TRANSDUCE-H

Transparent Durable and Cost-Efficient Flexible Heaters

Programm / Ausschreibung	Produktion der Zukunft, Produktion der Zukunft, 32. AS PdZ - Nationale Projekte 2019	**Status**	abgeschlossen
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Zeitraum	2020 - 2022	**Projektlaufzeit**	26 Monate
Keywords	Transparent heaters, spray-pyrolysis, spray coating		

Projektbeschreibung

Das Projekt entwickelt transparente, langlebige und kosteneffiziente flexible Heizkomponenten für Anwendungen mit hohem Potenzial. Transparente Heizkomponenten sind in der Automobil-, Optoelektronik-, Optik- und Smart-Windows-Industrie weit verbreitet und haben daher einen großen Markt. Anspruchsvolle, moderne Anwendungen (z.B. feine Displays und intelligente Fenster) erfordern transparente Heizelemente, die ein homogenes optisches Erscheinungsbild, eine hohe Transparenz, eine hohe Heizleistungsdichte und eine homogene Heizverteilung aufweisen - Anforderungen, die nach Lösungen verlangen, die über die derzeitigen draht-basierten Technologien hinausgehen. Auch Anwendungen in beliebigen 3D-Formen benötigen Heizkomponenten die verformbar sind, z.B. Dünnschichtbeschichtungen auf thermoplastischen Folien als Substrat.
Die gewählte Lösung sind daher transparente Dünnfilme. Gegenwärtig ist das überwiegend verwendete Dünnfilmmaterial Indiumzinnoxid (ITO), das zwar eine hohe Transparenz und elektrische Leitfähigkeit aufweist, dessen Verwendung jedoch durch die hohen Kosten für Indium, die Verwendung teurer Geräte auf Vakuumbasis für dessen Abscheidung und die Sprödigkeit des Keramikmaterials beeinträchtigt wird.
Um diesen Nachteilen zu begegnen, werden im Rahmen des Projekts Lösungen entwickelt, die kostengünstige, transparente und leitende Oxidmaterialien auf Basis von dotiertem Zinkoxid mit metallischen Nanodrähten kombinieren. Diese werden unter Umgebungsbedingungen durch Sprühbeschichtung und Sprühpyrolyse bei reduzierten Temperaturen abgeschieden und sind mit den flexiblen Substraten kompatibel. Darüber hinaus werden im Rahmen des Projekts auch Einbettungsprozesse der Dünnfilme und Nanomaterialien mit Polymeren sowie alternative Passivierungsansätze mit anorganischen Materialien angewendet, um dauerhafte und verformbare Heizelemente zu erhalten. Schlussendlich, wird das Projekt innovative Heizungskonzepte für verschiedene Zielanwendungen entwickeln und testen.

Abstract

The project develops transparent, durable and cost-efficient flexible heaters for high-potential applications. Transparent heaters are widely implemented in the automotive, optoelectronics, optics and smart windows industries and therefore represent a high volume market. Demanding, modern applications (e.g. fine displays and smart windows) need transparent heaters that have a homogeneous optical appearance, high transparency, high heating power density and spatial heating homogeneity - requirements calling for solutions beyond the current wire-based technologies. Also, heater applications in

arbitrary 3D shapes, necessitate flexible heaters that are deformable, e.g. thin film heaters on thermoplastic foils as substrates.
Transparent thin films are therefore the solution of choice. Currently, the predominantly used thin film material is indium tin oxide (ITO), combining high transparency and electrical conductivity. However, ITO is compromised by the cost of indium, the use of expensive, vacuum-based equipment for its deposition and the brittleness of the ceramic material.
To address these shortcomings, the project will develop solutions which combine low cost transparent conducting oxide materials based on doped zinc oxide, with metallic nanowires. These are deposited at ambient conditions using spray coating and spray pyrolysis at reduced temperatures, compatible with the flexible substrates. To obtain durable and deformable heaters the project will also apply embedding processes of the thin films and nanomaterials with polymers, as well as alternative passivation approaches with inorganic materials. Last but not least, the project will develop and test innovative heater designs for various targeted applications.

Endberichtkurzfassung

The most significant results of the project TRANSDUCE-H can be summarized as follows:

1) Low temperature recipes have been developed for the spray deposition of doped zinc oxide (ZnO) films, ZnO nanoparticles (NPs) and silver nanowires (Ag-NWs), combining excellent electrical, optical and stuctural properties.

More specifically, for the first time in the literature, we reported the spray pyrolysis of high quality doped ZnO films at temperatures as low as 240°C, which allows the use of transparent polyimide (PI) foils as substrate. This was possible through the development of improved precursor solutions and deposition parameters, allowing the precursor decomposition at lower temperatures. Trilayers of doped ZnO/Ag-NWs/doped ZnO on PI show sheet resistance below 10 Ohm/sq with optical transmittance up to 80% (including the substrate), with the NWs completely embedded between the oxide layers, which guarantees their chemical and thermal stability.

On the other hand, composites of Ag NWs and ZnO NPs or conductive polymers have been deposited at temperatures below 100°C, allowing the use of temperature sensitive foils such as polycarbonate (PC). These composites feature excellent opto/electrical properties, similar to the values mentioned above.

2. The heating performance of the developed tranparent flexible heaters has in many cases surpassed the state-of-the-art in the market or literature. For example, the heaters on PI foil reached maximum temperatures up to 220°C, with fast ramp up times of <10 secs. Heaters on the PC substrate have reached temperatures >140°C, surpassing the requirements for the envisaged applications.

3. Up-scaling of the deposition process to substrates of 5x5 cm 2 took place, without compromising the properties of the coatings. These larger samples delivered the same excellent heating performance as the smaller ones and have shown that, when appropriately encapsulated, can resist harsh chemical environemts, such as immersion into fuel. They have also been succesffully tested under mechanical stress (compressive and tensile bending), showing that their properties remain largely unaffected. For example, the bending of heaters on PC substrate in a radius down to to 4 mm, does not lead to any change in their resistance and attained temperature.

4. Demonstrators implementing the developed heaters were successfully built, integrating the processes of the transparent coating deposition, design and deposition of the electrical contacts, encapsulation, etc.

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