LATEX-BASED FAST SELF-REPAIR MECHANISMS IN PLANTS AS ROLE MODELS FOR THE DEVELOPMENT OF BIO-INSPIRED SELF-HEALING POLYMERS

Georg Bauer[1], Anke Nellesen[2] and Thomas Speck[1,3]

[1]University of Freiburg, Plant Biomechanics Group Freiburg, Botanic Garden, Faculty of Biology, Schänzlestr. 1, 79104, Freiburg. Germany.
Email: georg.bauer@biologie.uni-freiburg.de

[2]Fraunhofer Institute UMSICHT
Osterfelder Straße 3, 46047 Oberhausen. Germany
Email: anke.nellesen@umsicht.fraunhofer.de

[3]Competence Networks Biomimetics and *BIO*KON

Keywords: Self-healing, Plant latex, Bio-inspired, Polymers

ABSTRACT

Polymers are often used in fields of application with high mechanical loads. Thereby, components may fail even far below their maximum critical load due to micro-cracks. As micro-cracks are found in every component, a smart way to prevent these cracks from propagation is to equip the components with self-healing abilities. In nature, many self-healing mechanisms can be found. For a transfer into technical materials such as elastomeric polymers, especially fast self-healing mechanisms are promising. One of these mechanisms is the coagulation of latices that in many plants is involved in the sealing of lesions.

We quantified the self-healing abilities of the Weeping Fig (*Ficus benjamina*), a latex bearing plant. In addition to a fast sealing of lesions in the bark (Fig. 1), it could be proved that the tensile strength of the bark was partly restored after a short period of time after injury (corresponding to the time after which changes in latex transparency were observed, indicating the coagulation being at its final stage). The recovery of this mechanical property can be attributed to the coagulation of the plant latex.

In further studies, this fast self-healing mechanism was elucidated as a biological role model for self-healing polymers. Inspired by a theory found in the literature [1] and by experimental data a first generation self-healing polymer was developed and will be improved in the near future. The coagulation theory of *Hevea brasiliensis* latex reports the sealing of lesions after injury by cross linking rubber particles via the protein hevein. In an intact plant this protein is stored in vacuolar structures which are found in branched micro-pipe systems (laticifers) with an internal pressure of up to 15 bar [2] and burst due to a pressure drop as soon as the latex discharges.

Our analyses prove that during latex coagulation of the Weeping Fig an amide peak occurs indicating protein-binding also in case of this plant species [3]. More detailed examinations on several latex bearing plant species from the genera *Ficus*, *Euphorbia* and *Campanula* were conducted for an interspecific comparison of latex coagulation mechanisms. The pressure dependence of latex coagulation was tested with a self-built pressure box, where fresh stem segments were injured under a constant pressure up to 9 bar. A pressure dependent mechanism was found in all plant species, although differences in the courses of the pressure-time-curves were observed. An oxygen dependency of the coagulation could not be found in any of the plant species mentioned above. Particle size analyses of the fresh latex via laser diffraction yielded large differences between plant species belonging to different genera. This result was confirmed by identification and measurement of the particles in the latex via cryo scanning electron microscopy.

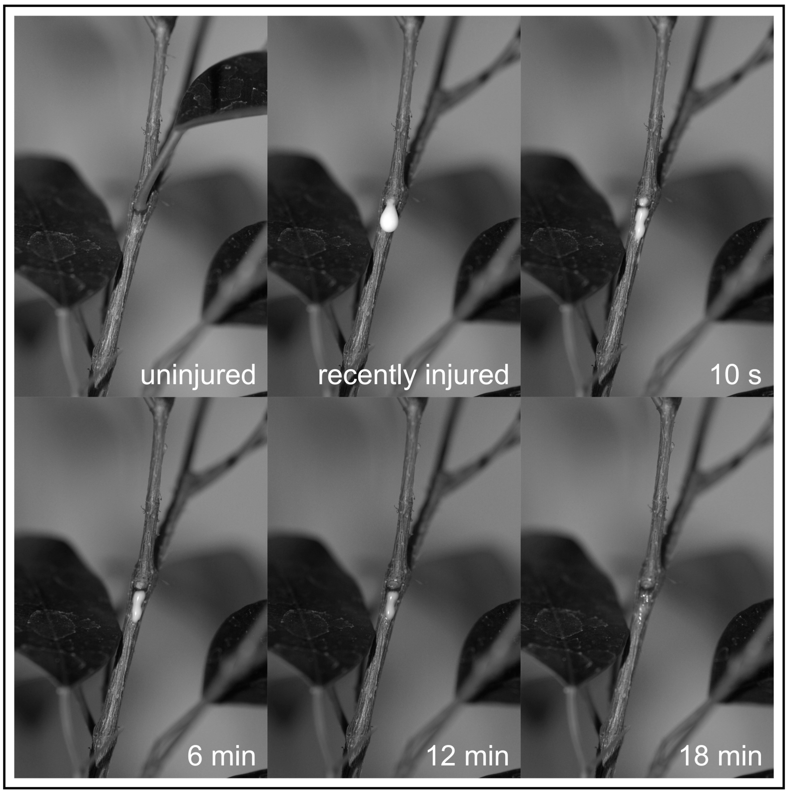

Figure 1: Fast sealing of lesions due to coagulation of the latex of the Weeping Fig.

The results of our studies suggest different mechanisms of latex coagulation for different systematic groups. A more detailed identification of these mechanisms would be a promising step towards a broad range of possibilities for transferring these findings into technical polymers with bio-inspired self-healing functions.

The studies presented here are part of the project ‘Self-healing polymers “OSIRIS”’, which is funded within the scope of the funding directive BIONA by the German Federal Ministry of Education and Research. We also thank our research partners for assistance and many helpful discussions.

REFERENCES

[1] J. d’Auzac, J.-C. Prevot and J.-L. Jacob, What’s new about lutoids? A vacuolar system model from Hevea latex, *Plant physiology and biochemistry*, **33**, 1995, pp. 765-777.

[2] B. R. Buttery and S. G. Boatman, Manometric measurement of turgor pressures in laticiferous phloem tissues, *Journal of Experimental Botany*, **17**, 1966, pp. 283-296.

[3] G. Bauer, A. Nellesen and T. Speck, Biological latices in fast self-repair mechanisms in plants and the development of bio-inspired self-healing polymers, *Proceedings of the 5th International Conference on comparing Design in Nature with Science and Engineering ‘Design and Nature V’ (Eds. C.A. Brebbia, A. Carpi), Pisa, Italy, June 28-30, 2010*, WIT Press, Southampton, pp. 453-459.