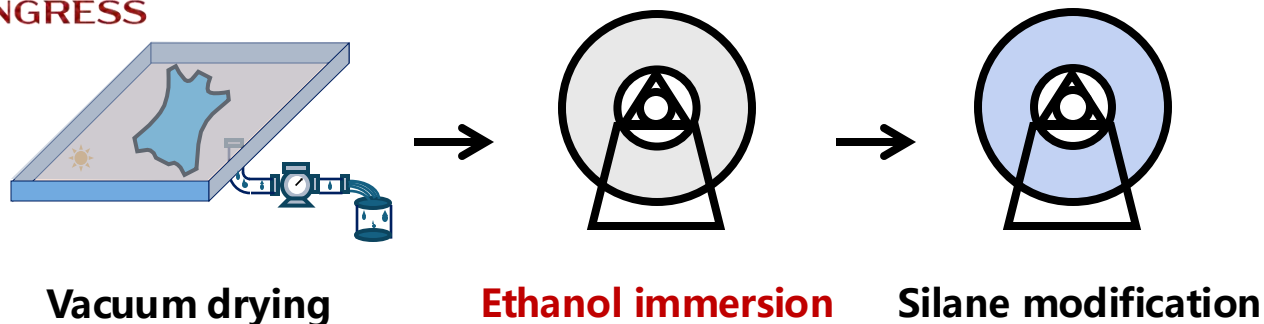
□ Effect of vacuum drying on leather performance



Vacuum drying efficiently removes moisture without affecting silane distribution and leather quality

3. Silane modification of wet-blue

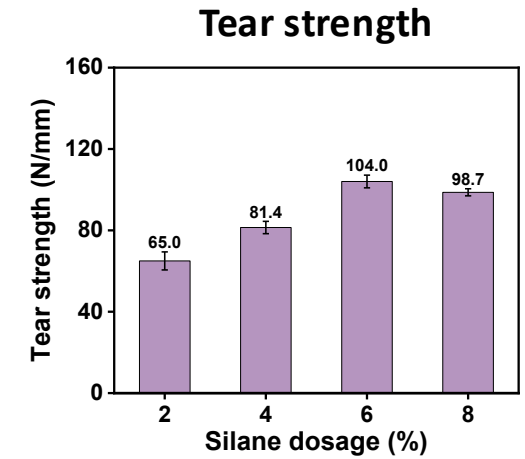
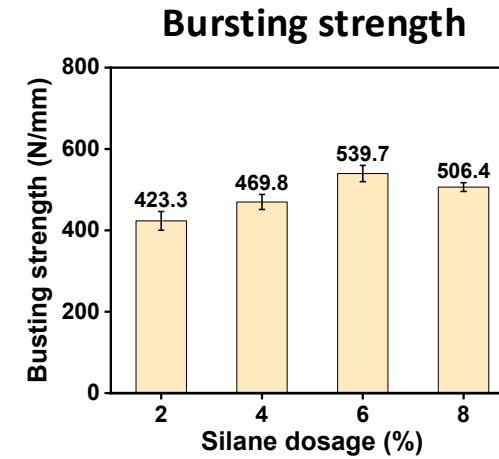
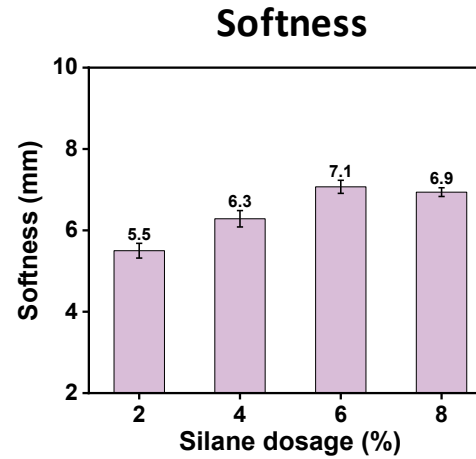
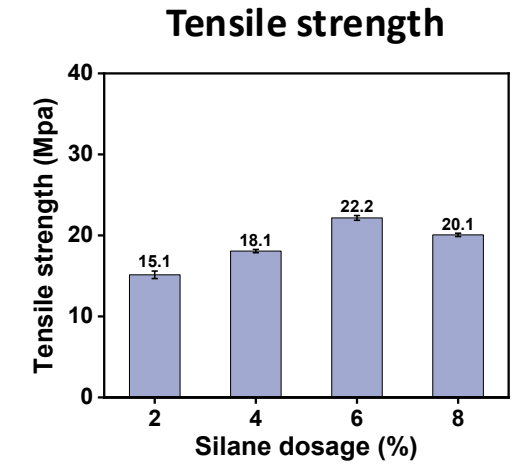
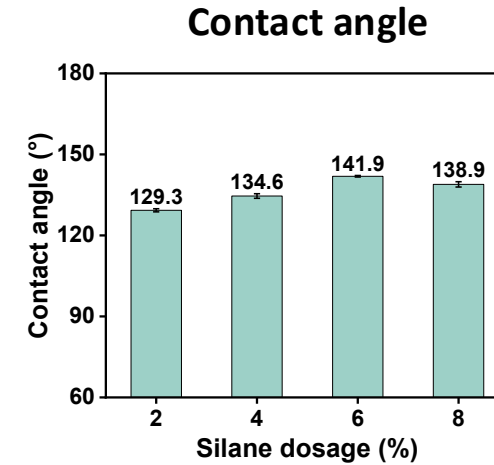
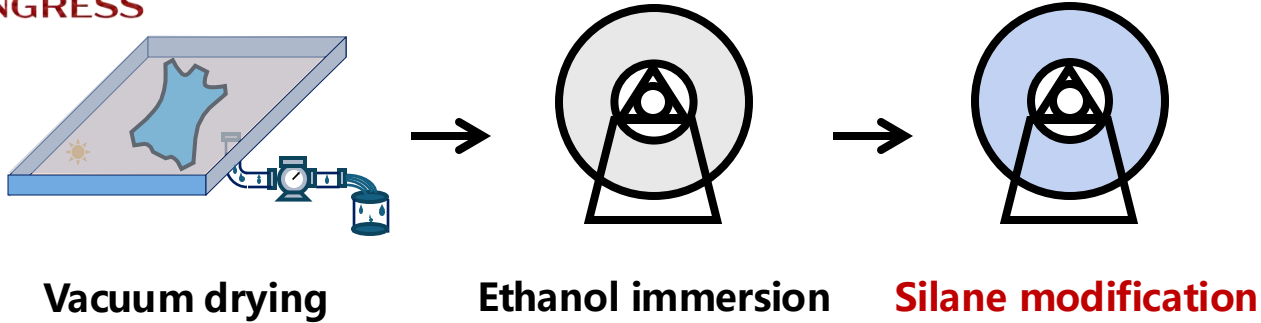
□ Effect of ethanol immersion time on leather performance



