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Nanocomposites and Polymer Thin Films: from Gas Phase Synthesis to Functional Applications

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Among the functional nanocomposites, our group has focused on highly filled particulate metal-dielectric nanocomposites films due to their unique functional properties with hosts of applications. To explore collective interactions between the particles, we control the particle separation on the nanoscale by employing vapor phase deposition, which is a scalable approach permitting, inter alia, excellent control of the filling factor.

For deposition of functional polymer thin films, we have recently used initiated chemical vapor deposition (iCVD) to avoid decomposition of the functional groups [1]. Examples include highly stable electrets for electret microphones and magnetoelectric sensors [2], 3D superhydrophobic coatings [3], nanoscale gradient copolymers, and strain-invariant conductors for soft robotics [4]. For the fabrication of the nanocomposites, the nanoparticles can form during gas phase co-deposition via self-organization or by means of high-rate gas aggregation cluster sources, which provide independent control of filling factor and size as well as in situ monitoring and control of the composition of alloy nanoparticles. Recent examples of nanocomposites range from plasmonic meta-materials through photoswitchable [5] molecular plasmonic systems to memristors and memsensors for neuromorphic electronics [6]. We also explored nanoscale synergetic effects of plasmonics and photocatalysis [7], e.g. for photoinduced enhanced Raman spectroscopy (PIERS) [8].

In cooperation with the group of Oleg Lupan, we have also used alloy nanoparticles with tailored composition to enhance the sensitivity and selectivity of chemical sensors made up of micro and nanostructured wide-bandgap semiconductors [9]. Cross-sensitivity against moisture could be successfully eliminated with fluoropolymer coatings deposited by iCVD [10].

In addition to particulate nanocomposites, we are also concerned with multilayer nanocomposites. Here, emphasis is put on magnetoelectric sensors consisting of magnetostrictive and piezoelectric components on a vibrating beam. We also use electrets for readout and for obtaining a well-defined nonlinear restoring force [11].

References

1. Schröder, S., Polonskyi, O., Strunskus, T., Faupel, F.: Nanoscale gradient copolymer films via single-step deposition from the vapor phase. Materials Today 37, 35-42 (2020). https://doi.org/10.1016/j.mattod.2020.02.004
2. Schröder, S., Strunskus, T., Rehders, S., Gleason, K., Faupel, F.: Tunable polytetrafluoroethylene electret films with extraordinary charge stability synthesized by initiated chemical vapor deposition for organic electronics applications. Sci Rep 9, 2237 (2019). https://doi.org/10.1038/s41598-018-38390-w
3. Aktas, O.C., Schröder, S., Veziroglu, S., Ghori, M.Z, Haidar, A, Polonskyi, O., Strunskus, T., Gleason, K., Faupel, F.: Superhydrophobic Surfaces: Superhydrophobic 3D Porous PTFE/TiO_2 Hybrid Structures. Adv. Mater. Interfaces 6, 1970029 (2019). https://doi.org/10.1002/admi.201801967
4. Barg, I., Rasch, N. K. F., Strunskus, T., Adelung, R., Kienle, L., Faupel, F., Schröder, S., Schütt, F.: Strain-Invariant, Highly Water Stable All-Organic Soft Conductors Based on Ultralight Multi-Layered Foam-Like Framework Structures. Adv. Functional Mater. 221268 (2023) https://doi.org/10.1002/adfm.202212688
5. Burk, M. H., Schröder, S., Moormann, W., Langbehn, D., Strunskus, T., Rehders, S., Herges, R., Faupel, F.: Fabrication of Diazocine-Based Photochromic Organic Thin Films via Initiated Chemical Vapor Deposition. Macromolecules 53, 1164 (2020). https://doi.org/10.1021/acs.macromol.9b02443
6. Vahl, A., Carstens, N., Strunskus, T., Faupel, F., Hassanien, A.: Diffusive Memristive Switching on the Nanoscale, from Individual Nanoparticles towards Scalable Nanocomposite Devices. Sci. Rep. 9, 1 (2020).

https://doi.org/10.1038/s41598-019-53720-2

7. Veziroglu, S., Obermann, A. L., Ullrich, M., Hussain, M., Kamp, M., Kienle, L., Leißner, T., Rubahn, H,-G., Polonskyi, O., Strunskus, T., Fiutowski, J., Es-Souni, M., Adam, J., Faupel, F., Aktas, O. C.: Photodeposition of Au Nanoclusters for Enhanced Photocatalytic Dye Degradation over TiO_2 Thin Film, ACS Appl. Mater. Interfaces 12, 149 (2020). https://doi.org/10.1021/acsami.9b18817
8. Shondo, J., Veziroglu, S., Tjardts, T., Sarwar, T. B., Mishra, Y. K., Faupel, F., Aktas, O. C.: Nanoscale Synergetic Effects on Ag–TiO_2 Hybrid Substrate for Photoinduced Enhanced Raman Spectroscopy (PIERS) with Ultra-Sensitivity and Reusability. Small18, 2203861 (2022). https://doi.org/10.1002/smll.202203861
9. Vahl, A., Lupan, O., Santos-Carballal, D., Postica, V., Hansen, S., Cavers, H., Wolff, N., Terasa, M.-I., Hoppe, M., Cadi-Essadek, A., Dankwort, T., Kienle, L., de Leeuw, N.H., Adelung, R., and Faupel. F.: Surface functionalization of ZnO:Ag columnar thin films with AgAu and AgPt bimetallic alloy nanoparticles as an efficient pathway for highly sensitive gas discrimination and early hazard detection in batteries, J. Mater. Chem. A 8, 16246-16264, (2020). https://doi.org/10.1039/D0TA03224G
10. Schröder, S., Ababii, N., Lupan, O., Drewes, J., Magariu, N., Krüger, H., Strunskus, T., Adelung, R., Hansen, S., and Faupel, F.: Sensing performance of CuO/Cu2O/ZnO:Fe heterostructure coated with thermally stable ultrathin hydrophobic PV3D3 polymer layer for battery application, Materials Today Chemistry 23, 100642, 2468-5194, (2022). https://doi.org/10.1016/j.mtchem.2021.100642
11. Mintken, M., Schweichel, M., Schröder, S., Kaps, S., Carstensen, J., Kumar Mishra, Y., Strunskus, T., Faupel, F., and Adelung R.: Nanogenerator and piezotronic inspired concepts for energy efficient magnetic field sensors Nano Energy 70, 104420 (2020). https://doi.org/10.1016/j.nanoen.2018.11.031