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Self-Reinforced UHMWPE Homocomposite for Medical Implants

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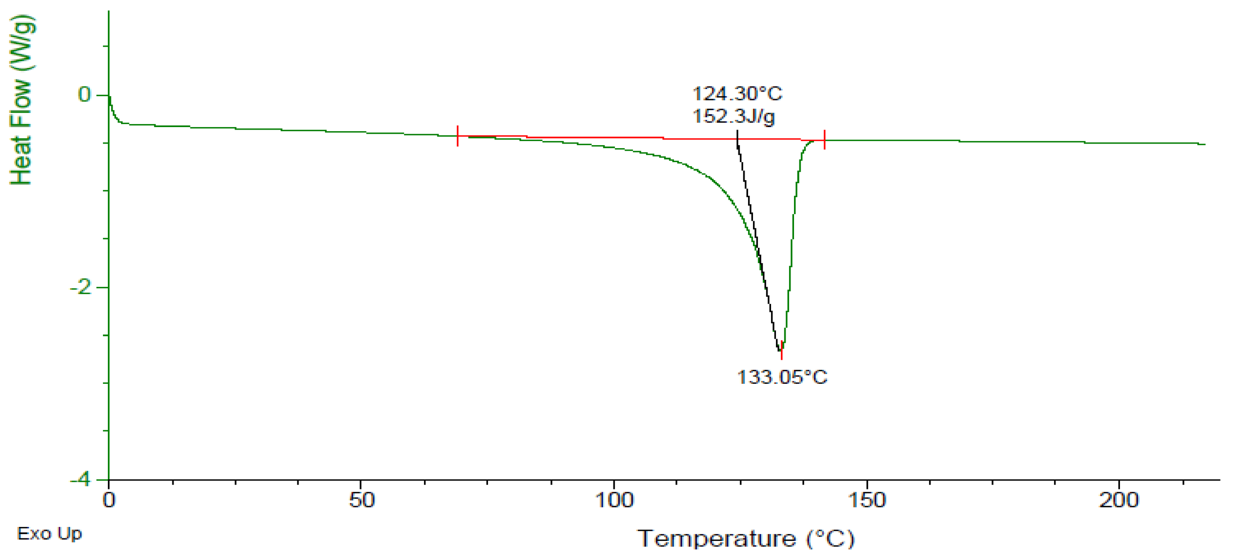
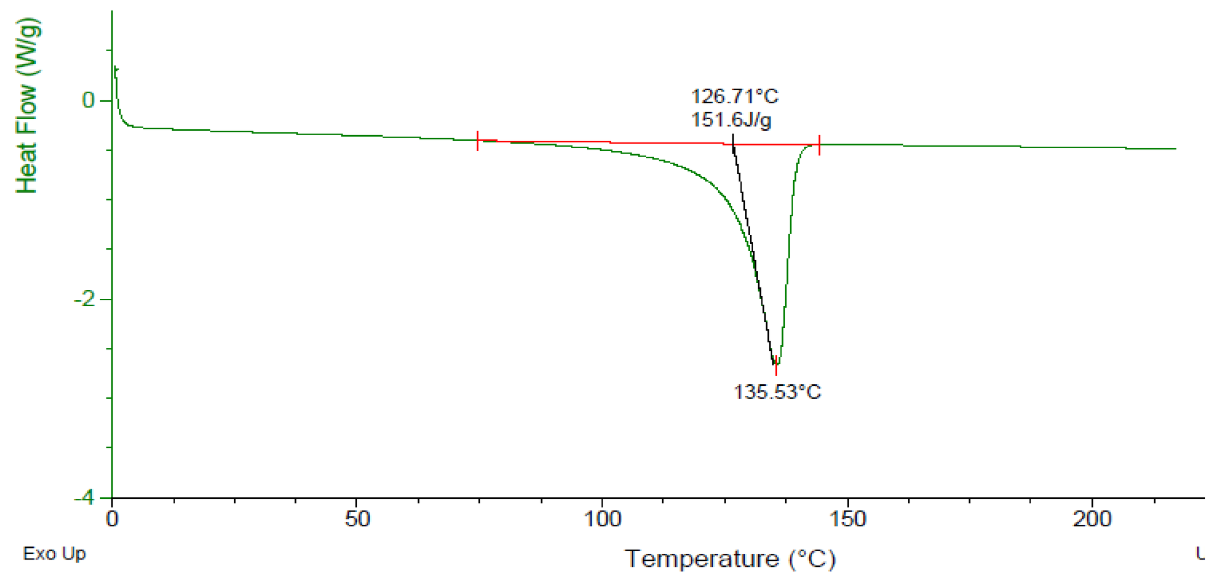
Introduction: The aim of our research is the development of UHMWPE homocomposites, by reinforcing GUR 1020 matrix material with Dyneema fibers. We would like to use the produced self-reinforced composite primarily for the inserts of joint implants. UHMWPE is a material with amazing mechanical and tribological properties, which is biocompatible and extremely inert. It is used successfully in countless areas (e.g. cut-resistant clothing, bulletproof structures, inserts for artificial joints). However, like all raw materials, it also has disadvantages, such as low heat resistance and - typical of polyolefins - difficult compatibility. Currently, the inserts of the implants are manufactured from UHMWPE, but they break down after a while. There can be countless reasons for the breakdown, but wear and tear plays a partial role in all of them. That is why, during our research, we produced a homocomposite from UHMWPE that has more favorable properties in terms of failure than traditional UHMWPE inserts. Our tests were made possible by the fact that the DSM company recently (2006) launched the biocompatible UHMWPE fiber (Dyneema Purity), which has since quickly gained ground as a suture material and as an alternative to metal fibers. Thus, both our matrix material and our reinforcement material are fully biocompatible - and have been used with confidence - and the difficult compatibility typical of polyolefins can be overcome, since both our matrix material and our reinforcement material are UHMWPE.

