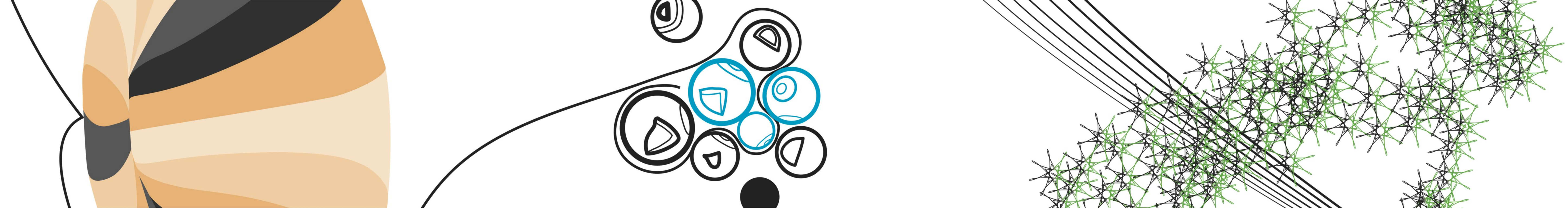

How to design rubber materials withstanding Martian environment?

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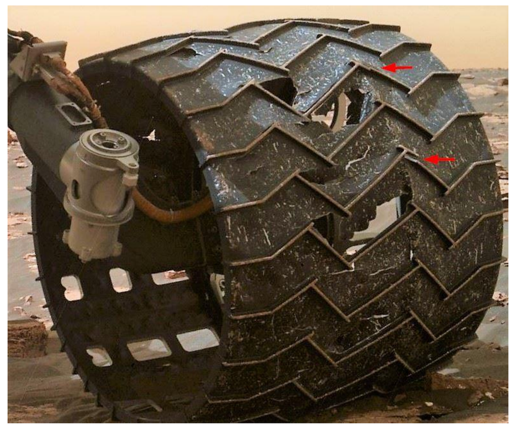
Why do we need rubber on Mars?

- Rubber returns to its original shape after deformation - perfect material for designing **tires**, seals, cable covers, dampers and many others functional elements.
- In view of Mars exploration and future colonization elastic materials will be required for sealing systems in buildings, rover tires, cable covers transmitting electricity from solar panels to buildings, etc.



Curiosity rover wheel damage[3]

- ✓ Maximum speed of current Martian rovers equal 0.18 km/h[5], which limits the exploration performance significantly.
- ✓ Future Martian rovers will be much more autonomous[8], thus, they will not require constant tele-operation form Earth and could explore Mars much faster on rubber tires.

How to overcome the issues?

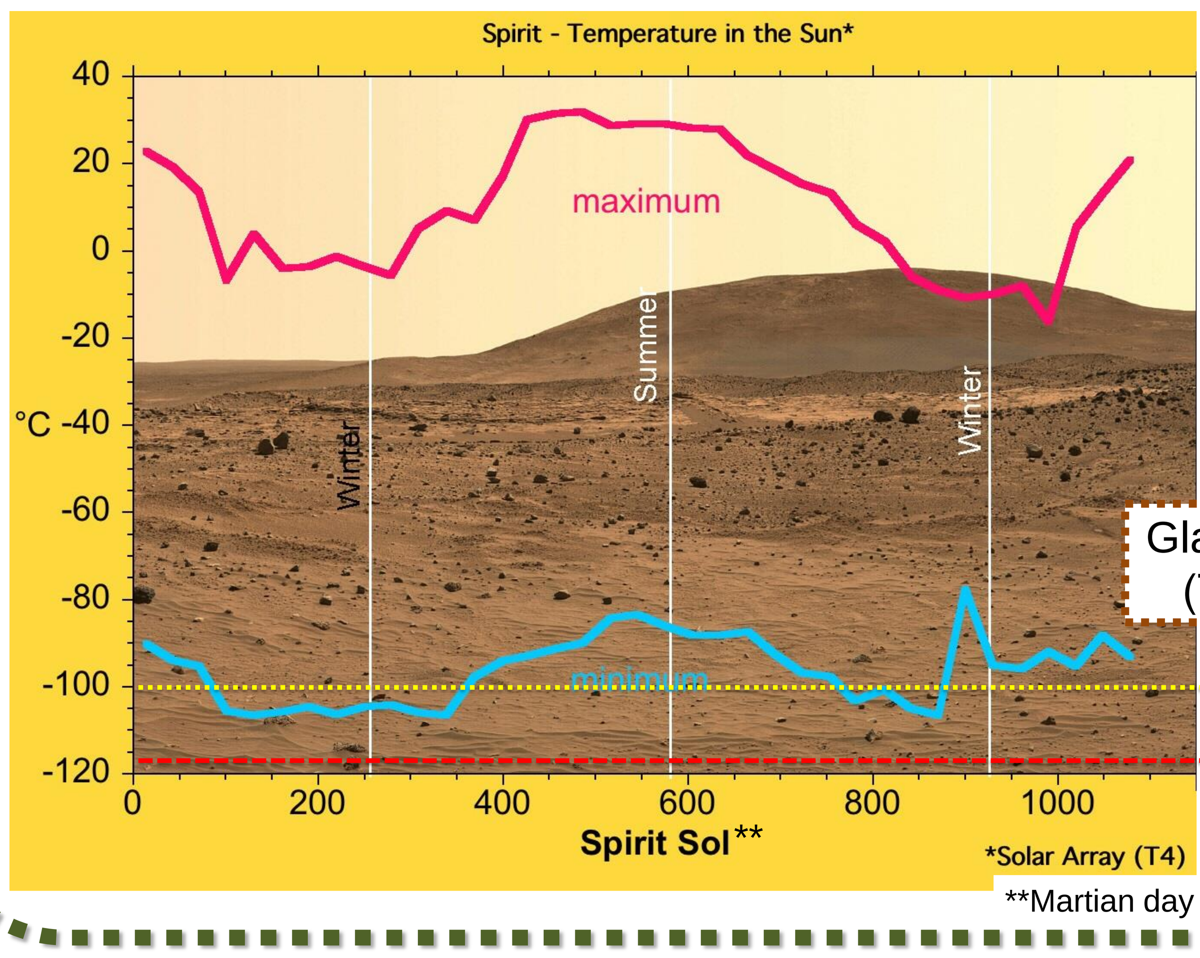
Radiation resistance:

