PYROLYSIS

Investigation of the influence of supercritical carbon dioxide treatment on meta-aramid fiber: Thermal decomposition behavior and kinetics

Zhang, C., Jiang, Y.-X., Sun, J.-P., Xiao, H., Shi, M.-W., Long, J.-J. 2020. Investigation of the influence of supercritical carbon dioxide treatment on meta-aramid fiber: Thermal decomposition behavior and kinetics, *Journal of CO2 Utilization, 37*, 85-96

Influence of supercritical carbon dioxide (SCF-CO2) on the thermal decomposition behavior and kinetics of meta-aramid fiber was investigated at the first time, in order to develop some fundamental bases for sustainably and cleanly manufacturing some relative products from this fiber with the supercritical green medium. Particularly, the thermal decomposition behavior of treated samples was explored and characterized by thermogravimetric and differential thermogravimetric analysis (TGA-DTGA). The kinetics of the main steps of thermal decomposition was also investigated via different kinetics models. The results show that an influence of SCF-CO2 treatment on the thermal decomposition behavior of the fiber was observed by TGA-DTGA, accompanied with successive and partially overlapped predominant two-step degradation as sample temperature from 380.0 °C to 700.0 °C, as well as a small pyrolysis Step three at 650.0 °C to 800.0 °C. Decreases in thermal property and behavior were detected by TGA-DTGA for the samples as treatment temperature from 80.0 °C to 120.0 °C. The fitted results reveal that good linear regressions of the TGA-DTGA data were achieved from the kinetics models accompanied with high values of adjusted R-Square. The kinetics parameter of the apparent activation energy (E) decreased with the treatment temperature from 80.0 °C to 120.0 °C, as well as with the conversion degree (α) of the samples. Moreover, a second-order chemical reaction mechanism for the predominant thermal decomposition steps was successfully supposed by Coats-Redfern and Achar-Brindley-Sharp-Wendworth models combined with a solid mechanism function of C2.

Microwave Assisted Preparation of Self-Extinguishing Cotton Fabrics by Small Molecules Containing Phosphorous and Nitrogen.

Chang, S., Condon, B. and Smith, J. 2019. Microwave Assisted Preparation of Self-Extinguishing Cotton Fabrics by Small Molecules Containing Phosphorous and Nitrogen. *Current Microwave Chemistry, 6*(1), 3-12

Introduction: New methods for preparing surface modification of flame retardant cotton fabrics were employed by applying a microwave-assisted technique with a minimum amount of co-solvent. Efforts at flame retardant cotton fabrics treated with economic and environmentally friendly flame retardant compounds based on the small molecules piperazine, PN and PNN, were done successfully. Methods and Results: The evidence of flame retardant chemical penetrations or surface modification of cotton fabrics was confirmed by Scanning Electron Microscope (SEM), and the treated cotton fabrics were evaluated by flammability tests, such as 45°angle (clothing textiles test) and limiting Oxygen Index (LOI). Thermogravimetric analysis of all treated cotton fabrics in a nitrogen atmosphere showed high thermal stability, as decomposition occurred between 276.9~291.2°C with 30.5~35.7% residue weight char yield at 600°C. Limiting Oxygen Index (LOI) and the 45° angle flammability test were used to determine the efficiency of the flame-retardant treatments on the fabrics. LOI values for control twill fabric showed ~18 vol% oxygen in nitrogen, whereas the highest treatment level had 32 vol%. High add-on treatments with flame retardants also readily passed the 45° angle flammability test. Conclusion: In the Microscale Combustion Calorimeter (MCC) tests, a decline in heat of combustion was shown through the smaller values acquired for THR, HRC and Tmax for all PN and PNN samples.

One-pot fabrication of superhydrophobic and flame-retardant coatings on cotton fabrics via sol-gel reaction

Lin, D., Zeng, X., Li, H., Lai, X. and Wu, T. 2019. One-pot fabrication of superhydrophobic and flame-retardant coatings on cotton fabrics via sol-gel reaction. *Journal of colloid and interface science, 533*, 198-206

