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Explanatory accompanying text for Poster:

Surface Activation of Spent Coffee Grounds by DCSBD Plasma for Potential Use as Sustainable Rubber Filler

The presented research focuses on the utilization of spent coffee grounds (SCG) as a sustainable alternative filler for rubber compounds, with emphasis on surface modification using Diffuse Coplanar Surface Barrier Discharge (DCSBD) plasma technology. The work reflects current trends in sustainable materials engineering, circular economy principles, and environmentally friendly surface activation methods applicable in modern elastomer technologies and advanced polymer systems.

Experimental analyses confirmed that SCG represents a material with dominant organic character and significant potential for further functionalization. Thermogravimetric analysis revealed a major mass loss of approximately 79.2% within the temperature range of 200 – 450 °C, corresponding to the decomposition of organic constituents, while the residual inorganic fraction remained only 0.8 wt.%, indicating minimal ash content. The DSC analysis additionally confirmed the presence of residual moisture and characteristic thermal transitions associated with dehydration and structural transformations of the material. The performed sieve analysis also demonstrated that most particles remained above 125 µm, confirming the heterogeneous morphology of the material and indicating the need for further optimization of grinding and dispersion processes for future rubber compound applications.

One of the most significant findings was related to the effect of DCSBD plasma treatment on the surface properties of SCG. After 60 s plasma exposure, the polar component of surface free energy increased substantially from 0.1 mJ/m^2 to 3.5 mJ/m^2, accompanied by a reduction in the water contact angle from 96.5° to 78.4°, indicating a considerable improvement in surface wettability and hydrophilicity. FTIR spectroscopy further confirmed chemical modification of the SCG surface through increased intensity of hydroxyl and amino functional groups in the 3200 – 3500 cm^{-1} spectral region and partial reduction of carbonyl-related bands. These observations indicate that plasma treatment promoted the formation of reactive oxygen-containing functional groups, which are important for improving interfacial compatibility with elastomer matrices.

DCSBD plasma technology represents a highly progressive and environmentally friendly approach for the activation of natural and waste-derived materials under atmospheric-pressure conditions. Unlike conventional chemical treatments, plasma modification enables rapid and solvent-free surface activation without significant degradation of the bulk structure of the material. The generated diffuse plasma contains a high concentration of reactive species, radicals, ions, and UV photons capable of initiating controlled physicochemical transformations on the material surface. In the case of SCG, plasma exposure improved surface polarity and modified the chemical composition of the outer layers, which may positively influence filler–rubber interactions, adhesion mechanisms, and dispersion behavior in future elastomer composites. The observed changes confirm the strong potential of DCSBD plasma for sustainable modification of bio-based fillers intended for technical applications.

An important aspect of the presented work is its universal character. Although the study focuses on spent coffee grounds, the proposed methodology combining thermal analysis, wettability evaluation, FTIR spectroscopy, and plasma surface activation can be directly transferred to other bio-based fillers and agricultural waste materials. The approach therefore creates a broader experimental framework for the development of sustainable fillers derived from renewable or waste resources, including lignocellulosic particles, biomass residues, or carbon-rich organic by-products. Such materials may partially replace conventional petroleum-based or mineral fillers in rubber compounds and polymer systems while simultaneously reducing environmental burden and supporting circular material utilization strategies.

The obtained results demonstrate that DCSBD plasma treatment can effectively enhance the interfacial activity and potential adhesion behavior of SCG toward elastomer matrices without the use of chemical activators. This concept directly corresponds with the objectives of the VEGA no. 1/0251/26 research activities focused on plasma activation of fillers and surface modification of elastomer systems for sustainable rubber technologies. The study therefore represents a promising basis for future integration of plasma-modified biofillers into advanced rubber composites with reduced environmental impact and improved surface-interaction performance.