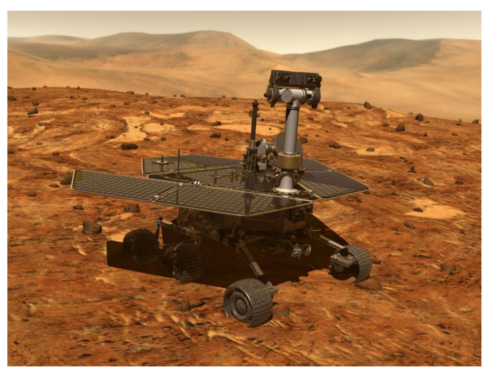
- ✓ Application of self-healing techniques for the rubber molecules
- ✓ Addition of heavy metals and their oxides as functional fillers

Low temperature performance:

- ✓ Synthesis of a thermoplastic elastomer containing soft blocks (elastic performance) and stiff blocks (mechanical endurance)
- ✓ Blending of two types of rubber preserving elastic properties at low temperatures (low glass transition temperatures):
  - ➢ **Silicone rubber** providing higher **radiation** & **aging resistance**;
  - ➢ **Butadiene rubber** providing better **wear** & **mechanic endurance.**

Temperature changes on Mars Surface recorded by the Spirit rover[2,10]

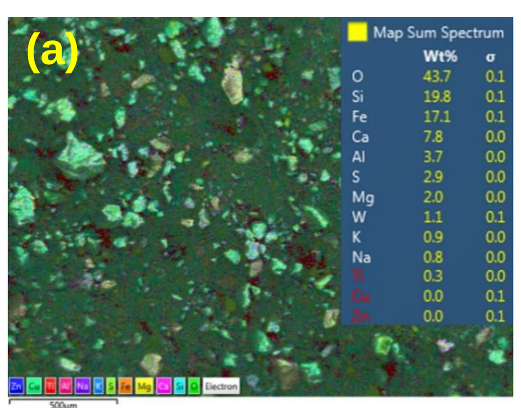


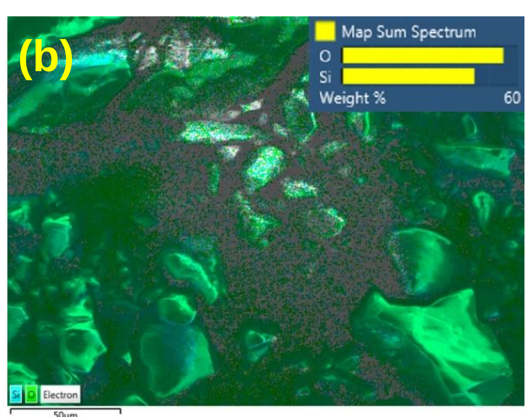


Can we involve In-Situ Resource Utilization?

