Charged Nanocarbons as Effective Reducing Agent in Nanoparticle Synthesis

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INTRODUCTION

Graphitic nano carbons are promising carbon based alternative for various novel applications due to their size and surface area. In this study, sustainable synthetic graphitic nano carbons have been used as starting material to synthesize metal nanoparticle/nano carbon composite materials with remarkable electro catalytic activity.

EXPERIMENTAL STUDY / METHODOLOGY

It will be demonstrated that graphitic nano carbons can be intercalated by potassium metal as it has been recently shown for graphitic nanofibres.[1] The intercalated graphitic nano carbons have been directly solvated in THF by stirring and have been subsequently characterized intensively. Additionally, their reducing character has been exploited to generate metal nanoparticles attached to the framework of the carbon. The characteristics of the as generated composite materials have been studied in detail by various techniques such as HR-TEM, TGA, XRD, XPS among others and their catalytic properties in terms of the oxygen reduction reaction (ORR) have been determined.

RESULTS AND DISCUSSION

Graphitic nano carbons with lateral sizes below 50 nm can be intercalated successfully by potassium metal, in analogy to graphite with flakes in the µm range.[2,3] This material dissolves in absolute organic solvents with the aid of stirring.

Nanoparticle graphene composite have attracted vast interest due to the synergistic interplay between the properties of graphene and the attached nanoparticles.[4] Up to date, the majority of examples published on the generation of NP/graphene composites rely on surfactant/water based dispersions of graphene or graphene oxide. In an additional step, the metal salt as well as the reducing agent needs to be merged with the respective dispersion.[5]

It has been demonstrated that potassium intercalated GICs are an excellent reducing agent used to generate metal nanoparticles attached to graphitic surface.[6,7]

GICs made out of nano sized graphitic material can be efficiently exploited to synthesize nanoparticles (NP). The presented procedure has advantages over the conventional methods, as the reduction of the metal takes place in close proximity to the carbon lattice, the addition of any further reduction agent can be avoided, and only a single by-product is generated.

Carbon nano materials are promising materials for electro catalytic application thanks to their high surface areas, electrical conductivity and stability in acidic or basic aqueous solutions.[8,9]

This as-produced material exhibits a unique size distribution and interesting morphology. The conductivity within the composite is ensured by the graphene layers connecting the nanoparticles efficiently with the electrodes. Therefore, high electro catalytic activity in the ORR, electron transfer numbers close to four and long term stability have been observed for this nano carbon / nano particle composite material.

CONCLUSION

Solutions of reduced graphene are a promising alternative synthetic approach to generate graphene/nanoparticle composite materials. The exploitation of graphitic nano carbons in this reaction scheme allows generating unique composite materials with amazing catalytic properties.

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REFERENCES

1. Huang K., *et al.*(2016). *Nanoscale* 8 (16), 8810-8818.
2. Pénicaud A., *et al.* (2013). *Acc. Chem. Res*. 46 (1), 129–137.
3. Vallés C., *et al.* (2008) *J. Am. Chem. Soc*. 130, 15802–15804.
4. Xia, W., *et al.* (2016) *Angew. Chem. Int. Ed.* 55 (8), 2650-2676.
5. Yin, P. *T., et al* (2015) *Chem. Rev. 115 (7), 2483–2531.*
6. Furstner, A., *et al* (1989) *J. Catal. 118 (2), 502–506.*
7. Neiva E., *et al* (2015) *J. Colloid Interface Sc.* 453, 28-35.
8. Mazzaro, R., *et al* (2015) *ChemistryOpen* 4 (3), 268-273.
9. Catheline, A., *et al* (2015) *J. Mater. Res.* 30 (13), 2009-2017.