Waterproof and flame-retardant fabrics are widely utilized in many fields, such as automotive interiors, indoor decorations, outdoor clothing and tents. Herein, a facile one-pot sol-gel approach was developed to construct superhydrophobic and flame-retardant (SFR) coatings on cotton fabrics. The cotton fabric was activated by O2 plasma and then immersed into the ethanol suspension containing tetraethoxysilane (TEOS), hydroxyl-terminated polydimethylsiloxane (HPDMS) and ammonium polyphosphate (APP). The hydrogen bonding interaction between APP and cellulose motivated the APP to attach to the cotton fibers during the initial stirring process. After the addition of ammonia, the in situ sol-gel reaction of TEOS and HPDMS was initiated to generate polydimethylsiloxane-silica hybrid (PDMS-silica). The micro-nano structured composite coating on cotton fabric was successfully fabricated by the PDMS-silica and APP. The SFR cotton fabric showed outstanding durability and self-cleaning ability with a water contact angle (WCA) above 160°. When exposed to fire, the SFR cotton fabric quickly charred to extinguish the fire by generating a dense intumescent char layer under the physical barrier effect of PDMS-silica and the intumescent flame-retardant effect of APP. This one-pot approach for fabricating SFR cotton fabric is simple, cost-effective and timesaving, demonstrating significant advantages in practical production.

Flame retardant vinylon/poly(m-phenylene isophthalamide) blended fibers with synergistic flame retardancy for advanced fireproof textiles

Zhang, X., Shi, M. 2019. Flame retardant vinylon/poly(m-phenylene isophthalamide) blended fibers with synergistic flame retardancy for advanced fireproof textiles, *Journal of Hazardous Materials, 365*, 9-15

Superior flame retardant textiles are urgently needed to address high fire and heat risks. This study provides a simple and effective strategy to improve the flame retardancy of textiles through a synergistic effect between the blended fibers, and a system with synergistic in flame retardant vinylon (FRV)/poly(m-phenylene isophthalamide) (PMIA) blended fibers is discovered. The FRV/PMIA 50/50 exhibits a much higher time to ignition and a lower peak heat release rate than those of the neat components, indicating a synergistic flame retardancy between constituents. The corresponding mechanism is explored. The residual char layer formed by blended fibers connects together and keeps the original fiber shape, which acts as a barrier slowing heat transmission and gas diffusion. Concurrently, thermal degradation analysis of blended fibers implies that both components mutually interact with each other, resulting in a higher experimental amount of incombustible gases at an early degradation stage and lower experimental amount of combustible gases at a later degradation stage as compared to the theoretical one. Therefore, the synergistic flame retardancy in FRV/PMIA blended fibers is attributed to the actions in the condensed and gas phases during pyrolysis. This work provides an effective strategy to design fireproof textiles.

Condensed tannin from Dioscorea cirrhosa tuber as an eco-friendly and durable flame retardant for silk textile

Yang, T.-T., Guan, J.-P., Tang, R.-C., Chen, G. 2018. Condensed tannin from Dioscorea cirrhosa tuber as an eco-friendly and durable flame retardant for silk textile, *Industrial Crops and Products, 115*, 16-25

Condensed tannin derived from Dioscorea cirrhosa tuber was employed as a novel and eco-friendly flame retardant agent for enhancing the thermal shielding and flame retardant properties of silk textile. A facile adsorption technique of condensed tannin in the weakly acidic condition was able to impart good and durable flame retardancy to silk fabric. In the treatment process, the adsorption, diffusion and deposition of condensed tannin onto silk fiber took place. The flame retardancy was demonstrated by limiting oxygen index, vertical burning and pyrolysis combustion flow calorimetry tests. The treated fabric exhibited the limiting oxygen index above 27% and the char length below 12 cm even after 20 washing cycles. The thermogravimetric analyses of the treated fabric and the morphological studies

of the burned fabric residue suggested that a significant condensed-phase mechanism contributed to the improvement in the flame retardancy of silk fabric. In addition to flame retardancy, antibacterial and antioxidant activities were imparted to silk fabric. Such multifunctional properties provided by condensed tannin can expand the application of flame retardant silk. The present research indicates that condensed tannin is a promising alternative to traditional flame retardants for the finishing of silk textile.