- Functional fillers can contribute to over 50 % of a rubber material mass.
- Martian regolith can be a source of a silica-filler

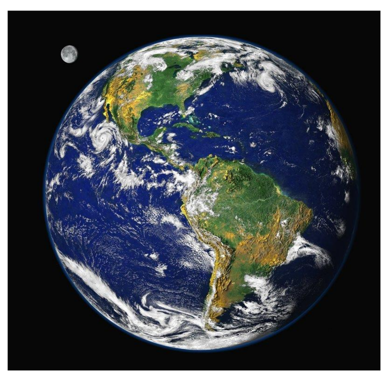
SEM-EDS pictures and elemental composition of the MMS-2[9] Martian regolith simulant (a) and of the silica produced from it by a precipitation method (b) – **own preliminary results.**





Why we don't use rubber on Mars?

Comparison of Earth[6] and Martian[1,7] environmental conditions



	Earth	Mars
Temperature range	-88 – 58 °C	- 140 – 30 °C
Pressure	101.3 kPa	0.6 kPa
Radiation	Low – 3.0 mSv/a	High – 400-500 mSv/a; additionally occasional solar proton events
Atmosphere	28 % oxygen; 71 % nitrogen; 1 % other	96 % carbon dioxide; <2 % argon; <2% nitrogen; <1% other

Biggest challenges:

- ✗ Galactic and solar cosmic radiation damages chemical structure of rubber molecules
- ✗ Most of the rubber types loose their elastic properties at those low temperatures

Solution approach

Elastomer phase:

- Blend of silicone and butadiene rubber
- Soft (elastic) and stiff (reinforcing) block copolymer

&

Chemical functionalization and additives facilitating **self-healing** properties

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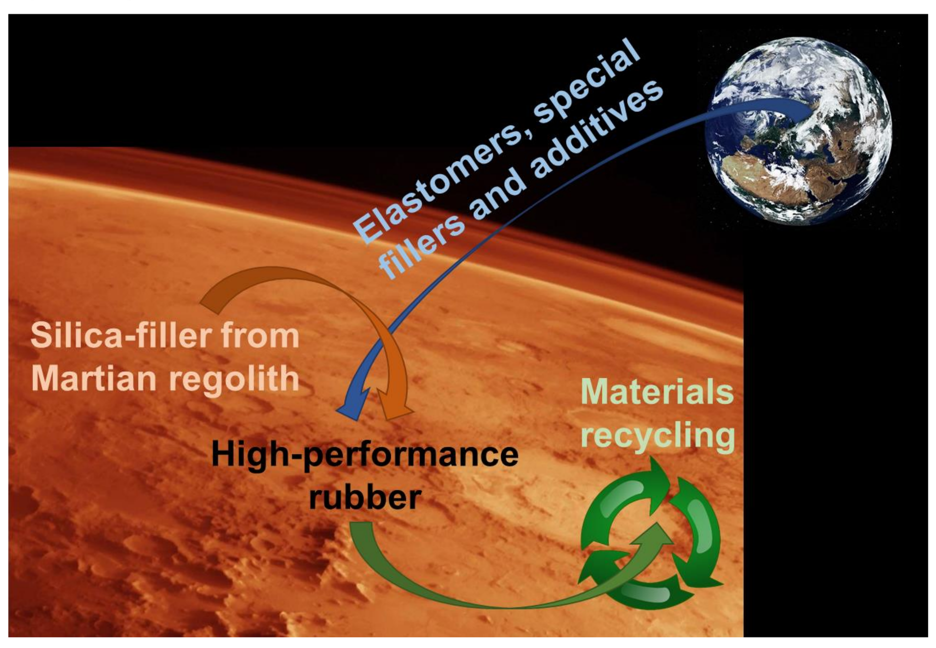
Functional fillers:

- Heavy metals & their oxides for radiation resistance
- Silica reinforcing filler produced from Martian regolith (ISRU)

*Airless tire concept of Bridgestone[4]

Proposal for a whole rubber production chain:

1. Manufacturing and transporting of elastomers and additives from Earth
2. Synthesizing of silica-filler from Martian regolith
3. Compounding and shaping the rubber materials
4. Material recycling of used rubber elements



References (all accessed 5 Oct 2019):

1. https://mars.nasa.gov/all-about-mars/facts/
2. https://mars.nasa.gov/mer/spotlight/20070612.html
3. https://www.spaceflightinsider.com/missions/solar-system/wheel-treads-break-curiosity-rover/
4. https://www.bridgestonetire.com/tread-and-trend/tire-talk/airless-concept-tires
5. https://mars.nasa.gov/mer/mission/rover/wheels-and-legs/
6. https://visibleearth.nasa.gov/images/54388/earth-the-blue-marble
7. https://solarsystem.nasa.gov/planets/mars/in-depth/
8. https://earthsky.org/space/mars-rovers-self-driving-technology-tested-by-uk
9. https://www.themartiangarden.com/mms2/mms2
10. https://solarsystem.nasa.gov/missions/spirit/in-depth/

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