60 min of ethanol immersion
 further facilitates water removal

3. Silane modification of wet-blue

□ Effect of silane dosage on leather performance

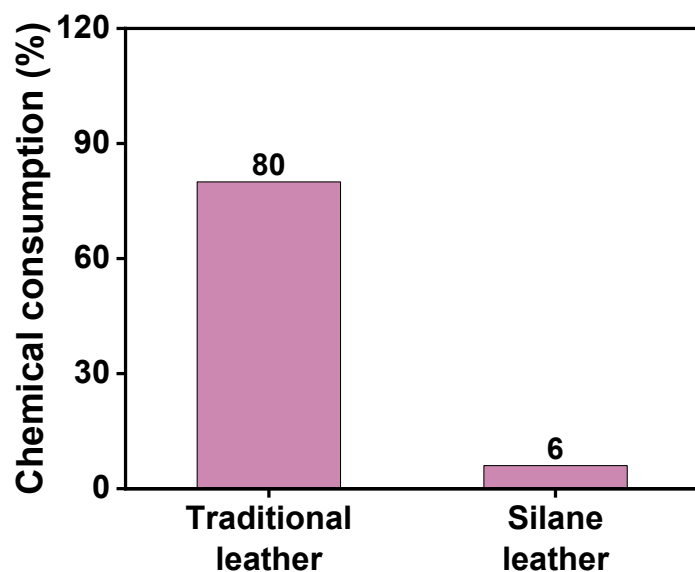


6% silane provided excellent
 hydrophobic and physical
 properties to the leather

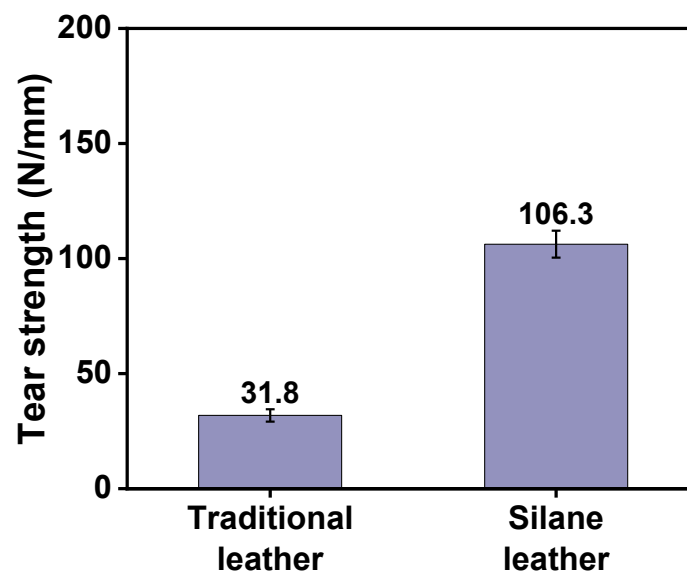
3. Silane modification of wet-blue

Assessment of overall performance

Post-tanning chemicals reduced by more than 90%



Tear strength increased by more than 200%



Appearances of innovative leather



Innovative technology reduces post-tanning chemicals while enhancing crust leather strength

4. Conclusion

- **Silane modification** introduces hydrophobic long-chain groups, thereby improving the water resistance, inter-fiber separation, and overall physical properties of Fe-tanned leathers
- **Silane modification** of wet-blue leather imparts excellent hydrophobicity and **mechanical properties** to the final product while reducing the consumption of **post-tanning chemicals**

Collagen and Leather

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Collagen biomaterials
Collagen functional materials
Novel utilization of collagen
Collagen utilization in food industry
Tanning chemistry
Leather chemicals
Novel technology of leather manufacture
Polymeric materials and coating technology
Cleaner production and environmental management
Transdisciplinary researches related with collagen and leather
Biomass conversion and renewable materials

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