Adsorbents made from textile scraps: preparation, characterization and application for removal of reactive dye

Correia, J., Vasques Mendonça, A.R., de Souza, S.M.A.G.U., Valle, J.A.B. 2018. Adsorbents made from textile scraps: preparation, characterization and application for removal of reactive dye, C*lean Technologies and Environmental Policy, 20*(4), 839-853

Textile scraps from the clothing industry were used to prepare a low-cost adsorbent to remove anionic dye from textile effluents. Adsorbents were prepared through pyrolysis and chemical activation with K2CO3. These samples were characterized through thermogravimetric analysis, scanning electron microscopy, N2 adsorption/desorption isotherms, Fourier transform infrared spectroscopy, point of zero charge, isoelectric point, elemental composition and proximate analysis. Batch kinetic experiments and adsorption isotherm modeling were conducted in different conditions. The surface properties of the adsorbents were significantly influenced by the activation process. The highest BET surface area (SBET = 358.55 m2 g−1) was attributed to the sample with chemical treatment. The results indicate that activation process raised 700% the adsorption capacity. The adsorption was strongly dependent on the pH. For the activated adsorbent, 6 g L−1 was sufficient for the complete removal of 40 mg L−1 Reactive Black 5 (RB5) solution. The monolayer capacity was up to 10.3 mg g−1 and was higher than a commercial activated carbon commonly used in textile sector, which was 9.7 mg g−1.

Waste management system in the clothing industry in Santa Catarina State Brazil: An initial overview

Correia, J., Dal Forno, A.J., Marangoni, C. and Valle, J.A.B. 2018. Waste management system in the clothing industry in Santa Catarina State Brazil. M*anagement of Environmental Quality: An International Journal*

Purpose - The purpose of this paper is to identify and diagnosis waste management practices used by clothing manufacturing companies in Santa Catarina state Brazil. Design/methodology/approach - The data for this multiple case study were obtained from

interviews and by using a questionnaire to collect company data. After the analysis of the responses to questionnaires issued to 22 companies, a scoring system was developed to systematically classify these companies at either a basic, intermediate or advanced levels. Findings - According to the classification used, eight companies were characterized at the basic level, eight at the intermediate level and six as advanced. Most of the companies have already implemented measures for reuse or recycling of textile scraps, probably because of the economic value added. Research limitations/implications - The classification system proposed proved to be an effective tool for identifying: if each company had a plan of action involving requirements of Brazil's National Solid Waste Policy; if the company had a management system in accordance with Law 12,305; the quality of solid waste treatment at the entire company and in its clothing sector; if the company adopted shared responsibility actions; and if it had knowledge of the negative environmental impacts. Originality/value - This paper presents a classification system for companies based on a questionnaire. The system allows determining the degree of compliance with Brazilian waste management legislation.

Investigating the composition and degradation of wool through EGA/MS and Py-GC/MS

Sabatini, F., Nacci, T., Degano, I. and Colombini, M.P., 2018. Investigating the composition and degradation of wool through EGA/MS and Py-GC/MS. *Journal of analytical and applied pyrolysis, 135*, 111-121

Wool has been the most widely used textile fiber in Europe since the Iron Age. It was largely employed to weave fabrics and clothes, and also for artistic purposes such as producing tapestries. This kind of artworks is among the most fragile of our heritage and is often in bad preservation conditions. Thus, the knowledge on the degradation processes of wool fibers is crucial for conservation issues. In the present study, we tested the potentialities of Pyrolysis coupled with Gas Chromatography and Mass Spectrometry (Py-GC/MS) and Evolved Gas Analysis coupled to Mass Spectrometry (EGA/MS) for the characterization of woolen reference samples, also subjected to artificial ageing, and of historical and archeological samples. The reference sheep wool yarns were prepared with different mordants and dyes, and have been analyzed both after storage in the dark for three years after preparation, and artificially aged for different time intervals and at different relative humidity values. We created a detailed pyrolysis database, evidencing the phenomena occurring with ageing and including camel wool for comparison. The ageing process undergone by the proteinaceous fraction of wool has also been investigated through monitoring specific fragment ions in the EGA profiles. The relevant parameters affecting the degradation process identified in this study match those assessed in previous investigations by different and complementary techniques, thus validating our approach. We proved that the novel approach based on EGA/MS is suitable for quickly assessing the conservation conditions of the woolen yarns and represents an advantage with respect to more time-consuming and complex methods, such as GC/MS or High Performance Liquid Chromatography (HPLC).