Technology setting:
We wanted to produce a self-reinforced UHMWPE composite in which the matrix material and the outer surface of the fibers melt and form a suitable adhesive bond. At the same time, the reinforcing material retains the incredible orientation characteristic of UHMWPE. This is theoretically possible, since the melting point of the UHMWPE fibers is slightly higher than that of the matrix material due to the outstanding orientation of the fibers. In the first step, we performed a DSC test on both the matrix material and the reinforcing material in order to determine their melting point and hence the processing temperature.



DSC curve of matrix material



DSC curve of the reinforcement material

Sintering:
The fibers were ground with a cryogenic grinder and then mixed with the matrix material. The sintering experiments were carried out in the thermal chamber of a universal material testing device.

Cryogenic grinder

Acknowledgments:
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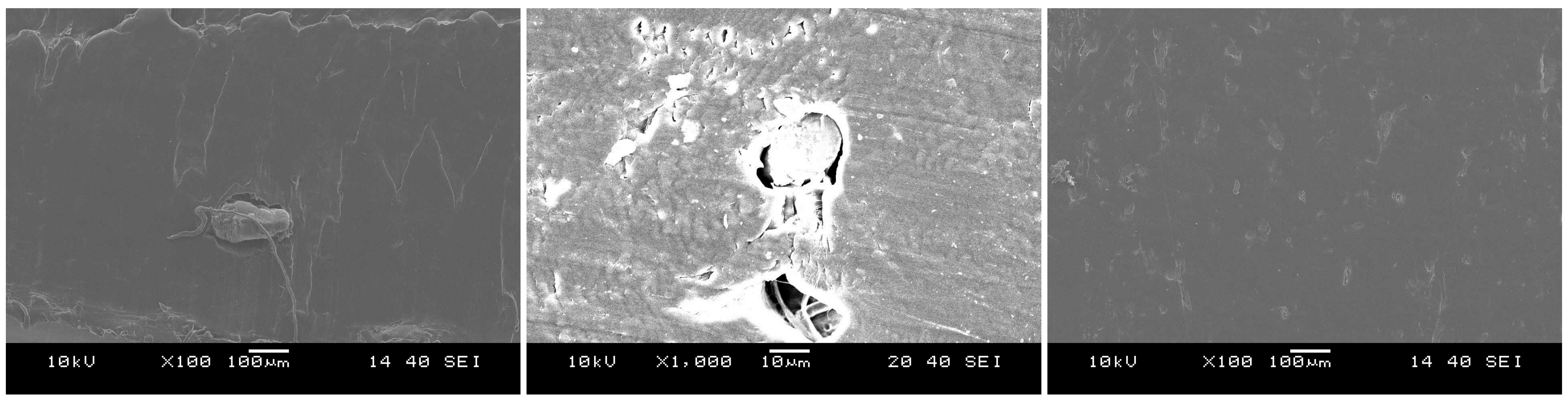
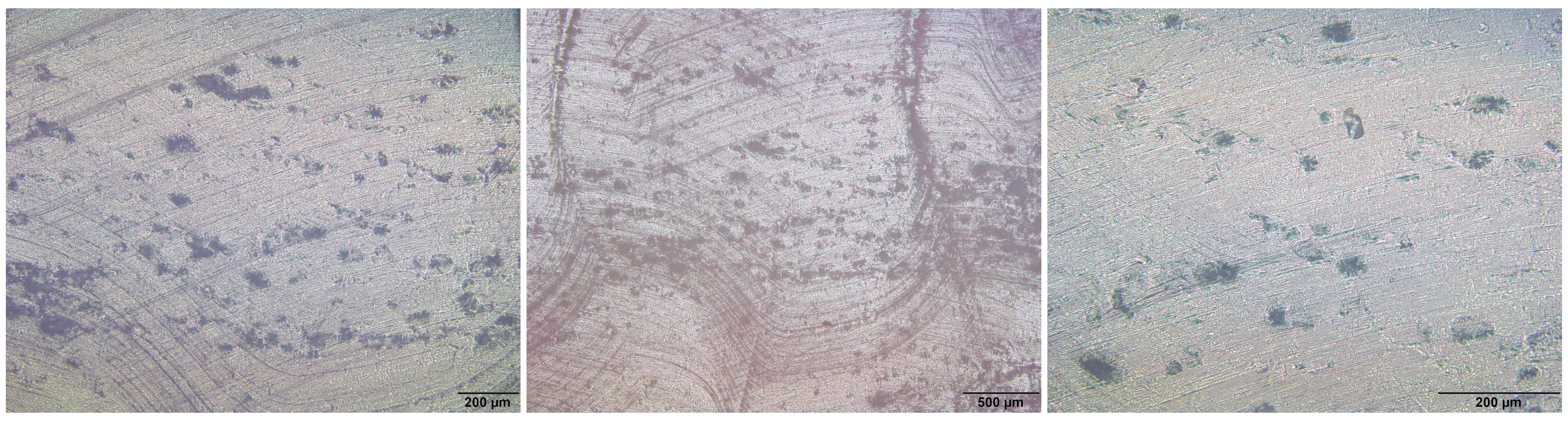
Sintering setup

Examination of UHMWPE homocomposites:
In the first step, SEM and optical microscopic images were taken to see if there were fibers left and how the fiber-matrix adhesion turned out.

