



Fig. 6. Schematics of measurement geometries (not to scale): photocatalytic reactor.

$[NO_x]_{max}$: the maximized concentration of nitrogen monoxides, ppb;

$[NO_x]_{min}$: the minimized concentration of nitrogen monoxides, ppb;

t_0 : time point when UV light turns on;

t_1 : time point when UV light turns off;

c_{in} : concentration of gas in (this value is equal to $[NO_x]$ max), ppb;

The latter measure is used to calculate the amount of NO removed in micromoles per square meter per hour, using Eq. 7.

$$r = \frac{(f)}{22.4} \left\{ \int_{t_0}^{t_1} ([NO]_0 - [NO]) dt + \int_{t_0}^{t_1} ([NO_2]_0 - [NO_2]) dt \right\} \quad (7)$$

where

r: amount of nitro oxides removed by the test sample, $\mu\text{mol m}^{-2}\text{h}$;

f: flow rate converted into that at the standard state (0°C , 1.013 kPa), L min^{-1} ;

$[NO]_0$: inlet concentration of nitrogen monoxide, ppb;

$[NO]$: outlet concentration of nitrogen monoxide, ppb;

$[NO_2]_0$: inlet concentration of nitrogen dioxide, ppb;

$[NO_2]$: outlet concentration of nitrogen dioxide, ppb;

A: surface area of cement paste samples, m^2 ;

T: time to UV radiation, min;

22.4: volume of 1 mol ideal gas at the standard state (ideal gas law).

2.3.4. Environmental scanning electron microscope (ESEM)

ESEM (Quanta FEG 250, FEI, Hillsboro OR, USA) was used to observe the morphology and microstructure of the NT@RCBS. Different from traditional scanning electron microscopy, ESEM requires no pre-treatment such as drying, conduction, or dehydration. Hence, the samples were directly placed under the lens to obtain the micrographs. The micro-spectroscopy elements were analysed by energy dispersive X-ray spectroscopy (EDS, Oxford Instruments 7274).

2.3.5. Mercury intrusion porosimeter (MIP)

An automatic mercury intrusion analyzer (AutoPore IV9500) produced by McMuretck Instrument Company of the United States was used for pore structure determination. All data acquisition and processing were controlled and completed by the computer. The maximum pressure of the instrument is 33,000 Psia, and the pore size can be measured in the range of 6–360,000 nm. Samples were in advance oven dried at 105°C , for 12 h and then placed into the machine for analysis.

2.3.6. Durability test (anti-abrasion performance)

The durable performance of photocatalytic mortar is embodied by the anti-abrasion performance. To simulate natural abrasion triggered by wind, touching, and stepping [18], one abrasive paper with grade of Cw 220-2c was utilized to abrade the sample surface by 500 times back and forth. To ensure the same abrasion condition (friction force) for all samples, the gravity that was perpendicular to the friction and the friction coefficient that was determined by friction surfaces were maintained exactly the same. The former was realized by attaching the abrasive paper to the surface of a brick with constant weight; whilst the latter was achieved by updating abrasive papers for each testing sample. Each result was the average of three paralleled tests.

3. Results and discussion

3.1. Characterization of CPs

Fig. 7(the upper subgraph) presents the micrograph of NT@RG. EDS performed at point 44 reveals that the material loaded onto the surface of RG is NT. In comparison, point 46 held almost no Ti. That is, the soaking method ensures only some parts of the surface of RG are covered by NT while some other parts are not. It is crucial because photorefraction is provided by transparent areas that should not be covered by NT. On the contrary, **Fig. 7**(the lower subgraph) exhibits the micrograph of NT@RCBS and confirms that NT is loaded onto part of the surface and filled into some pores of RCBS during the preparation of the CPs. This statement contains two sections. First, some NT is loaded onto part of the surface of RCBS. It is proved by the ESEM pictures along with the EDS (see **Fig. 7**). Since the spectrum at both points 54 and 55 display high proportions of Ti that is not held by RCBS itself (see **Table 1**). In particular, during the soaking, the RCBS was fully immersed into the NT solution. That is to say, NT particles surrounded the RCBS and had the equal chance to load onto any part of RCBS because no particular part of RCBS was proved to have the capacity of selective adsorption. Furthermore, the ESEM and EDS were pictured randomly. To some degree, they at least prove that the majority of RCBS surface is covered by NT. Second, RCBS has a porous structure and extremely rough surface. Some NT particles are deposited and accumulated inside the pores as well as on the surface. This is proved by the porosity and pore size distribution analysis, with results in **Fig. 8b**. The porosities of RCBS and NT@RCBS are 29 and 26.5%, respectively. The reduced porosity of NT@RCBS relative to RCBS is due to the filling of NT after the soaking. The absolute reduction is only 2.5% which echoes the limited NT loading amount measured by the analytical balance below. Furthermore, referring