Flammability of natural plant and animal fibers: a heat release survey

Galaska, M.L., Horrocks, A.R. and Morgan, A.B., 2017. Flammability of natural plant and animal fibers: A heat release survey. *Fire and Materials, 41*(3), 275-288

With increased interest in sustainable materials for use in building materials and clothing, there is a renewal in the use of natural fibers (plant or animal-based) versus synthetic fibers in a variety of applications. However, there is not as much information available on the flammability of these natural fibers especially when they are used in products where purification techniques used in conventional textile processing are not required. The literature to date suggests that all of the fibers can be grouped into two categories: cellulosic and animal, with the assumption that regardless of original species, the flammability is similar for fibers within each category. In this report, we have conducted a survey via microcombustion calorimetry to determine if all cellulose-based and all protein-based fibers are the same from a heat release perspective. Our findings show that this is not the case, and there are notable differences in fiber types within each genus. Further, how the natural fiber has been treated prior to use can have some dramatic effects on heat release caused by residual impurity content. The results in this paper suggest that there is more to be learned about these natural fiber types in regards to their inherent flammability.

Cellulose/paraffin composite fibers for thermal energy storage and temperature regulation, Materials Science Forum

Xia, W., Xiang, H.X., Chen, W.P., Li, Y., Chen, W., Chen, L.J., Zhao, J., Zhu, M.F. 2017. Cellulose/paraffin composite fibers for thermal energy storage and temperature regulation, *Materials Science Forum, 898*, 2318-2328

Cellulose is a good bio-based material for rich resources and recyclability. Paraffin is widely used in the field of energy storage and temperature regulation due to its excellent heat storage properties and mature preparation technology. In this paper, the cellulose fibers with energy storage and temperature regulation were prepared by wet spinning process using paraffin as phase change material. Field Emission Scanning Electron Microscope (FE-SEM), X-Ray Diffraction (XRD), Differential Scanning Calorimetry (DSC) and Thermal Gravimetric Analysis (TGA) were utilized to characterize the morphology structure, crystalline properties, phase transition properties and heat resistance of fibers and so on. The results showed that the fiber surface without holes and paraffin was uniformly distributed in the cellulose matrix, and paraffin was not easily overflow during the process of phase change. Paraffin and cellulose substrate had good compatibility due to the interaction of hydrogen bonding, and 30% of paraffin did not cause a significant impact on the degree of crystallinity and thermal stability of cellulose fibers. Enthalpy of the resultant functional fibers could reach 27.44 J/g, and the thermal decomposition temperature was over 300 °C. The fibers possessed the phase change ability and certain mechanical

properties. Furthermore, it was found that the fibers still had good resistance to washing under extreme conditions.

An alternative for the end-of-life phase of flame retardant textile products: Degradation of flame retardant and preliminary settings of energy valorization by gasification

Yasin, S., Curti, M., Rovero, G., Behary, N., Perwuelz, A., Giraud, S., Migliavacca, G., Chen, G., Guan, J. 2017. An alternative for the end-of-life phase of flame retardant textile products: Degradation of flame retardant and preliminary settings of energy valorization by gasification, *BioResources, 12*(3), 5196-5211

It is well established that current flame retardant (FR) products at disposal generate various ecological hazards. Irrespective of their environmental impacts, the FR market is growing and is estimated to reach 2.8 million tons globally in 2018. In the textile domain, FRs are incorporated into baby clothing, pushchairs, car seats, etc. When disposed, these FR textile products end up in a landfill or are incinerated. These disposal processes are unsustainable. With landfilling, there is a huge chance of the FR product leaching into the environment. Similarly, FRs decrease energetic yields in the incineration process due to incomplete combustion. To cope with such issues, degradation and elimination of the FR product from the textile products before disposal could be a sustainable alternative. This study dealt with the preliminary degradation of flame retardant from the cotton textiles and its thermal characterization. Energy valorization by gasification is considered beneficial opposed to incineration with overall low energy recovery. The initial optimum gasification conditions including FR-treated cotton as a feeding material and potential outcomes of FR-treated cotton after degradation were characterized.

Silica precursor as synergist for cotton flame retardancy

Grancaric, A.M., Botteri, L., Alongi, J. and Tarbuk, A. 2016. Silica precursor as synergist for cotton flame retardancy