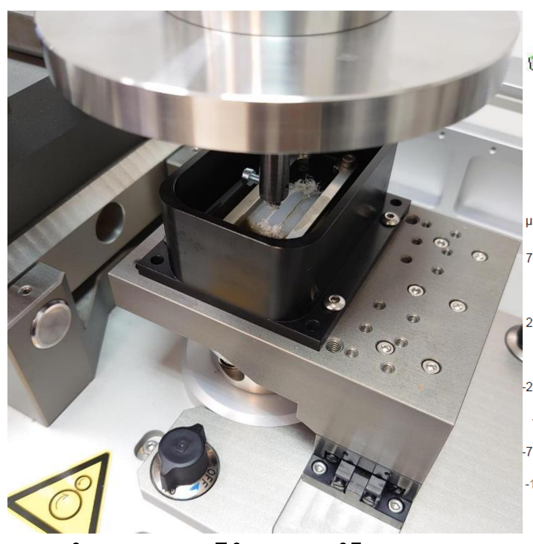


Electron microscopic images of the self-reinforced UHMWPE composite

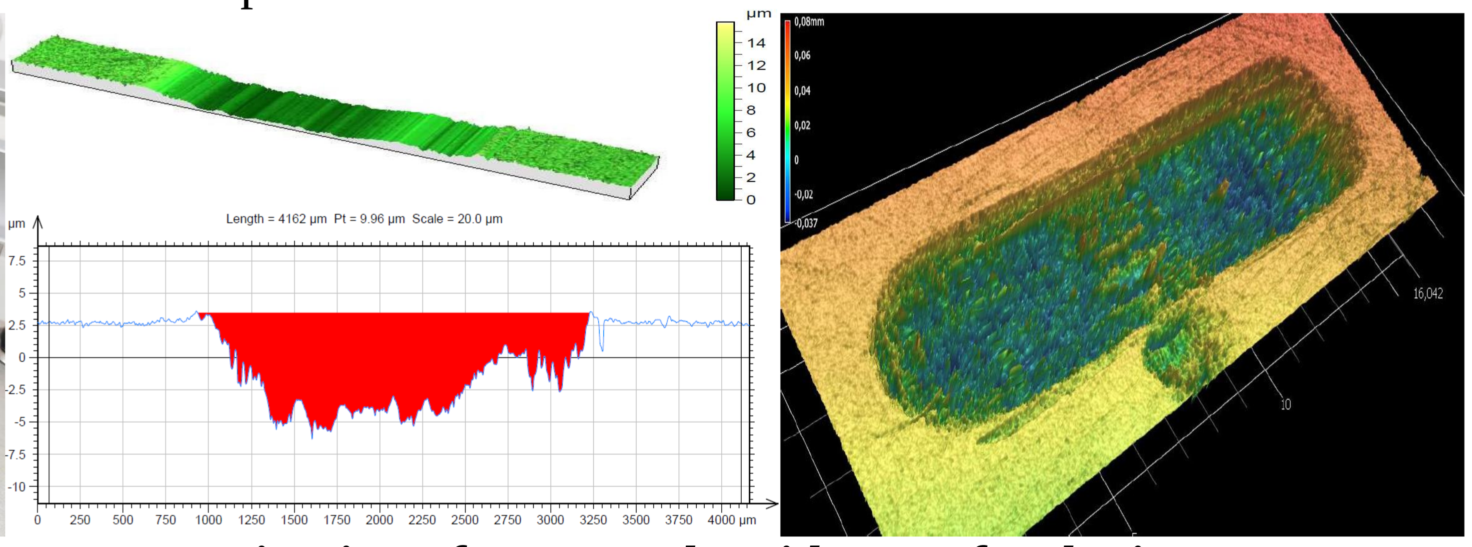


Optical microscopy images of the self-reinforced UHMWPE composite

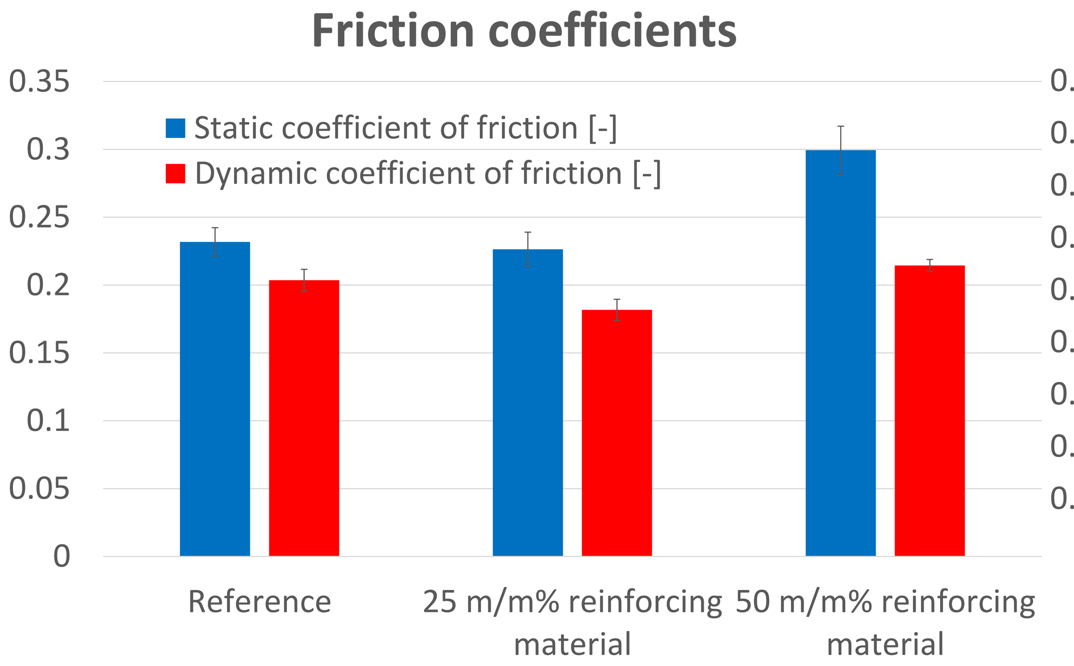
In the second step, the wear tests of the samples was performed on a pin-on-disc tribometer, and then static and dynamic friction coefficients were calculated. The wear marks were examined with a confocal microscope and the wear rate was determined.

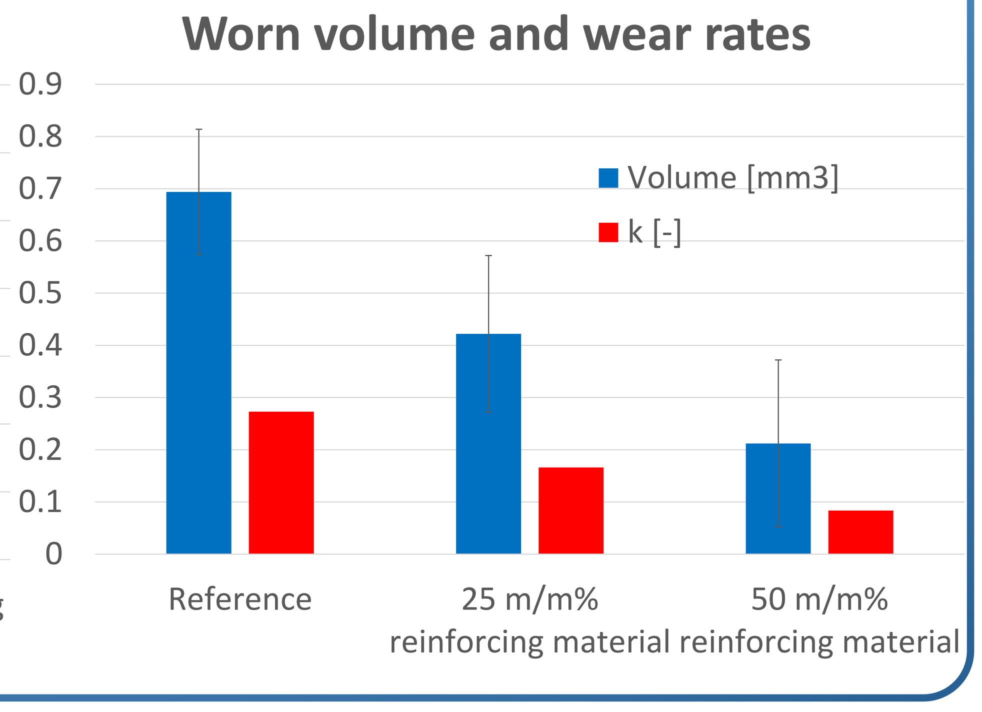


Pin-on-disc tribometer



Examination of wear marks with a confocal microscope





Summary: We can now stably produce self-reinforced UHMWPE composites for medical use. According to the microscopic images, we succeeded in melting the matrix material and the outer part of the fibers, thereby ensuring the proper adhesion relationship, while at the same time the fibers retained their orientation. According to our tribological tests, the addition of UHMWPE reinforcing material significantly improved the resistance to wear, and at the same time, it also slightly increased the friction factors. However, it has been proven that the UHMWPE homocomposite is more resistant than the traditional UHMWPE insert.