Purpose - The cotton and its blends is the most commonly used textile material in the design and production of protective clothing. However, as the cellulose textiles are the most flammable materials it is necessary to improve its flame retardancy. The government regulations have been the driving force for developing durable flame retardants finishes for textile, to improve its performance and to reduce the negative impact on the environment. The paper aims to discuss these issues. Design/methodology/approach - This paper investigates the effect of silica precursor (tetraethoxysilane – TEOS) added in bath with conventional flame retardant urea/ammonium polyphosphate in full and half concentration for achieving environmental-friendly cotton flame retardancy. Silica precursors have excellent thermal stability and high heat resistance with very limited release of toxic gases

during the thermal decomposition. Synergistic effect between urea/ammonium polyphosphate and TEOS has been calculated. Thermal properties of treated cotton fabrics were determined by limiting oxygen index (LOI), thermogravimetric analysis (TGA) and microscale combustion calorimeter (MCC). Findings - TEOS, significantly improves the flame retardancy of cotton when added in the bath with conventional flame retardants urea/ammonium polyphosphate by increasing the LOI values and other thermal properties as increasing char residue measured by TGA and higher heat release rate measured by MCC. Originality/value - This paper represent a good synergistic effect between urea/ammonium polyphosphate and TEOS. This phenomena is evident in better thermal properties when TEOS was added in the bath with conventional flame retardant especially for half concentration of urea/ammonium polyphosphate.

Flame retardants based on amino silanes and phenylphosphonic acid

Kappes, R.S., Urbainczyk, T., Artz, U., Textor, T. and Gutmann, J.S., 2016. Flame retardants based on amino silanes and phenylphosphonic acid. *Polymer Degradation and Stability, 129*, 168-179

The sol-gel approach offers a new class of flame retardants with a high potential for textile applications. Pure inorganic sol-gel systems do, however, typically not provide an effect sufficient for a self-extinguishing behavior on its own. We therefore employed compounds with nitrogen and phosphorous containing groups. Especially the combination of compounds with both elements, using the synergism, is promising for the aim to find well-applicable, environmental friendly, halogen-free flame retardants. In our approach, the sol-gel network ensured on the one hand the link to the textile as non-flammable binder. On the other hand, the sol-gel-based networks modified with functional groups containing nitrogen groups provided flame retardancy. In this way, a flame retardant finishing for textiles could be obtained by simple finishing techniques as, e.g., padding. Besides a characterization with various flame tests (e.g., according to EN ISO 15025 – protective clothing), we used a combination of cone calorimetry, thermogravimetry coupled with infrared spectroscopy analysis and scanning electron microscopy to analyze the mechanism of flame retardancy. Thus, we could show that the main mechanism is based on the formation of a protection layer. This work provides a model system for sol-gel-based flame retardants and has the potential to show the principle feasibility of the sol-gel approach in flame retardancy of textiles. It therefore lays the groundwork for tailoring sol-gel layers from newly synthesized sol-gel precursors containing nitrogen and phosphorous groups.

Parametric study of fabric characteristics' effect on vertical flame test performance using numerical modeling

Kim, E., Dembsey, N., Godfrey, T.A. 2016. Parametric study of fabric characteristics' effect on vertical flame test performance using numerical modeling, *ASTM Special Technical Publication, 1593*, 78-101

A parametric study of fabric characteristics' effect on performance in the standard vertical flame test (VFT; ASTM D6413) is conducted using computational fluid dynamics modeling. This bench-top test is used for characterizing fire performance of textiles during the fabric design stage to determine flame resistance. The advantage of utilizing modeling to study fire performance of textiles during VFT is the ability to conduct detailed studies of the effect of fabric characteristics on flame spread. First, two textile materials are chosen for modeling that exhibit two limit cases: either complete flame spread (nylon 6,6/cotton fiber fabric; NYCO) or self-extinguish (flame-retardant rayon/nylon 6,6/para-aramid fiber fabric; FR Army combat uniform) in the VFT. Parameter estimation for various model parameters - kinetic parameters and heat of reactions, heat of combustion, thermophysical parameters, and optical parameters-is performed for these samples by combination of independent measurements and numerical optimization using bench-scale experimental data. Second, parametric analysis is conducted for these two cases. The parameter values are varied one at a time, and their effect on the pyrolysis modeling (one-dimensional cone test simulation) and the flame spread modeling (threedimensional VFT simulation) are analyzed. Based on this work, the parameters that are significantly sensitive to modeling outputs (i.e., switch from complete flame spread to self-extinction or vice versa) are identified. Third, understanding the sensitive parameters in this VFT modeling with fabric samples, a new sample is modeled-flame-retardant cotton fiber fabric, FR cotton. The modeling results show that numerical modeling is capable of capturing the fire characteristics of a fabric sample when parameters are carefully estimated, especially the sensitive parameters. Understanding the effects of fabric characteristics on different fire behaviors observed in the standard VFT through numerical modeling will help designers more efficiently and effectively develop fire-safe fabrics.

A study on the thermal properties of polysulfonamide fiber

Lu, X.-P., Xu, Y.-Q., Ye, J.-Q. 2016. A study on the thermal properties of polysulfonamide fiber, Textile Bioengineering and Informatics Symposium Proceedings 2016 - 9th Textile Bioengineering and Informatics Symposium, TBIS 2016, in conjunction with the 6th Asian Protective Clothing Conference, APCC 2016, 791-799

Polysulfonamide (PSA) fiber belongs to polyamide aromatic polymer materials. In order to study the termal stability of PSA, thermo gravimetric analysis was used to obtain the thermogravimetric progress of the fiber. The pyrolysates of the fiber were identified by pyrolysis-gas chromatography/mass spectrometry, and the thermal behavior was analyzed

using differential scanning calorimetry. The results obtained from thermal decomposition process indicate that the existence of the conjugated aromatic rings and the additional sulfone group structure in its molecular main chain enable PSA fiber has high degradation temperature and can be applied to various fields in our daily life.

In situ degradation of organophosphorus flame retardant on cellulosic fabric using advanced oxidation process: A study on degradation and characterization

Yasin, S., Behary, N., Giraud, S., Perwuelz, A. 2016. In situ degradation of organophosphorus flame retardant on cellulosic fabric using advanced oxidation process: A study on degradation and characterization, *Polymer Degradation and Stability, 126*, 1-8

N-methylol dimethyl phosphonopropionamide (MDPA) is one of the most effective organophosphorus flame retardants for cellulosic fabrics, used in combination with Trimethylol melamine (TMM) to obtain durable and improved flame retardant properties. While their use is responsible for severe health problems, there is a need today to study methods to eliminate or degrade the durable flame retardant products which stay on discarded flame retardant textiles. The final aim is to improve the reusability of discarded textiles and to increase their energetic yield during the incineration phase. In this work, the degradation and mineralization of the flame retardant MDPA on cellulosic fabric, was studied using an advanced oxidation process (AOP) based on Fenton reaction. The effect of varying concentrations of Fenton's reagents (H2O2 and Fe2+ in aqueous medium) on the degradation of the MDPA was studied. The degradation of MDPA in aqueous media was monitored by measuring chemical oxygen demand (COD) of the reaction mixture over time. The mechanical properties of the cellulosic fabric after Fenton's reaction were unaltered in both warp and weft directions. The flammability test and thermogravimetric (TGA and DTG) results confirmed the degradation of MDPA flame retardant from the fabric. Pyrolysis combustion flow calorimeter (PCFC) confirms that there is a higher heat release after Fenton's reaction degradation which makes the degraded flame retardant cotton interesting for energy production by incineration.

Kinetics of pyrolysis of ramie fabric wastes from thermogravimetric data

Zhu, F., Feng, Q., Xu, Y., Liu, R., Li, K. 2015. Kinetics of pyrolysis of ramie fabric wastes from thermogravimetric data, *Journal of Thermal Analysis and Calorimetry, 119*(1), 651-657

The reutilization of the ramie-based textile waste or scraps from textile production through pyrolysis is a promising route for producing bio-fuels. In this work, the thermal behaviors and pyrolysis kinetic of used ramie fabric were investigated using thermogravimetric

analysis at different heating rates of 5, 10, 20, and 40 °C min-1 under nitrogen conditions. Three model-free methods, the isoconversional Kissinger, Kissinger-Akahira-Sunose (KAS) and Flynn-Wall-Ozawa (FWO) models and Coats-Redfern model-fitting method were employed to identify the kinetic triple including activation energy, pre-exponential factor, and reaction model. It was established that the Coats-Redfern model-fitting method was suspectable for determining the kinetic reaction mechanism but the most probable reaction R (R2 or R3) function can be evaluated on the basis of the activation energy value which is nearest to the value of E a obtained by the FWO and KAS methods. A kinetic compensation effect, represented by the equation lgA = -1.3515 + 0.0808E a can be observed

---

Pyrolysis kinetics of recycled polyesters, International Journal of Clothing Science and Technology

Al-Juaidiyah, J. 2015. Pyrolysis kinetics of recycled polyesters, *International Journal of Clothing Science and Technology, 27*(4), 523-531

Purpose – The purpose of this paper is to study the non-isothermal degradation kinetics of recycled polybutylene terephthalate, polytrimethylene terephthalate and polyethylene terephthalate using thermogravimetric analysis (TGA) in a nitrogen atmosphere. Design/methodology/approach – To achieve this goal, the author utilized standard kinetic models, such as Coats-Redfern and Kissinger equations, for analysis of the TGA data. Findings – When applied to the TGA data, the Kissinger model resulted in a coefficient of determination (R2) value greater than 0.99. Originality/value – This study describes the maiden application of the Kissinger model to obtain the preexponential factor (A) and activation energy (E) for different polyester systems used in the textile industry.

Prospective environmental life cycle assessment of nanosilver T-shirts

Walser, T., Demou, E., Lang, D.J., Hellweg, S. 2011. Prospective environmental life cycle assessment of nanosilver T-shirts, *Environmental Science and Technology, 45*(10), 4570-4578

A cradle-to-grave life cycle assessment (LCA) is performed to compare nanosilver T-shirts with conventional T-shirts with and without biocidal treatment. For nanosilver production and textile incorporation, we investigate two processes: flame spray pyrolysis (FSP) and plasma polymerization with silver co-sputtering (PlaSpu). Prospective environmental impacts due to increased nanosilver T-shirt commercialization are estimated with six scenarios. Results show significant differences in environmental burdens between nanoparticle production technologies: The "cradle-to-gate" climate footprint of the

production of a nanosilver T-shirt is 2.70 kg of CO2-equiv (FSP) and 7.67-166 kg of CO2-equiv (PlaSpu, varying maturity stages). Production of conventional T-shirts with and without the biocide triclosan has emissions of 2.55 kg of CO2-equiv (contribution from triclosan insignificant). Consumer behavior considerably affects the environmental impacts during the use phase. Lower washing frequencies can compensate for the increased climate footprint of FSP nanosilver T-shirt production. The toxic releases from washing and disposal in the life cycle of T-shirts appear to be of minor relevance. By contrast, the production phase may be rather significant due to toxic silver emissions at the mining site if high silver quantities are required.

High surface area carbide-derived carbon fibers produced by electrospinning of polycarbosilane precursors

Rose, M., Kockrick, E., Senkovska, I., Kaskel, S. 2010. High surface area carbide-derived carbon fibers produced by electrospinning of polycarbosilane precursors, *Carbon, 48*(2), 403-407

Highly porous carbide-derived carbon fibers have been synthesized by electrospinning of polycarbosilane with subsequent pyrolysis and chlorination. The resulting ultrathin fibers show specific surface areas up to 3116 m2 g-1 and very high storage capacities for hydrogen up to 3.86 wt.% at 17 bar and 77 K. Due to the outstanding adsorption performance and other properties such as high temperature stability and the unique CDC fiber shape, this new kind of fiber material offers promising possibilities for several applications like air or liquid filters or textiles for protective clothing. Application as a flexible electrode material for supercapacitors is conceivable.

Mathematical Model of Heat and Mass Transfer within Fabric Used for Fire Protective Clothing under High Temperature Conditions

Zhu, FL., Gu, BH., , Li., SC, Wang., WY, An., Y. 2010. Mathematical Model of Heat and Mass Transfer within Fabric Used for Fire Protective Clothing under High Temperature Conditions, Progress in Safety Science and Technology, Vol. VIII, PTS A and B, Progress in Safety Science and Technology Series, 7th International Symposium on Safety Science and Technology (ISSST).

The paper reports an improved model of heat and mass transfer considering which considered the influence of pyrolysis was established to predict thermal performance of heat-resistant fabric under high heat flux conditions. The new model has been validated using data from modified Radiant Protective Performance (RPP) tests of flame-resistant

cotton fabric. The simulated results were compared with experimental data and time to the 2nd degree burn can be predicted based on skin burn model. This work provided a foundation for further researching heat transfer characteristics of heat resistant fabric exposed to a simulated fire. This also provided the theoretical and technological basis for study on degradation for combustible textiles.

Resources recovery of waste rayon by pyrolysis: kinetics study

Huang, H.C., Chang, C.Y., Chen, Y.H., Shie, J.L., Lin, J.P. and Wu, C.H. 2004. Resources recovery of waste rayon by pyrolysis: kinetics study. *Journal of the Chinese Institute of Chemical Engineers, 35*(6), 623-632

Rayon derived from natural biomass fibers are extensively used in the production of a wide range of commercial industrial, and engineering products especially rayon clothes. The rayon discharged by textile industry, and consumers are becoming a large proportion of wastes. The conversion of rayon to various useful materials such as lower molecular weight organic compounds (liquid fuels and combustible gas) and carbonaceous fibers or activated carbons via pyrolysis not only solves the disposal problem but also matches the wastes minimization and resource utilization. Before considering the thermal treatment of utilization of rayon clothes, one should investigate the behavior of rayon alone during the thermal treatment. The pyrolysis of rayon is thus examined with a thermal gravimetric analyzer (TGA). The kinetics of the thermal pyrolysis of rayon is conducted using nitrogen as the carrier gas in 378-800K and at various constant heating rates (beta) of 5, 12 and 20K/min. The results indicate that the entire pyrolysis process of rayon under the experimental conditions of this investigation can be described by two competitive reactions forming volatiles and residues (including carbon). The corresponding activation energies (E), reaction orders (n) and frequency factors (A) of volatiles and char formed by the two competitive (parallel) reactions of pyrolysis of rayon are 171.6 and 191.8 kJ/mol of E, 1 and 1.5 of n, and 4.3 x 10(11) and 5.6 x 10(12) s(-1) of A, respectively. All this information is useful to the proper design of a pyrolysis system of rayon.

Durable Flame-Retardant Finished Cotton Fabrics Characterized by Thermal Degradation Behaviors

Nakanishi, S., Masuko, F., Hashimoto, T. 1999. Durable Flame-Retardant Finished Cotton Fabrics Characterized by Thermal Degradation Behaviors, *Journal of Applied Polymer Science, 71*(6), 975-987

After a series of investigations on the durable flame-retardant finishes, it was thought to be important to study these durable flame-retardant finished materials from the thermal analytical standpoint. Accordingly, cotton fabric was finished with N-methylol dialkyl

phosphonopropionamide (Pyrovatex C) by thermofixation and tetrakis (hydroxymethyl) phosphonium sulfate (THPS) precondensate by ammonia cure (Proban), as well as with THPS monomer by heat cure under various conditions, and subjected to the thermogravimetry (TG) to observe thermal degradation behaviors and obtain apparent activation energy (Ea). TG curves of Proban-finished samples showed the largest shift to lower temperatures with a steep slope; thermofixed THPS-finished sample gave a smaller shift with similar steep slope, whereas Pyrovatex-finished samples exhibited a similar shift but with a gradual slope. Ea versus residual ratio curves led us to conclude that C - N bond-rich Proban polymer requires the highest Ea and decomposes with considerable rapidity, whereas ethylene-bond-rich Pyrovatex-finished samples with melamine crosslinking decompose gradually with the lowest Ea. As for the relationship between flame retardance and Ea distribution in the process of thermal degradation, typical differences among the above three kinds of finished samples were found, which are compared and discussed.

Developments in flame retardants for heat and fire resistant textiles—the role of char formation and intumescence

Horrocks, A.R. 1996. Developments in flame retardants for heat and fire resistant textiles—the role of char formation and intumescence. *Polymer Degradation and Stability, 54*(2-3), 143-154

The currently available heat and flame resistant textiles are reviewed. These fall into two groups, each of which is based on the use of non-thermoplastic fibres as the major fibre component. The first group consists of flame retarded cellulosic, wool and certain man-made fibre-containing fabrics which are well established in various markets, have moderate to high heat and flame resistance and are available at reasonable cost. Performance limitations are determined by stability of the chars produced following interaction of the flame retardants and the fibre when heated. The second group relies on the exploitation of the inherent heat and flame resistance of aromatic and carbonized fibres which form chars with superior mechanical stabilities, and hence barrier properties, compared with the first group. However, fibres within this group are expensive, often difficult to process and, from an environmental point of view, difficult to recycle. Thermoplastic fibres such as polyester, polypropylene and polyamide, even when flame retarded using either comonomeric, modifications or additives introduced during polymerisation and/or fibre extrusion stages, melt drip and/or form holes when exposed to flame. They cannot, therefore, be used in applications, such as protective clothing and barrier textiles, where sustained thermal protection via char formation is an essential requirement. The mechanism and role of char formation are discussed and the incorporation of intumescents in textile materials explored. Recent developments have shown that combinations of flame retarded char-forming fibres and intumescents may give rise to a consolidated fibrous char-reinforced intumescent char which exhibits enhanced heat and flame resistance compared to individual chars. These interactive fibre-intumescent combinations offer opportunities for creating high

performance barrier textiles based on more conventional, cost effective and environmentally acceptable raw materials.